THE AIRCRAFT ACCIDENT INVESTIGATION BOARD / NORWAY

HAV 02/93

REPORT ON THE CONVAIR 340/580 LN-PAA AIRCRAFT ACCIDENT NORTH OF HIRTSHALS, DENMARK, ON SEPTEMBER 8, 1989

SUBMITTED FEBRUARY 1993

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Note: This is an extract in English of the official Norwegian report dated February 12, 1993. Any formal references required should be made to the original Norwegian report. It should be noted that the numbering of the paragraphs in this extract corresponds to the numbering in the original document.

SUBMITTED FEBRUARY 1993

The Aircraft Accident Investigation Board has compiled this report for the purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to recommend preventive action. It is not the Board's task to apportion blame or liability. Use of this report for any other purpose than for flight safety should be avoided.

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REPORT ON THE CONVAIR 340/580 LN-PAA AIRCRAFT ACCIDENT NORTH OF HIRTSHALS, DENMARK, ON SEPTEMBER 8, 1989

Aircraft type:	Convair CV-340/580
Registration:	LN-PAA
Owner:	Thoresen Invest A/S P.O. Box 212 N-3501 HØNEFOSS, Norway
Operator:	Partnair A/S N-1330 OSLO LUFTHAVN, Norway
Crew	5 - fatally injured
Passengers	50 - fatally injured
Place of accident:	Skagerrak, approximately 10 n. miles north of Hirtshals, Denmark, 57°43,19'N, 010°04,87'E (area of the main wreckage)
Date and time:	September 8, 1989 at 1638:30 hrs LT. (LT = UTC + 2 hours)

All times stated in this report are local time, unless otherwise indicated.

SYNOPSIS

The Aircraft Accident Investigation Board, Norway (AAIB/N), was informed about the accident on September 8, 1989 at 1910 hrs. The organisation of an investigation team was immediately initiated. The accident took place in Danish-controlled air space, but also in international waters. The Aircraft Accident Investigation Board, Denmark, dispatched a representative who arrived at the Hirtshals Sea Rescue Station at 0500 hrs the next morning. The Danish inspector assisted the AAIB/N, in accordance with the agreement made amongst the investigating authorities in the Nordic countries.

PARTICIPATING EXPERTS AND CONSULTANTS

The National Transportation Safety Board (NTSB), as the representative of the investigating authorities in the state of manufacture, was notified of the accident on September 9, 1989. In accordance with ICAO Document Annex 13, Aircraft Accident Investigation, the NTSB appointed representatives to assist in the investigation. The following persons participated in the investigation during the period October 5-12, 1989:

Mr. Lowell G. Ellabarger, NTSB/Allison Div., General Motors Corporation (GMC)
Mr. Joseph C. Wissel, Allison Div., GMC
Mr. William L. Jones, Allison Div., GMC
Mr. Douglas C. Glazier, Hamilton Standard
Mr. E. Ross Gibbs, Pacific Propellers, Inc.

During the investigation, the following representatives from NTSB and from the manufacturer, General Dynamics, Convair Division, (GDCD) assisted in examining the wreckage at the AAIB/N technical facility at Kjeller:

Mr. Thomas E. Haueter, NTSB, accredited representative, in February 1990

Mr. Joe Epperson, NTSB, in February 1990
Mr. Gregory J. Phillips, NTSB, in February 1990
Mr. Ladd F. Mastny, GDCD, in October 1989 and February 1990
Mr. Robert S. Baldwin, GDCD, in October 1989 and February 1990

In addition, the following individuals and companies assisted in the investigative work:

- Egil Alnaes, M.D., aviation medicine
- Hans Arnegaard, Captain, formerly employed by Partnair A/S (PAS)
- Sigve Barvik, Consultant, RNoAF
- Per Bruun, Captain, Partnair A/S Pilot Union
- F.M. Medak, Aviation consultant, formerly employed by Fairchild Aviation Recorders
- Christian Moi, Inspector, formerly employed by SAS
- Grete Myhre, PH.D., RNoAF Institute of Aviation Medicine
- Lt. Col. A. Stein , RNoAF ret.
- Accident Investigation & Research Inc. (AIR), Ottawa, Canada
- Aeroroed Consult HB, Karstorp, Sweden
- Air Accidents Investigation Branch (AAIB), UK
- Cranfield Institute of Technology, College of Aeronautics, Cranfield Aviation Safety Centre, UK
- The Norwegian Defence Research Establishment, Kjeller
- Garrett Engine Division, USA
- RNoAF Air Materiel Command, Kjeller
- The Foundation for Scientific and Industrial Research of the Norwegian Institute of Technology, Trondheim and S.I., Oslo
- Statoil Laboratory, Bamble
- Veritec, Høvik
- Zoological Museum, Oslo
- Asker & Baerum Police Station, as well as the National Bureau of Crime Investigation, the Royal Armament Research and Development Establishment and Mr. W.

Korsgaard, FAA, USA

SUMMARY

LN-PAA was on a charter flight en route from Oslo to Hamburg. Shortly after the aircraft had entered Danish-controlled air space the air traffic controller at Copenhagen Air Traffic Control Centre (ACC) observed that the aircraft turned unexpectedly to the west and then disappeared from the radar screen. When the crew did not respond to radio-calls, steps were taken to locate the aircraft. Since an aircraft accident was suspected, a search and rescue team from Hirtshals was sent to the scene. The accident was confirmed when the team found several bodies. Extensive search and rescue action was then initiated. 31 victims, as well as parts of the wreckage, were found floating in the sea and were brought to Hirtshals. Later, the rest of the wreckage was found scattered over several square kilometers of the seabed. An additional 19 victims were found in the area. Five persons are still missing.

Subsequent investigation has shown that undampened oscillations developed on the fixed surfaces and control surfaces of the aircraft tail. The oscillations were initiated by abnormal wear and tear on parts that were not manufactured in accordance with the aircraft specifications supplied by the manufacturer. The abnormal wear was not properly repaired during the last maintenance overhaul carried out on the aircraft. Undampened oscillations in the elevator contributed to the complete breakdown of the aircraft tail.

The aircraft Auxiliary Power Unit (APU) was in operation at the time of the accident. The front support of the unit had not been made in accordance with the specifications issued by the manufacturer and the support had failed prior to impact. The fact that the APU was operating with a

defective support had an influence on the oscillations in the empennage.

The cause of the accident was loss of control and stability as a consequence of defects in the structure of the primary control surfaces (para. 3.2.).

1 FACTUAL INFORMATION

1.1 HISTORY OF THE FLIGHT

1.1.1 On September 8, 1989, LN-PAA was on a charter flight to Hamburg. The flight was due to depart at 1500 hrs. The call sign was Partnair (PAR) 394.

The departure was delayed by almost an hour due to the Civil Aviation Administration, Norway (CAA/N) and the catering company having suspended PAS' credit. Once the financial problem was settled the crew was given permission to depart.

During the period September 6-8, 1989 LN-PAA experienced some technical problems with the left AC power system. The AC generator was replaced, but the malfunction in the system remained. On the flight to Hamburg it was decided to use the APU generator as the electrical power source for the left AC system.

LN-PAA took off at 1559:50 hrs. The flight proceeded normally to the planned cruise level, which was FL 220. At 1604 hrs PAR 394 was cleared direct to AAL VOR/DME (Aalborg). When the aircraft climbed through FL 180 at 1616 hrs, the crew was informed by Oslo ACC about strong westerly winds at altitude. The air traffic controller suggested a 10° heading change to the right (figure 1).

At 1622 hrs PAR 394 was informed that the radar service from Oslo ACC terminated and that the flight would enter

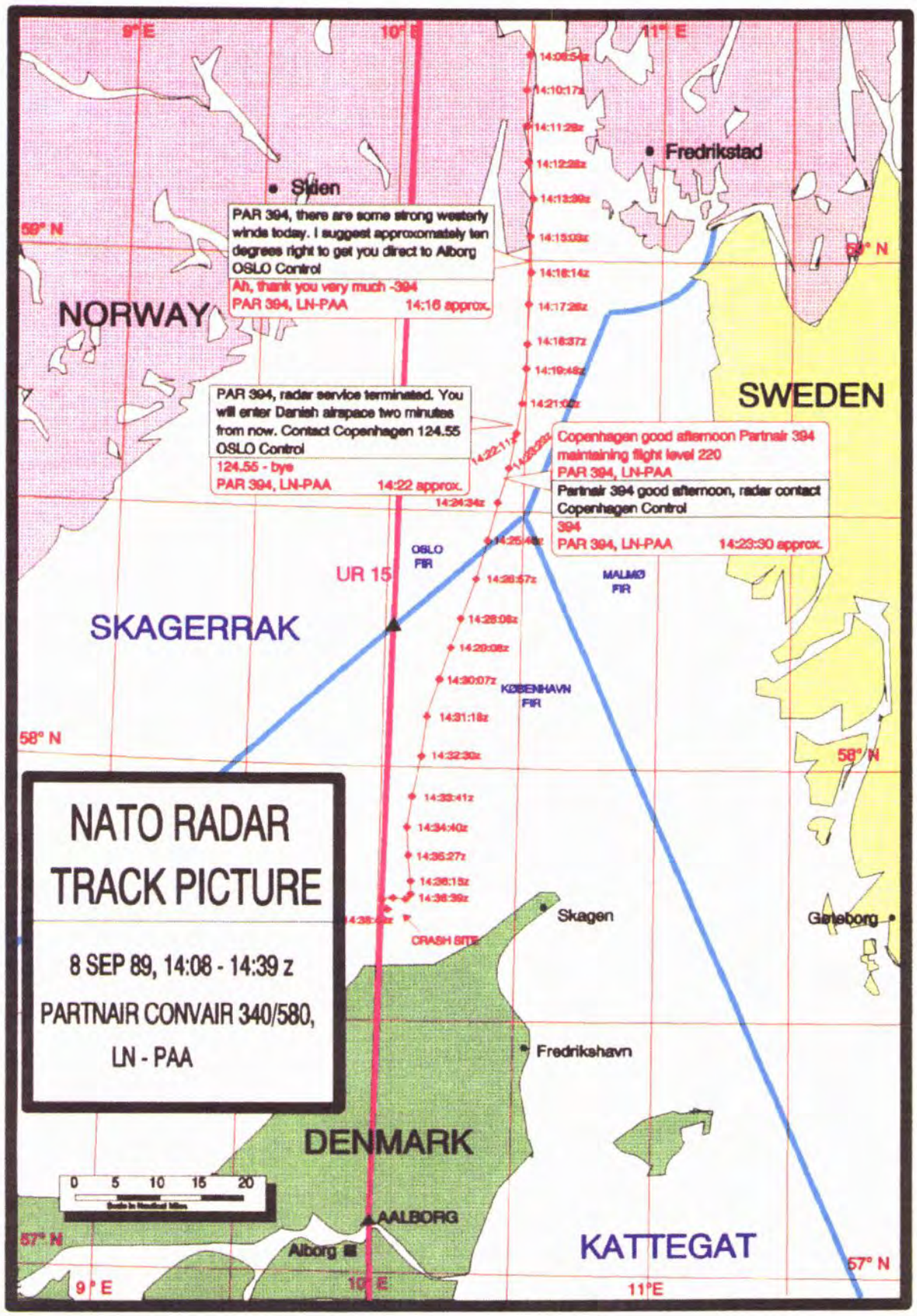

NATO RADAR
TRACK PICTURE
8 SEP 89, 14:08 - 14:39 z
PARTNAIR CONVAIR 340/580,
LN - PAA
PAR 394, there are some strong westerly winds today. I suggest approxomately ten degrees right to get you direct to Alborg OSLO Control
Ah, thank you very much -394
PAR 394, LN-PAA 14:16 approx.
PAR 394, radar service terminated. You will enter Danish airspace two minutes from now. Contact Copenhagen 124.55 OSLO Control
124.55 - bye
PAR 394, LN-PAA 14:22 approx.
Copenhagen good afternoon Partnair 394 maintaining flight level 220
PAR 394, LN-PAA
Partnair 394 good afternoon, radar contact Copenhagen Control
394
PAR 394, LN-PAA 14:23:30 approx.
NORWAY
SWEDEN
DENMARK
SKAGERRAK
KATTEGAT
Skien
Fredrikstad
Skagen
Fredrikshavn
Göteborg
AALBORG
Alborg
UR 15
OSLO FIR
MALMÖ FIR
KØBENHAVN FIR
CRASH SITE
9° E
10° E
11° E
59° N
58° N
57° N
0 5 10 15 20

FIG. 1

Danish-controlled air space in 2 minutes. PAR 394 was then requested to contact Copenhagen ACC.

According to the aircraft's Flight Data Recorder (FDR), LN-PAA reached its cruising level at 1623 hrs. Half a minute later the crew established contact with Copenhagen ACC and informed them that PAR 394 was maintaining FL 220, whereupon Copenhagen ACC confirmed that they had radar contact. This was the last radio contact anyone had with PAR 394. The next control point was AAL VOR/DME.

Apparently, the flight proceeded normally until the air traffic controller at Copenhagen ACC observed that the radar signals from PAR 394 showed an unexpected right turn and then disappeared from the radar scope.

At 1640 hrs the air traffic controller tried to contact PAR 394, but there was no reply. He tried again several times.

At 1642 hrs the ATS in both Denmark and Norway initiated an investigation to locate the aircraft. At 1659 hrs it was decided to inform the rescue authorities in Norway and Denmark.

It turned out that a serious accident had occurred. None of the 55 persons on board survived.

1.2 INJURIES TO PERSONS

INJURIES	CREW	PASSENGERS	OTHERS
FATAL	5	50	-
SERIOUS	-	-	-
NONE	-	-	

1.3 DAMAGE TO AIRCRAFT

The aircraft was completely destroyed.

1.4 OTHER DAMAGE

None.

1.5 PERSONNEL INFORMATION

1.5.1 The Pilot-in-Command, male, aged 59, had, at the time of his last licence renewal, a total flight time of 16,779 hrs, 14,720 hrs of which were as Pilot-in-Command. He had a total of 1,200 hrs on this type of aircraft since being checked out in February 1986. His duty time had been adhered to in accordance with the CAA/N point system.

1.5.2 The co-pilot, was a captain, male, aged 59, and also the Company's Flight Operations Manager. His total flight time when his licence was last renewed was 16,731 hrs, 11,926 hrs of which were as Pilot-in-Command. He had a total of 675 hrs on this type of aircraft since being checked out in February 1988. His duty time had been adhered to in accordance with the CAA/N point system.

1.5.3.1 The cabin crew consisted of two air hostesses, aged 42 and 41. Their licences were issued on April 3, 1970 and August 29, 1974, and valid until April 28, 1991 and June 13, 1994, respectively.

1.5.3.2 A mechanic accompanied the flight in order to inspect the aircraft during its stopover in Hamburg. He was 41 years of age and had both a flight mechanic's licence, Type II, issued on July 1, 1981 and a Type I licence issued on July 4, 1983. The licences were valid until February 21, 1991 and July 4, 1991, respectively.

1.6 AIRCRAFT INFORMATION

1.6.1 General information

The aircraft was registered in the Norwegian Civil Aircraft

Register in May 1986 as having registration letters LN-PAA and Register Certificate No. 2202.

1.6.1.1 *Aircraft details*

Manufacturer:	General Dynamics Corporation, Convair Division, San Diego, California, USA
Type:	Twin-engine turboprop. passenger aircraft CV-340/580
Serial number:	56
Year of manufacture:	1953
Total aircraft time: (TAT)	36,943 hrs
No. of landings:	15,116
A/C hrs since Major Overhaul (MO) in 1986:	1,913 hrs
Configuration:	52 passenger seats in the cabin
Certificate of Air-worthiness valid until:	May 31, 1990
Insurance:	Sev. Dahl's Assurancekontor A/S
Engine type:	Detroit Allison Diesel 501D13 Accepted time between overhaul (TBO) for power section, turbine and gear box all have 8,700 hrs
Propeller type:	GMC Aero Products A6441FN-606 Accepted TBO: 6,000 hrs/55 months

Engine No. 1:	S/N 501512 P/N 6828400 TSO: 6,199 hrs
Gear box:	S/N 601431 P/N 6792726 TSO: 8,268 hrs
Turbine:	S/N 700717 P/N 6847100 TSO: 6,114 hrs
Engine No. 2:	S/N 501348 P/N 6828400 TSO: 2,792 hrs
Gear box:	S/N 601026 P/N 6874193 TSO: 4,417 hrs
Turbine:	S/N 700504 P/N 6847100 TSO: 1,921 hrs
Propeller No. 1:	S/N HC 645 P/N 6505499 TSO: 1,928 hrs
Propeller No. 2:	S/N HC 2747/P-453 P/N 6505499 TSO: 716 hrs
APU:	S/N 61P-5964 P/N 85-91C TSO: 1,744 hrs
AC generator 1:	S/N JA361-719 P/N 2CM353C17 TSO: 6.5 hrs
AC generator 2:	S/N KD391-136 P/N 2CM353C17 TSO: 121 hrs
APU AC generator:	No S/N P/N 2CM353C17 TSO: 1920 hrs
DC generator 1:	S/N R858 P/N 30F02-9-E TSO: 1,838 hrs
DC generator 2:	S/N RR1467 P/N 30F02-9-G TSO: 310 hrs

1.6.1.2 The daily inspection (DI) was carried out at 0700 hrs on September 8, 1989. An MO was performed on May 25, 1986 when the Total Aircraft Time (TAT) was 35,024 hrs.
The yearly S-check was completed on April 4, 1989.
D-check No. 3, where a C-check was included, was completed on August 23, 1989 with a TAT of 36,883 hrs.

1.6.2 <u>Aircraft history</u>

1.6.2.1 After the accident, the AAIB/N received comprehensive documentation which enabled them to reconstruct most of the operational life of the aircraft up until September 8, 1989. The oldest documents contained information which was mainly of historical interest. The AAIB/N therefore distinguished between events and recorded information

before and after the aircraft became the property of Kelowna Flightcraft Ltd (KFC) in August 1985. This was done because the aircraft was then subject to an MO, as well as other more extensive modifications, after which the aircraft started a new period. The AAIB/N has scrutinized the background documentation connected with the inspections carried out after this date. This study provided the Board with detailed knowledge of the maintenance carried out during the period up until the time the accident took place.

1.6.2.2 The aircraft's first owner was United Airlines, who accepted it directly from the manufacturer in 1953. There were ten other owners before PAS received the aircraft in May 1986. The following owners and registration numbers have been found in the aircraft documentation:

MAR 1953	United Airlines, Chicago, Illinois	N-73128
AUG 1959	General Motor Corp., Detroit, Michigan	N-5120
MAY 1971	Servicio Aereo de Honduras S.A. (SAHSA)	HR-SAX
1978	Time Aviation	N-9012 J
SEP 1979	Charter Air Center Inc.	N-9012 J
FEB 1981	Caribbean Aircraft Development Inc. Opa Locka, Florida	N-770 PR
JUN 1981	Puerto Rico International Airlines (Prinair)	N-770 PR
APR 1983	UCO Airlines Incorporated Carolina, Puerto Rico	N-770 PR
Unknown	Puerto Rico International Airlines	N-770 PR

OCT 1984	PQF Corporation Verona, Pennsylvania	N-770 PR

From September 1984 to August 1985 the aircraft was not in service, and was to be found at Opa Locka, Florida.

AUG 1985	Kelowna Flightcraft Ltd. Kelowna, Canada	C-GKTF
MAY 1986	Partnair A/S Oslo Lufthavn, Fornebu, Norway	LN-PAA

1.6.2.3 *Time span 1953 - 1985*

1.6.2.3.1 During this period several modifications were carried out. In 1960 the original engines were replaced by Detroit Allison Diesel-type, model 501D13 turboprop engines, and the aircraft designation was changed to CV-340/580.

In 1963, while the aircraft was still owned by GMC, the Gas Turbine Compressor (GTC) P/N 85-90 was replaced by P/N 85-91C. FAA form 337, which contains the documentation for the installation, describes the new component as an APU installed in the aircraft tail cone.

Some time between 1963 and 1979 the APU was removed and a GTC was re-installed. The documentation for this work is missing, but a log entry, stating that a GTC was removed in 1979 was found.

1.6.2.3.2 There were few aircraft logs available between 1953 and May 1971 and there were only a few pages found dated between 1970 and 1971. In May 1971 the aircraft was purchased by SAHSA. Many of the documents dated between 1971 and 1978 are available in Spanish.

1.6.2.3.3 In September 1978 the aircraft suffered a nose gear failure, causing extensive damage. The aircraft was

temporarily repaired in La Ceiba, Honduras, by Hayes International Corp., and was subsequently flown to the Company's workshops in Dothan, Alabama, USA, where it remained until July - August 1979. No connection between this damage and the cause of the accident which took place on September 8, 1989 has been ascertained.

The aircraft and all its components underwent an MO during this period, as specified by the Allegheny Airlines Airframe Overhaul Manual. At the same time, the following modifications/installations and inspections/repairs were carried out:

- Interior and exterior emergency lights
- Radio Altimeter and Ground Proximity Warning System (GPWS)
- Cockpit Voice Recorder (CVR)
- Flight Data Recorder (FDR)
- Passenger Oxygen System
- GTC was replaced by an APU
- Cabin interior for 48 passengers
- Stringer inspection
- Repair of corrosion damage and other maintenance log entries

Documentation for all the above work is available.

1.6.2.3.4 From September 6, 1984 to August 21, 1985 the aircraft was not operational and was to be found at Opa Locka, Florida. There are no operational documents covering this period. The aircraft was then purchased by KFC. It arrived at

Kelowna Airport on August 22, 1985. At that time the aircraft had a TAT of 35,024 hrs and had accumulated 13,733 landings.

1.6.2.3.5 An examination of the available documentation from the operational life of the aircraft up to 1985 showed that maintenance work carried out on the aircraft had been documented.

1.6.2.4 *Aircraft history while under the ownership of KFC and PAS from 1985 to 1989*

1.6.2.4.1 KFC, a combined air transport and aircraft maintenance company, purchased S/N 56, Registration No N 770 PR, from Prinair of Puerto Rico in 1985. The aircraft was made temporarily airworthy and ferried to Kelowna on August 22, 1985. KFC immediately initiated an overhaul programme on the aircraft based on its own "Phase Inspection Programme". This work was reported to Transport Canada Aviation in a letter dated October 22, 1985.

1.6.2.4.2 At the beginning of 1986 PAS became interested in purchasing the aircraft. At this time the aircraft had a Canadian registration, C-GKFT. PAS carried out an inspection on the aircraft. In connection with this inspection Fred. Olsen Air Transport Ltd (FOF) sent a representative to evaluate KFC's standards and get a general impression of the aircraft when it was disassembled. FOF already had technical responsibility for the other two CV-340/580 aircraft PAS owned.

On January 21, 1986, FOF completed an aircraft maintenance status report. The aircraft was still being overhauled. Meetings between FOF and PAS were held at Fornebu on January 9, February 5 and March 20, 1986, in connection with the PAS purchase of the aircraft.

1.6.2.4.3 An agreement was made between KFC and PAS summarising the maintenance work to be carried out before transfer of

ownership. One of the conditions in the agreement was that the Kelowna Flightcraft Phase Inspection Programme in the maintenance documentation should be replaced by the Allegheny Airlines Airframe Overhaul Manual of August 15, 1977. The reason for this was that FOF already used this manual for the other two CV-340/580 aircraft owned by PAS. In order to adapt LN-PAA to these conditions, an MO was carried out.

1.6.2.4.4 A maintenance contract, Contract No. 1360 for the purpose of aircraft maintenance, already existed between FOF and PAS. The purpose of the agreement was to define individual responsibilities of the two parties regarding maintenance of the operator's CV-340/580 aircraft. The agreement stated that FOF's responsibility was "the technical responsibility and maintenance (with the exception of line maintenance)", and that FOF was to approve the mechanics who would perform the line maintenance and troubleshooting during daily operations. Some PAS and FOF representatives gave contradictory information to the AAIB/N regarding responsibility for line maintenance.

On May 15, 1986, LN-PAA was included in the agreement. The last revision of the agreement was dated December 7, 1987. The agreement was approved by the Norwegian CAA on July 24, 1986.

1.6.2.5 As was mentioned earlier, quite a few modifications were carried out on LN-PAA before 1986. In addition to the engines being replaced, the following modifications should be mentioned: the installation of the APU in the tail cone, the reconstruction of the heating and ventilation system and the modification of the AC-supply system in that a third generator was to be driven by the APU.

During the overhaul in 1986 the following modifications and new installations were carried out:

- Pressure refueling and fuel dumping system
- Increase in the maximum allowable take-off weight and the zero fuel weight
- New cabin flooring and fittings for a 52-seat version
- New cabin interior
- Adaptor for exterior heat and ventilation
- New galleys
- Standardisation of radio equipment
- Replacement of inverters with static inverters
- New Autopilot and Flight Director
- HF installation
- Evacuation slide
- Miscellaneous lighting

Some of the above mentioned modifications were carried out in accordance with a Supplemental Type Certificate (STC).

Once the overhaul was completed the aircraft was given a Canadian airworthiness certificate. This certificate was validated by the CAA/N on May 16, 1986 for a period of 30 days. A temporary registration certificate with the registration LN-PAA, valid for 30 days, was issued on May 15, 1986 by the Norwegian Consulate in Vancouver, as commissioned by the CAA/N. LN-PAA left Kelowna on May 26, 1986, and arrived at Fornebu on May 29, 1986.

1.6.3 <u>The aircraft maintenance system</u>

1.6.3.1 The maintenance system was based mainly on Allegheny Airline's maintenance documentation, which had been adapted by FOF. This system was used during the time LN-BWG and LN-BWN were owned by Nor-Fly Charter A/S and maintained by FOF. The system was transferred to PAS when this company purchased the two aforementioned CV-340/580 aircraft.

According to the approved Maintenance Schedule (MS) the system consisted of the following items:

1. Time limits

2. Line maintenance
   - A Pre-flight Check (Pre-departure check) shall be completed by the pilot before each departure and in accordance with the on-board check list.
   - A Daily Inspection (A-check) shall be completed and signed by a mechanic within 36 hrs (see note).
   - A B-check shall be completed by a mechanic after every 75th hour of operation (see note).

3. A C-check shall be completed after every 300th hour of operation. The B-check is then included.

4. A D-check shall be completed after every 600th hour of operation. Both B- and C-checks are then included.

5. A Major Overhaul is carried out as a Block Overhaul Period System, consisting of four intervals (Blocks 1-2-3-4). Each interval shall not exceed 5,000 hours of operation.

6. An S-check shall be completed every 12th month (plus/minus 2 months) for the renewal of the airworthiness certificate.

7. A Supplemental Inspection Document (SID) specifies that an inspection shall be carried out in addition to the aforementioned maintenance.

8. In addition, the Maintenance Schedule (MS) consists of the following items:

   - Special Scheduled Maintenance
   - Unscheduled Maintenance
   - Component Change
   - Test Flight
   - Weighing

NOTE:
In the MS there is a revision, issued by FOF in 1988, which states that the intervals between A-checks are to be increased from 24 to 36 hours and that the intervals between B-checks are to be increased from 60 to 75 hours of operation. Neither the FOF nor the PAS maintenance documentation used in the respective checks contains the aforementioned revision.

1.6.3.2 *Other maintenance requirements*

1.6.3.2.1 Supplemental Type Certificate (STC)

A general explanation of the STC as it has been developed in the USA is as follows:

After an aircraft has been type-rated it is not unusual for an operator, maintenance organisation or supplier of systems or equipment to aircraft to want to initiate extensive changes, which makes an application for a Supplemental Type Certificate - STC - necessary. The applicant must then substantiate, to the satisfaction of the Civil Aviation Authorities, that the modification conforms to current airworthiness requirements. Furthermore, it is a requirement that the modification neither affects, nor is affected by, earlier modifications. When inquiry is made into supplemental type certification previously carried out, it is apparent that this requirement may be difficult to adhere to when a number of extensive modifications have been carried out.

A large number of extensive modifications may also create problems in other areas. An example of this is in the establishment of satisfactory maintenance routines. For type certificates, a manufacturer makes recommendations with respect to the lifetime of components and intervals between one maintenance and another. These recommendations are usually the basis for the maintenance system operators seek to obtain approval for from the civil aviation

authorities. When some or all units of an aircraft type are modified in such a way that the new configuration is quite different from the original version, it is the responsibility of the operator concerned to prepare new maintenance routines and obtain approval for them. This may often require expertise that is not always available to the owners/operators.

Problems also arise with regard to the aircraft manufacturer's responsibility for supplying, and ability to supply, operators with after-sales support. In some cases, the STC is so extensive that the aircraft changes its designation. The STC-owner then takes over the role the original manufacturer/supplier previously had in obtaining technical documentation for the use and maintenance of the aircraft. This means that there is a possibility that valuable information is not conveyed to future owners.

1.6.3.2.2 LN-PAA was originally a Convair CV-340, constructed in accordance with the FAA regulations at that time - Transport Category CAR 4b. The aircraft was issued with Type Certificate No. 6A6.

1.6.3.2.3 The greatest modification in LN-PAA was the STC SA4-1100 installation of turbine engines. This also involved new electrical systems, new instruments and a new heat and ventilation system, as well as modifications in the structure and control systems. As a consequence the aircraft's model designation was changed from CV-340 to CV-340/580.

Other extensive modifications were the removal of the GTC from the right-hand engine nacelle and the installation of the APU in the aircraft's tail cone. This also led to alterations being carried out in the air pressure lines and in the ducting of the heat and ventilation system, as well as in the fuel system and fire extinguishing system.

The aircraft's fuel tank capacity, maximum allowable weight

for take-off and landing and Zero Fuel Weight were also increased.

1.6.3.2.4 These modifications were carried out in several stages, and some of them were done several times. This meant that the aircraft was converted to either its original or to its previous configuration, and then modified once again. This, together with the fact that the aircraft changed owners and operators many times, resulted in the aircraft maintenance documentation deviating to a large degree from the aircraft's actual configuration. This fact presented a problem in the process of preparation of satisfactory maintenance requirements.

1.6.3.3 *Airworthiness Directive (AD Note)*

1.6.3.3.1 In the light of reported findings, the original manufacturers, the STC owner or the sub-contractors may decide that they must draw up new maintenance requirements or recommend improvements. These would be distributed as a Service Bulletin (SB), Service Instruction (SI) or Service Letter (SL). In some cases, the reported conditions could be so extensive that the civil aviation authorities will conclude that they affect the aircraft's airworthiness. In such cases the authorities would accept the documentation issued in the manufacturer's service information and thereupon issue the information as an airworthiness directive, known as an AD Note in the USA. This means that the validity of the aircraft's airworthiness certificate is dependent on the specified inspections or improvements being completed within the time limit stipulated by the authorities. An AD Note is thus a mandatory directive that the civil aviation authorities use as a flight safety measure. The directive may also be released on the authorities' initiative, regardless of the manufacturer's evaluations.

1.6.3.3.2 For the CV-340/580, the General Dynamics Report ZS-34-1000, Supplemental Inspection Document (SID) was of considerable

importance (para 1.6.4.5). The object of this SID was to give operators a basis for which to carry out additional maintenance on aircraft which had been in operation for some time. This was in response to the programme the civil aviation administration in the USA - the FAA - had initiated to deal with the "ageing aircraft" problem. The FAA decided that ZS-34-1000 must be made compulsory, and therefore issued the contents of this report in AD Note 88-22-06. This airworthiness directive was to be incorporated in the aircraft's approved maintenance instructions within a year of the date of issue, November 14, 1988.

1.6.4 The aircraft's D-check No. 3 at KFC in 1989

1.6.4.1 Allegheny's maintenance documentation was revised by FOF to a D-check system. This consisted of six D-checks, each to be carried out at intervals of 600 flight hours. Each D-check consisted of a set of working cards. FOF had previously carried out D-checks Nos. 1 and 2 on LN-PAA. When D-check No. 3 and the SID requirements were supposed to be carried out, however, FOF did not have the capacity to do it. Their solution was to seek assistance from another workshop.

1.6.4.2 KFC was contacted. The workshop was available and maintenance approval was obtained from the CAA/N on July 7, 1989. In addition to the D-check being carried out, the SID requirements, certain modifications, and the repairing of faults in the aircraft, noted in the log and Beltframe inspection, SB 53-15, dated June 15, 1989, were also to be carried out. It was PAS intention to have all the inspections completed, irrespective of time limits. A Quality Plan for the work which was, amongst other things, to cover the conditions of mutual responsibility between the Company and the workshop, lines of communication between the Norwegian inspector and the FOF organisation, as well as the handling of parts and documentation was drawn up. Among the organisational conditions mentioned in

the plan was: whom the inspector should contact at FOF when there were problems regarding the aircraft structure and when he wanted to know how these problems should be solved. The work was carried out during July - August 1989 according to the FOF maintenance documentation, at which time an FOF inspector was present.

1.6.4.3 The "List of applicable work cards" for the D-check, which was a summary of all the work cards included in the inspection, had spaces for the aircraft registration, the number of the check and the date. None of these spaces were filled in. Neither the work cards nor the Maintenance Manual (MM) were revised in areas where considerable modifications had been carried out on LN-PAA, as, for example (with reference to the MS), on work cards D059, D181, D182 and D212, which had also been used on earlier D-checks.

After the D-check had been completed, a meeting was due to take place within a week to review the documentation with representatives from the engineering, control and production sections. According to FOF there had not been any time available to arrange this meeting before the accident took place.

1.6.4.4 In connection with D-check No. 3, a total of 282 work cards were written out. The check uncovered, among other things, some cracks in the fuselage and the wings, corrosion and defective rivets, as well as various other defects. Four of the cards had been completed after the two test flights which concluded the inspection. The repairs had been inspected and approved by signature.

1.6.4.5 *Supplemental Inspection Document SID ZS-34-1000*

SID ZS-34-1000, which is an extensive inspection with various time limits, was transferred by FOF to the workshop's own work cards. The inspection consists, among other things, of checking the four bolts that attach the

vertical fin to the fuselage. The pins and sleeves have to be removed and the fittings have to be checked for corrosion and cracks (SID 55-5-4). The inspection should be carried out on one attachment at a time. The holes should be measured and new pins and sleeves should be installed. The installation should be done according to sections 55-2-00 and 55-30-30 of the Maintenance Manual. Section 55-30-30 of the MM contains the procedure for removal and installation of the vertical fin.

1.6.3.3.3 The SID requirements were due to be carried out on LN-PAA during maintenance work in July/August 1989.

1.6.4.6 It is certain that KFC checked all four attachments using ultrasonic equipment, without removing the pins and sleeves. The work was signed for and stamped as being completed. During the inspection, however, it was discovered that the alignment marks for the pin and sleeve in the rear, right-hand attachment were displaced. This indicated wear, and the pin and sleeve were consequently replaced.

1.6.4.7 When the documentation was checked after the work on the aircraft was completed, the Norwegian inspector representing FOF discovered that inspection of the attachments had not been carried out according to the prescribed methods. He therefore did not approve the work. Since the aircraft had only accumulated 36,883 hrs and the inspection was to be completed within 40,000 hrs, he decided to bring the subject up when the aircraft had returned to Norway. The inspector is of the opinion that the matter was discussed with FOF before the decision was made. At this time LN-PAA was ready for a test flight and a renewed inspection of the attachments would cause delays.

The aircraft arrived at Fornebu on August 27, 1989, and was put back into service. During the period between the inspection and the accident on September 8, 1989, LN-PAA accumulated a total of 59:36 hrs.

1.6.4.8 KFC installed 437.5 lbs of iron plates as a fixed ballast in the nose section to compensate for the weight of the APU in the tail. This was done to avoid the use of a loose ballast. The installation of the fixed ballast was included in the aircraft's weight and balance documentation after a weight check was made on August 19, 1989. The compass swing on work card No 1005, para 7b, is not documented as having been completed after the installation.

1.6.4.9 In preparation for the Beltframe inspection, SB 53-15, dated June 15, 1989, blueprints were made of the stations that had to be checked. On the under-floor blueprints, stringers Nos. 9 and 10, to the left and right, respectively, were missing. The inspection covered damage to the framework caused by the installation of interior fittings, such as panels, equipment, etc. According to notes written on the blueprints, a large amount of such damage had been found. However, the position of the notes was misleading because they are marked on the outside of the framework on most of the blueprints (ref. SB 53-15, para. 1C and fig. 2, page 5).

1.6.5 Other information

1.6.5.1 The AAIB/N visited KFC in order to obtain information about the workshop and the work that was carried out on LN-PAA. The staff were cooperative and receptive to the questions asked. The workshop carries out maintenance work for several CV-340/580 aircraft operators from both Canada and the USA. A positive impression was given of normal standards in work routines. The company also manufactures spare parts, approved by GDCD, for this type of aircraft. During the visits, the rebuilding of aircraft (avionics, engines, fuselage extension) was in evidence.

1.6.6 Documentation

1.6.6.1 Where mention is made of the Flight Manual (FM), the Pilot's Handbook and the Minimum Equipment List (MEL) in

the report, reference is actually being made to those documents the AAIB/N received from PAS and FOF after the accident. The relevant documents, which were on board LN-PAA, were never recovered, with the exception of the cover of Pilot's Handbook No. 19.

1.6.6.2 The PAS Maintenance Release Document for CV-340/580, 200101-1, Daily Inspection, Volume 9, dated November 15, 1988, was not revised to include modifications carried out on LN-PAA. For example, in para. 9 the APU is indicated as being in Position 2 (in the aircraft's right wheel well), whereas the installation was actually located in the tail cone.

1.6.6.3 The MEL was not revised to include the aircraft's modification and equipment status. The same applied to documents which made reference to the MEL.

1.6.6.4 The aircraft's Technical Log, which was in the aircraft, was recovered after the accident. The AAIB/N has checked the logs for the days preceding the accident and found that the aircraft had been in frequent use. Statements made during the days after the accident regarding problems in starting the right-hand engine and closing the main entrance door/stairway, have been confirmed. These problems were recorded in the log on September 7, 1989. The repairs/adjustments were made, documented and signed for in Log No. 3660 on September 8, 1989 at 1450 hrs.

1.6.6.5 Signs of malfunction in the left-hand AC-system and generator were logged and acted upon as follows:

Log No. 3659, departure from Malmoe/Sturup on September 6, 1989 at 2236 hrs. for a positioning flight to Stavanger/Sola. En route the left AC system developed a fault. The log shows that the AC generator could not be connected to the corresponding system. The PIC decided to land at Oslo/Fornebu in order to have the malfunction corrected at the maintenance base before the scheduled flight the next day.

The left AC generator was changed during the night and signed for in the log on September 7, 1989 at 0600 hrs.

1.6.6.6 Log No. 3660, departure from Oslo/Fornebu on September 7, 1989 at 0718 hrs for a positioning flight to Stavanger/ Sola, a further flight to Aberdeen, followed by a return flight to Fornebu via Sola. The log shows the maintenance release for September 7th and 8th. It also contains the following three entries which refer to the faults noted that day:

1. "FWD AIR-STAIR NEEDS PUSHING FOR RETRACTION & CLOSING"
2. "LEFT ALTERNATOR OFF LINE"
3. "RIGHT ENGINE START RELAY HUNG UP ON TWO STARTS"

There is no indication as to which of the day's 4 sectors these faults occurred in. The aircraft technical log is not designed to show entries for any one sector.

Entry Nos. 1 and 3 were rectified by adjusting the door mechanism and changing a starter regulating valve. As regards Entry No. 2, it was noted that further flights could be made with the APU generator in operation. The entries were signed for on September 8, 1989 at 1450 hrs.

1.6.6.7 Log No. 3661, flight from Fornebu to Vaernes returning to Fornebu, departing September 8, 1989 at 0749 hrs and returning at 1018 hrs. The log contains the crew list for this flight as well as the following flight to Hamburg. In the remarks column there is only a signature. The maintenance release for September 8 had been entered in Log No. 3660.

1.6.6.8 The mechanic who carried out the inspection explained that LN-PAA had three faults entered in the log:

1. Difficulty in closing the main door.
2. The left AC generator was not functioning.
3. Problems when starting the right engine caused by a

malfunctioning starter air-valve.

The flight to Vaernes was an extra flight, and consequently there was not enough time available to rectify these three faults before departure. The mechanic joined the flight in order to assist, if necessary, with engine start at Vaernes. He has explained that the flight was completed without problem. The APU generator was used as a substitute for the left generator for approximately 15 minutes after take-off from Fornebu, i.e. while climbing to around 17,000 feet. The APU was then switched off and not used again. On the return flight the mechanic was seated in the cabin and was therefore unable to observe whether or not the APU was used. After arrival at Fornebu he changed the starter valve and adjusted the main entrance stairway. A functional check showed that the faults had been rectified.

1.6.6.9 According to the mechanic's witness statememt, several attempts were made to correct the fault in the left AC system, all of which were unsuccessful. The mechanic therefore contacted the shift foreman at FOF, who also had extensive experience with aircraft electrical systems. The troubleshooting, which had already been carried out, was examined and evaluated. They agreed that in order to find the fault the aircraft had to be grounded and the entire system checked. The Production Coordinator at PAS was informed that the problem had not been solved, and together they informed the Flight Operations Manager (the co-pilot on the accident flight). The Flight Operations Manager decided that the aircraft could be used with the APU generator as the source of electrical power to the left AC system, and then suggested to the mechanic that the decision should be entered in the Aircraft Log as "Released for flight with APU alternator operative".

1.6.6.10 The flight to Vaernes on September 8 and the accident flight are the only two flights where the AAIB/N was able to confirm that the APU was used while airborne. The latter flight was the only one known were the APU was in

continuous use.

1.6.6.11 With regard to para. 15.6 of Agreement No. 1360 between PAS and FOF, PAS was responsible for all line inspections as well as the rectification of all faults occurring in the course of daily operations. The work was to be carried out by personnel approved by FOF. Furthermore, FOF was to receive immediate and continuous information on all faults or conditions affecting the airworthiness of the aircraft.

1.6.6.12 According to the MEL, it was required that both of the AC-generators installed should be operative before departure. This MEL was not revised to take into account the LN-PAA configuration with a third AC generator mounted on the APU. The last revision of the MEL was dated June 1, 1987 (Issue No.2) more than a year after PAS put LN-PAA into service. The operation manuals used by the pilots (the Flight Manual and the Allegheny Airlines Pilot's Handbook, for example) which the AAIB/N received from the Company, did not mention any use of the AC generator on the APU as an alternative electrical power source during flight. In addition, the manuals contained drawings of the APU installation and its control panels. Use of the APU and the APU generator is included on the Normal Check List, but does not mention it as an alternative electrical source in flight. However, the AAIB/N received a file from the Company containing pictures of and technical documents for LN-PAA, and including a complete "Flight Manual Supplement" on the use of the APU while airborne.

Discussions the Board had with pilots and mechanics from PAS gave the impression that the APU generator was generally accepted as being one of the two necessary electrical power sources which had to be in operation in order to satisfy the MEL requirements. The AAIB/N was also informed that mention was made on the Emergency Check List of the use of the APU generator. It was stated on the list that the generator was only to be used should one of the engine-driven AC generators fail. The Emergency Check List

is only for use while airborne.

1.6.7 Weight and balance

The aircraft was loaded within the specified weight and balance limits.

1.7 METEOROLOGICAL INFORMATION

1.7.1 On the day of the accident there was high pressure over the North Sea and Scandinavia, with light winds over ground and sea. The wind at FL 240 was 260°/70 knots gradually decreasing to 10 knots at FL 30. Rain clouds were moving east to south-east over Northern Jutland on the afternoon of September 8, 1989. At its cruising level LN-PAA had good visibility between cloud layers. The command pilot of a Norwegian fighter aircraft en route from Aalborg to Rygge at FL 240 reported that he observed an aircraft below him heading in the opposite direction. The aircraft passed each other at 1629:28 hrs, according to radar observations.

1.7.2 The weather forecasts and observations from the relevant airports in connection with PAR 394's flight to Hamburg indicated that the weather conditions did not cause any difficulties when planning or carrying out the flight.

1.7.3 The following weather conditions and sea currents were logged on September 8, 1989 at 1740 hrs by Hirtshals Rescue Station:
south-westerly wind, 2 m/s, haze, strong easterly sea current.

1.7.4 The accident occurred during daylight.

1.7.5 The sea current in the wreckage area was calculated to be flowing in an easterly direction at 0.9 knots, based on the time of location and position of the debris from the aircraft in relation to the assumed point of impact (the position of the main wreckage).

1.8 AIDS TO NAVIGATION

1.8.2 There were no reports regarding abnormal operations.

1.9 COMMUNICATIONS

1.9.2 There were no reports regarding abnormal radio communications.

1.9.3 The last radio communication with LN-PAA was as follows:

1622 hrs:	Oslo ACC:	"Partnair 394, radar service terminated. You will enter Danish airspace two minutes from now. Contact Copenhagen 124.55, Oslo control."
	LN-PAA:	"124.55 - bye, Partnair 394."
1623 hrs:	LN-PAA:	"Copenhagen, good afternoon, Partnair 394 maintaining flight level two two zero."
	CPH ACC:	"Partnair 394, good afternoon, radar contact, Copenhagen control."
	LN-PAA:	"394"

After LN-PAA disappeared from the radar screen, PAR 394 was repeatedly called by Copenhagen Control and by other units which had been called in to assist - all to no avail.

1.10 AERODROME INFORMATION

Not applicable.

1.11 FLIGHT RECORDERS

A Flight Data Recorder (FDR) and a Cockpit Voice Recorder (CVR) were installed during extensive repair and modification work carried out in 1978 - 1979.

1.11.1 The recorders were found on the seabed, about 357 meters apart. Both had been torn loose from their brackets and

were found in the same area as the tail section in which they had been installed. The CVR box showed evident signs of having hit the water at high speed. One of the large, flat sides was indented in such a way that the pattern of the insulating material and box frame was imprinted in detail over the entire surface. Both boxes were made of thin, stainless steel. The FDR box did not have the same damage pattern, but was deformed in one corner and at one end.

1.11.2 Cockpit Voice Recorder (CVR)

1.11.2.1 The CVR system was installed during a modification, STC SA451EA, on August 27, 1979. The CVR at the time of the accident was a Sundstrand, P/N 980-6005-060, S/N 678, installed on April 4, 1989, which was mounted on a bracket riveted to the bulkhead at station (STA) 820.950. This bulkhead was also the aircraft structure to which the vertical fin front supports were attached.

1.11.2.2 The CVR tape was played back at the AAIB in the UK. It was revealed that the CVR had ceased functioning when the aircraft taxied into take-off position on the runway at Fornebu and the engines were shifted to high r.p.m.

1.11.2.3 An inspection of the Company's other two aircraft of the same type showed that LN-BWG had the same fault. The malfunction was caused by modifications carried out subsequent to the original installation of the CVR. One of these modifications was carried out so as to achieve an automatic switching of the electrical power source to the primary AC system when the engines were shifted to high r.p.m. for flight. Correct voltage and frequency from the engine-driven AC generators are only available at high, constant engine r.p.m. This switching was carried out automatically by means of relays, while this had previously been done manually in accordance with check lists. The relays installed in LN-PAA and other aircraft modified in the same way were of a type insufficiently protected from

environmental factors such as dust and corrosion. This installation caused low operational reliability. No instructions required the operation of the CVR to be checked using both electrical sources. The pilots checked the CVR before engine start, in accordance with the Prestart Check List, the CVR being powered from a DC source via a static inverter.

This malfunction was immediately reported to the CAA/N. The Board was later notified that the same malfunction had been discovered on other aircraft of the same type abroad.

1.11.2.4 According to the Daily Inspection Check List and the B-check the CVR was to be tested before engine start and before electrical power from the engine-driven AC generators was supplied. The current maintenance instructions did not contain any requirement for testing of the CVR with the engines running at high r.p.m. The Flight Manual (FM) assumed a manual switching to the AC power source (as was the case before installation of relays) and consequently indicated that the test should be carried out using electrical power from the engine-driven generators at high engine r.p.m. The pilots should carry out a check of the CVR at Point No. 2 on their "Before Start" check list. Any malfunction in the relays would therefore only have been discovered accidentally.

1.11.2.5 The recording of the conversation and sounds from the cockpit during the last 30 minutes before departure is of a good technical quality. Information from this recording confirms other witness statements that the co-pilot (the Flight Operations Manager) left the cockpit in order to settle financial matters with the CAA and the catering company. In addition, the tape contained the reading of check lists, engine start procedure and taxiing.

1.11.3 Flight Data Recorder

1.11.3.1 The FDR system was installed during modification STC SA604-

EA, on August 27, 1979. The FDR unit installed at the time of the accident was a Fairchild P/N 15600-501, Mod. 5424-501, S/N 5205. The metal foil magazine was P/N 5427, S/N 3032, and was overhauled and tested at the Braathens SAFE A/S workshop on August 17, 1987. The FDR was installed directly below the CVR at station 820.950.

1.11.3.2 This type of recorder uses metal foil to record the magnetic heading, indicated airspeed, pressure altitude, vertical acceleration and microphone keying data, with reference to a time axis. The recording of the vertical acceleration (G) did not work in this FDR. Equipment for recording the microphone keying data had not been installed.

The flight number and date (Trip and Date) are also recorded when the pilots enter them on the control panel. The foil is moved forward by an electrical motor at a constant speed of 0.1 inches per minute. The recordings are registered by mechanically-operated and/or electrically-operated diamond needles which come into contact with the foil every 0.55 seconds. Bellows linkage systems position the needles for the speed and altitude in accordance with changes in the dynamic and/or static pressure, as registered by the respective sensors. Compass system No. 2 is the source of the magnetic heading information. The signals are sent from the instruments in the cockpit to a servo in the FDR, which positions the needle. The Trip and Date are registered when a binary printer with an arm that moves 0.125 inches, plus or minus 0.005 inches, becomes activated as soon as the printer receives an electrical current.

The arms which keep the diamond needles, or knives, in position over the foil, are individually balanced. This is done by means of adjustment screws that change the distance of the arm's centre of gravity from the pivotal point. The arms will therefore have different natural frequencies.

1.11.3.3 The following specifications for a Fairchild FDR 5424-501 are quoted from the handbook:

"J Leading Particulars

Principle features and characteristics of the Flight Data Recorder

System Operation
Recording Speed..... 6 ins./hr
Recording Period ..... 300 hrs continuous *)

Recording Ranges
Altitude ..... -1000 to +50,000 ft
Airspeed ..... 0 to 450 knots indicated
Heading ..... 360 deg azimuth
Vertical Acceleration .. +6G to -3G

Recording Accuracy
Altitude ..... ±100 to ±700 ft
Airspeed ..... ±10 knots
Heading ..... ±2 deg
Vertical Acceleration .. ±0.2G

Strike Frequency
Alt, Airspeed, Heading 1.8 per sec (strikes once every .55 sec)
Vertical Acceleration Continuous, plus strike frequency .55 sec

Medium Motion Indicator Light:

Extinguishes ..... 60 to 300 seconds after start of recorder, depending upon tightness of medium in magazine
Illuminates ..... minimum 90 seconds after drive failure, minimum 45 seconds after govern stoppage or break of medium or exhaustion of medium immediately after external or internal power failure in the recorder"

*) NOTE: The foil has a time capacity of 400 hrs, 60 hrs of which are reserve time. It should be changed or reversed when there are 60 hrs or less left of its capacity.

1.11.3.4 The FDR shall also satisfy the minimum requirements for vibrations and harmonic oscillations, as stated in Federal Aviation Regulations FAR 37.150:

"3.1.3 Vibration

When installed in accordance with the instrument manufacturer's instructions, the recorder shall function properly and shall not be adversely affected when subjected to vibrations of the following characteristics."

Recorder Location in Airframe	Cycles per Second	Maximum Double Amplitude	Maximum Acceleration in G's
Air frame Mounted Structure	5-500	0.036 inches	10 G

7.7.1 Resonance

"The recorder, while operating, shall be subjected to a resonant frequency survey of the appropriate range specified in section 3.1.3 in order to determine if there exists any resonant frequencies of the parts. The amplitude used may be any convenient value that does not exceed the maximum double amplitude and the maximum acceleration specified in section 3.1.3."

"The recorder shall then be subjected to a vibration at the appropriate maximum double amplitude or maximum acceleration specified in section 3.1.3 at the resonant frequency for a period of 1 hour in each axis or with circular motion vibration, whichever is applicable. When more than one resonant frequency is encountered with vibration applied along any one axis, a test period may be accomplished at the most severe resonance, or the period may be divided among the resonant frequencies, whichever shall be considered most likely to produce failure. The test period shall not be less than one-half hour at any resonant mode. When resonant frequencies are not apparent within the specified frequency range, the recorder shall be vibrated for 2 hours in accordance with the vibration requirements of section 3.1.3 at the maximum double amplitude and the frequency to provide the maximum acceleration."

1.11.3.5 The foil which was installed in the magazine at the time of the accident was done so during the C-check carried out on March 28, 1989, at TAT 36,600 hrs. The running time of the foil was 343 hrs when the accident occurred at TAT 36,943 hrs. During an inspection of the maintenance data and of the foil it was revealed that the FDR had suffered

considerable operational malfunctions during this period. These were mainly the absence of any vertical acceleration reading and abnormal indications on the heading parameter.

1.11.3.6 The AAIB/N has neither a laboratory nor experts available to analyse the FDR readings. In order to obtain the broadest possible basis for evaluation several organisations were used:

- Scandinavian Airlines System, Flight Data Recording and Analysis, in Copenhagen (two assessments)
- National Transport Safety Board, USA
- Air Accidents Investigation Branch, UK
- Aviation Consultant F.M. Medak, an expert on the FDR in question, formerly employed by Fairchild Aviation Recorders, USA
- Accident Investigation and Research Inc., Canada

1.11.3.7 Experts from the last company mentioned conducted a comprehensive examination and assessment. The results from earlier readings and analysis were made available and taken into consideration. The AAIB/N therefore essentially used this last analysis as the basis for the description in this report.

The foil was examined through a stereo microscope on a table with X and Y coordinates. The readings were stored in a computer with a printer. Specific calibration data for this particular FDR were not available, and standard calibration data obtained from the NTSB were used in the examination. The recorded data were transferred to a graphic and analytical data program for further analysis.

According to FDR experts there is a possibility of there being differences between the various readings. This could be due to either mechanical, optical or manual inaccuracies. These differences could also be caused by individual interpretations.

The Flight Data Recorder's ability to withstand harmonic oscillations was evaluated. The minimum specifications for this design are found in FAR 37.150. Some of these specifications are listed in para. 1.11.3.4 above.

1.11.3.8 The complete reading from LN-PAA's last flight is shown in Appendix 2. The time axis indicates the elapsed time (FDR time) in minutes and seconds from the time the aircraft took off from Runway 24 at Fornebu. The accuracy of the foil movement, which should be 6 inches per hour, was checked. A number of flight recordings were examined and compared with logged airborne times. The comparison led to a suspicion that the foil movement was approximately one minute slow per hour of operation.

1.11.3.9 *Observations from the readings*

1.11.3.9.1 The aircraft climbed to 22,500 ft in 22:30 minutes. The average rate of climb was 1,000 ft per min. The altitude registration was thereafter constant until 35:35 FDR time. A deviation from the cruising altitude occurred at that time, which culminated in an altitude increase of 300 ft at 35:45 FDR time. This altitude increase was also registered by Skagen radar in mode C, which indicated that a 300 ft altitude increase had culminated at 1436:03 hrs UTC. By this time the aircraft had been airborne for 36:13 minutes since lift-off at 1359:50 UTC. At that point the FDR time indicated was 35:45 min, in other words, a difference of 28 secs. The suspicion that the FDR foil had moved approximately one minute too little per hour was thereby confirmed.

1.11.3.9.2 At 35:45 FDR time the recorded altitude decreased by 1,100 ft in only a few seconds. An altitude loss of 1,100 ft was also recorded by Skagen radar mode C during this phase of the flight.

1.11.3.9.3 The altitude trace recorded on the FDR foil showed a pronounced double line during climb, from 1,400 ft until

the FDR stopped functioning at 36:01 FDR time. At 1,400 ft the vertical speed fell and the indicated air speed increased temporarily to 217 knots.

1.11.3.9.4 When the aircraft established its cruising level the indicated airspeed increased from 185 knots to 215 knots, and then decreased to 200 knots. At 34:50 FDR time the final changes in airspeed began; within 40 secs the IAS decreased to 190 knots. At 35:30 FDR time the airspeed increased 16 knots in just a few seconds. At 35:45 FDR time a new increase of 25 knots in one second was registered.

1.11.3.9.5 During climb, the heading was stabilised at 186°M (magnetic). After 13 minutes FDR time the heading moved a few degrees to the right. About 16 minutes after take-off there was a new heading correction to the right, to 202°M. This coincides with a suggestion from the air traffic controller that the 10° to the right heading be corrected due to strong westerly winds at altitude. Between 20:50 and 30:30 FDR time the heading was close to 208°M.

1.11.3.9.6 At 30:30 FDR time a heading change of 8.5° to the left was recorded. At 33:40 FDR time the heading was again altered to the left by 5.5°. A minute later there was an additional heading change of 5.5° to the left. At approximately 35:40 FDR time a sudden, sharp change of heading to the left, greater than 12° was recorded. The extent of the change of heading cannot be accurately determined because wrinkles on the foil in this area makes a reliable reading difficult. There were, however, indentations that indicate the change of heading to be greater than 25°. This, in relation to the time axis, corresponds to a rate of turn of approximately 500° per minute (Appendix 3).

1.11.3.9.7 The expert for this particular FDR type explained to the Board that he had analysed readings from other FDRs in four different cases where similar heading patterns had been recorded (compared to the approximate 500° per min for LN-PAA) where a roll was observed before impact or where a

roll had been confirmed by the relative position of wreckage parts at the accident sites.

1.11.3.9.8 The binary printer registered 394 as the flight number and 8 as the date. In addition, four "event marks" were found during the last 7 seconds of the reading (Appendix 4). Fairchild FDR experts established that these marks represented a break in the electric power supply (115 volts, 400 cycles) to the recorder. These four indentations were found between 35:54 and 36:01 FDR time. At 36:01 FDR time the last break in the electrical power supply occurred.

1.11.3.9.9 When electrical power is supplied to the unit the printer arm will move in on the foil 0.125 inches from the edge. When there is a break in the power supply the arm will immediately return to its original position. Because of a slight inertia in the moving parts of the system the foil will move forward about 6/10 mm after a power break. This corresponds to about 15 seconds of normal operation.

1.11.3.10 Because the registration of the vertical acceleration was still inoperative after the maintenance work carried out in July/August 1989, the AAIB/N examined the maintenance documentation for the FDR inspection.

The basis for the maintenance of the flight and voice recorders are found in BSL D 1-12, para. 5. The regulations state:

> "The flight data recorder and the cockpit voice recorder shall be included in the aircraft's general maintenance system in such a way that their proper functioning and registration are continually checked and that the correct time for changing tapes or other registration media is safely guaranteed."

The maintenance documentation states that the C-check shall comprise a comparison of the altitude, speed and heading observed during a flight with the recorded values on the FDR (Ref Work Card C06). The flight crew log the observed

data on FOF Form 1950. The completed form shall be forwarded to the technical department of the maintenance organisation. When the accident occurred the form from the C-check of April 4, 1989 had still not been evaluated.

When the D-check, Card No. D502, had been carried out in July/August 1989 the same requirements from C-check Card No. C06 were not included. However, it was stated in the Maintenance Schedule that both the B and C-checks were to be included in the D-check (ref. MS Chapter 1, Card 10003). The consequence of this was that the FDR operation inspection, carried out during the C-check every 300th flight hour, inadvertently, on this occasion had its service interval increased to 600 hours.

1.11.3.11 The AAIB/N carried out systematic examinations of existing faults and abnormal readings, resulting in the following findings:

- The altitude parameter, registered as a double, broken line, as shown on photos 1, 2, 3 and 4, was a type of deviation not known from past experience.

- Neither the manufacturer nor others the AAIB/N have been in contact with were aware of any failure mechanism in the FDR which could possibly have caused the double lines.

- The double line on the altitude parameter occurred for the first time about 330 flight hours prior to the accident.

- The double line appeared during the last part of the climbing phase and into the first part of horizontal flight at cruising level.

- The first cases where the double lines are registered occurred on two or three consecutive flights, and were then absent again during the next five to ten flights.

PARTNAIR CONVAIR 580, LN-PAA:- FDR RECORDED FLIGHT DATA			
FLIGHT NUMBER SINCE OVERHAUL	DATE (dd-mm-yy)	AIRBORNE TIME (h:mm)	REMARKS
Note:- Aircraft arrived in Kelowna, British Columbia for overhaul on 5 July 1989			
1	23-Aug-89	1:31	Post-overhaul Test Flight
* 2 *	25-Aug-89	1:03	Post-overhaul Test Flight
3	26-Aug-89	4:00	Depart Kelowna, Ferry Flight to Oslo
4	26-Aug-89	3:11	Continuation of Ferry Flight
5	27-Aug-89	4:32	Continuation of Ferry Flight
6	27-Aug-89	3:19	End Ferry Flight at Oslo
7	28-Aug-89	2:46	
8	29-Aug-89	0:43	
9	30-Aug-89	2:04	
10	31-Aug-89	0:55	
11	31-Aug-89	1:15	
12	31-Aug-89	1:38	
13	31-Aug-89	1:45	
14	01-Sep-89	1:21	
15	01-Sep-89	1:20	
* 16 *	02-Sep-89	1:34	
17	02-Sep-89	1:06	
18	02-Sep-89	0:57	
19	03-Sep-89	1:06	
20	05-Sep-89	3:12	
21	05-Sep-89	3:50	
22	05-Sep-89	1:13	
23	06-Sep-89	1:08	
24	06-Sep-89	3:29	
25	06-Sep-89	3:38	
26	07-Sep-89	1:19	
27	07-Sep-89	0:55	
* 28 *	07-Sep-89	1:15	
29	07-Sep-89	1:00	
* 30 *	07-Sep-89	0:40	
31	08-Sep-89	0:56	
32	08-Sep-89	0:55	
* 33 *	08-Sep-89	0:36	Final accident flight
* Flights for which a photographic montage of the double Altitude trace is available *			

TABLE 1
(TABELL)

NOTE: THE FOIL IS MOVING FROM LEFT
TO RIGHT IN THE RECORDER

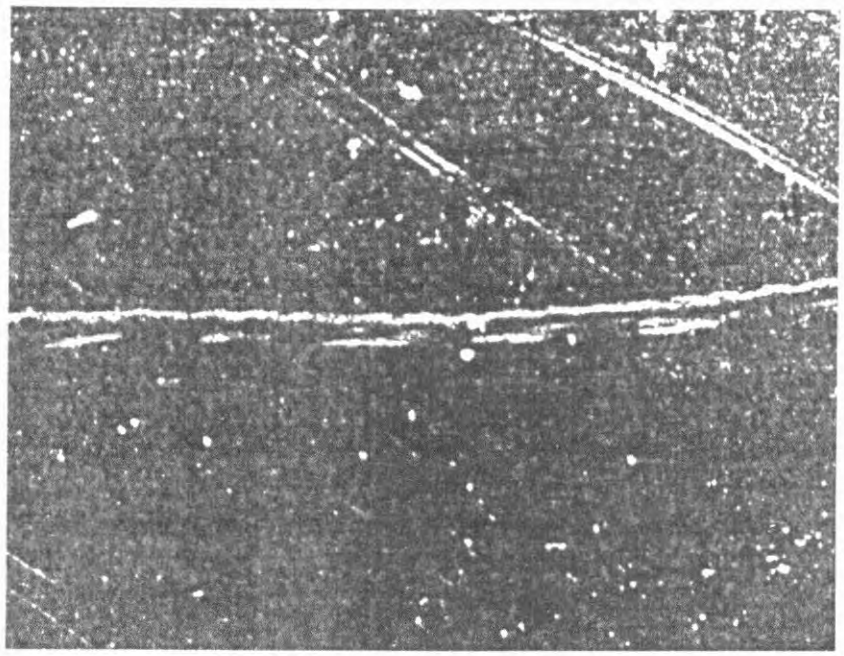


PHOTO 1 (FOTO) Typical double trace due to stylus resonance causing multiple alternative knife edge indentations on altitude parameter of Flight #2. Photo magnified 32 X.

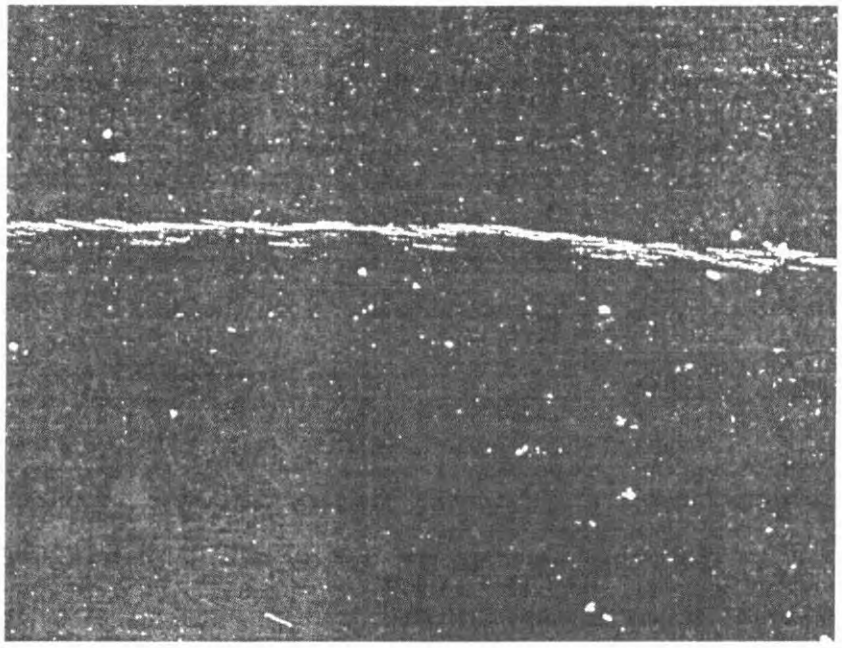


PHOTO 2 (FOTO) Typical double trace due to resonance on altitude parameter of Flight #16. Photo magnified 32 X.

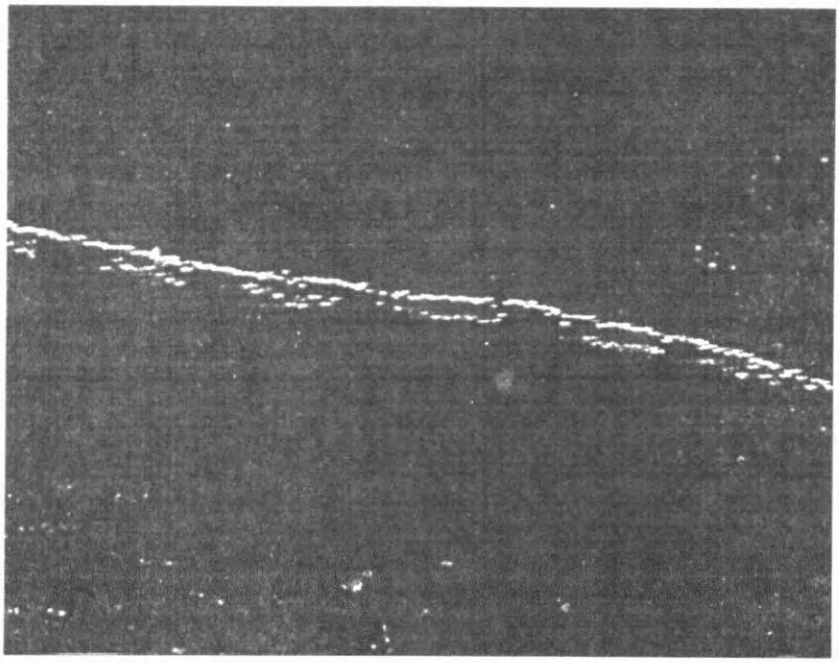


PHOTO 3 (FOTO) Typical double trace due to resonance on altitude parameter of Flight #28. Photo magnified 32 X.

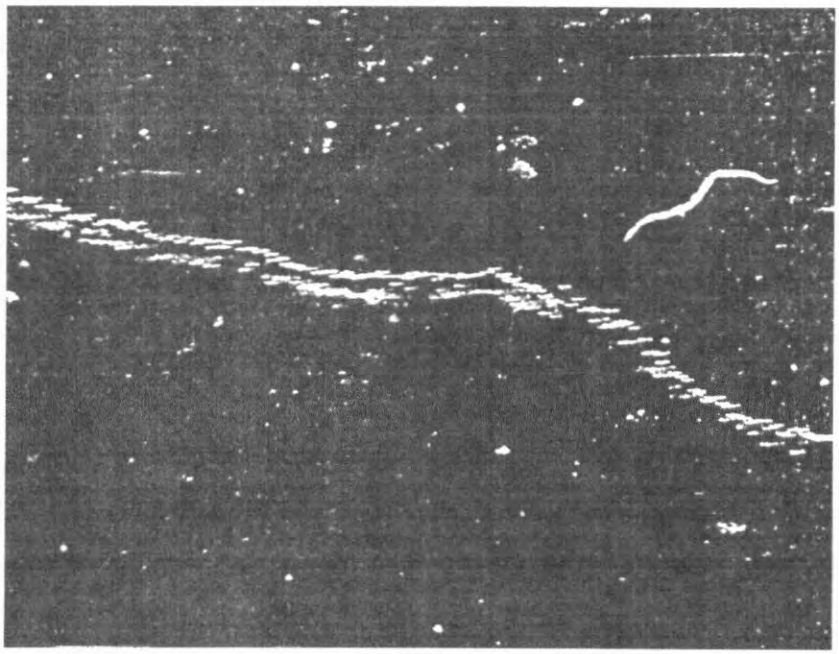


PHOTO 4 (FOTO) Typical double trace due to resonance on altitude parameter of the accident Flight #33. Photo magnified 32 X.

NOTE: THE PHOTO IS FROM THE CLIMB-OUT REGISTRATION

- The number of consecutive flights where the double lines occurred increased and the number of flights without the double lines decreased towards the maintenance period in July 1989.

- On the flights where double lines appeared these gradually remained for an increasingly longer time into the cruise segment of the flight.

- During the last approximately 100 flight hours before the maintenance visit to KFC in 1989 the double lines occurred on almost every flight.

- From 1986 until the maintenance visit in 1989 the line representing the heading parameter also showed abnormal readings.

- The vertical acceleration parameter malfunctioned over the period 1986-1989.

- During maintenance work the FDR system was repaired, but details of the repair is not documented.

- After the repair the heading parameter functioned normally.

- The vertical acceleration parameter did not function after the maintenance visit.

- After the maintenance visit the double lines on the altitude parameter appeared on only one of the first nine flights (table 1).

- From Flight No. 10 onwards, including Flight No. 33, the accident flight, the double lines appeared on 15 out of 23 flights.

- On the accident flight the double lines appeared while climbing through approximately 1,400 ft and remained

visible for the rest of the flight.

1.12 WRECKAGE AND IMPACT INFORMATION

1.12.1.1 The site of the accident was at sea, approximately 10 nm north of Hirtshals (figure 2). The location of the start of the search was based on radar information received and on the position of floating victims and wreckage. A side-scanning sonar was used to search the sea bed. Approximately 52 km^2 of the sea bed was searched with 100% overlapping. The area where the wreckage was found was limited to approximately 12.5 km^2. The main wreckage area covered approximately 3 km^2.

The depth of the sea varied from 90 m in the north to 40 m in the southern part near the coast of Jutland. Most of the seabed was covered with mud, whereas the shallowest areas in the south were covered with sand. There were periods of strong currents during the search. The currents on the surface were measured as being up to 4 knots and up to 2.5 knots on the sea bed.

1.12.1.2.3 About 90% of the wreckage was salvaged.

1.12.1.2.6 After the salvaging operation had been completed the positions of the wreckage parts were plotted on suitable maps. The positions of the essential parts are shown in figure 2.

1.12.2 The AAIB/N knew of a research project carried out at the Cranfield Institute of Technology in England, entitled "Trajectories of Falling Parts following In-Flight Break-up". The LN-PAA data were sent to the project leader for evaluation. The result of this work was there were no clear signs of the aircraft having completely broken up before impact with the water. However, there were data that could point to a partial break-up, most likely in the altitude range of 5,000 - 10,000 ft. One of the main points of argument was that the pattern registered on the seabed

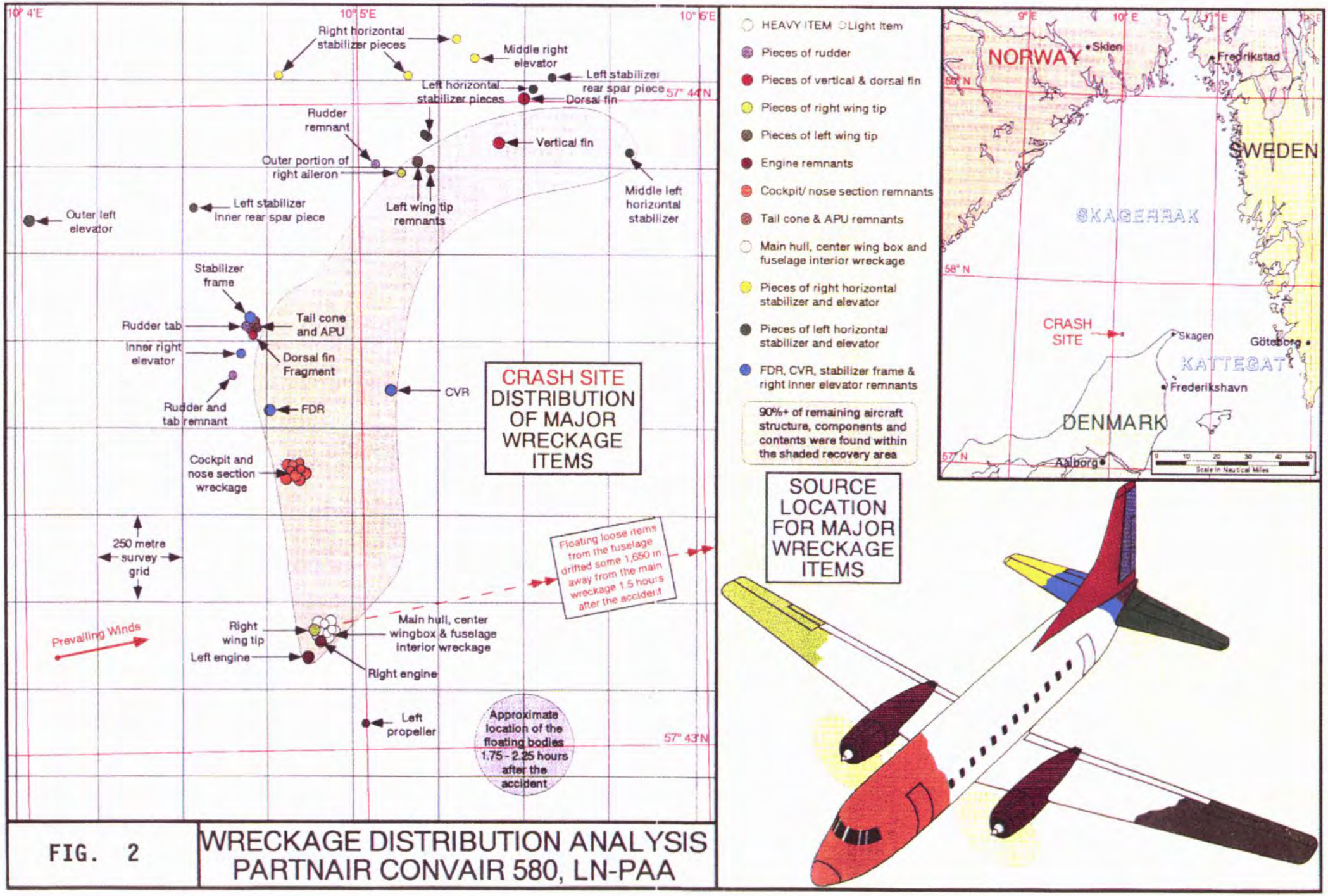


FIG. 2 WRECKAGE DISTRIBUTION ANALYSIS PARTNAIR CONVAIR 580, LN-PAA

indicated a wind direction of 240°. However, the Board had reliable information that the wind direction at all the actual altitudes was 260°.

The location of the wreckage on the sea bed was evaluated. One of the conclusions was that the parts from the left and right horizontal tail surfaces, respectively, lay in two approximate lines in a 260° direction.

1.12.3 Wreckage

1.12.3.1 The accident caused the aircraft to separate into several parts of varying sizes. In order to form a complete picture of the configuration of the wreckage it was necessary to reconstruct the aircraft methodically and to the greatest possible extent (photos 5 - 10).

1.12.3.2 In this report it is not practical to present a complete description of the damage to all the wreckage parts. The following will therefore be a general summary of the damage to the aircraft's main sections. The significant damage and findings are described in detail in para. 1.16. The description of the damage is classified under the following main sections:

- Fuselage
- Cockpit
- Tail section
- Interior and seats
- Wings
- Undercarriage
- Propellers and engines
- Instruments

1.12.3.2.1 *The fuselage*

The most extensive damage to the fuselage was to the forward left side. Practically the entire construction of this part of the fuselage broke up into small pieces in a

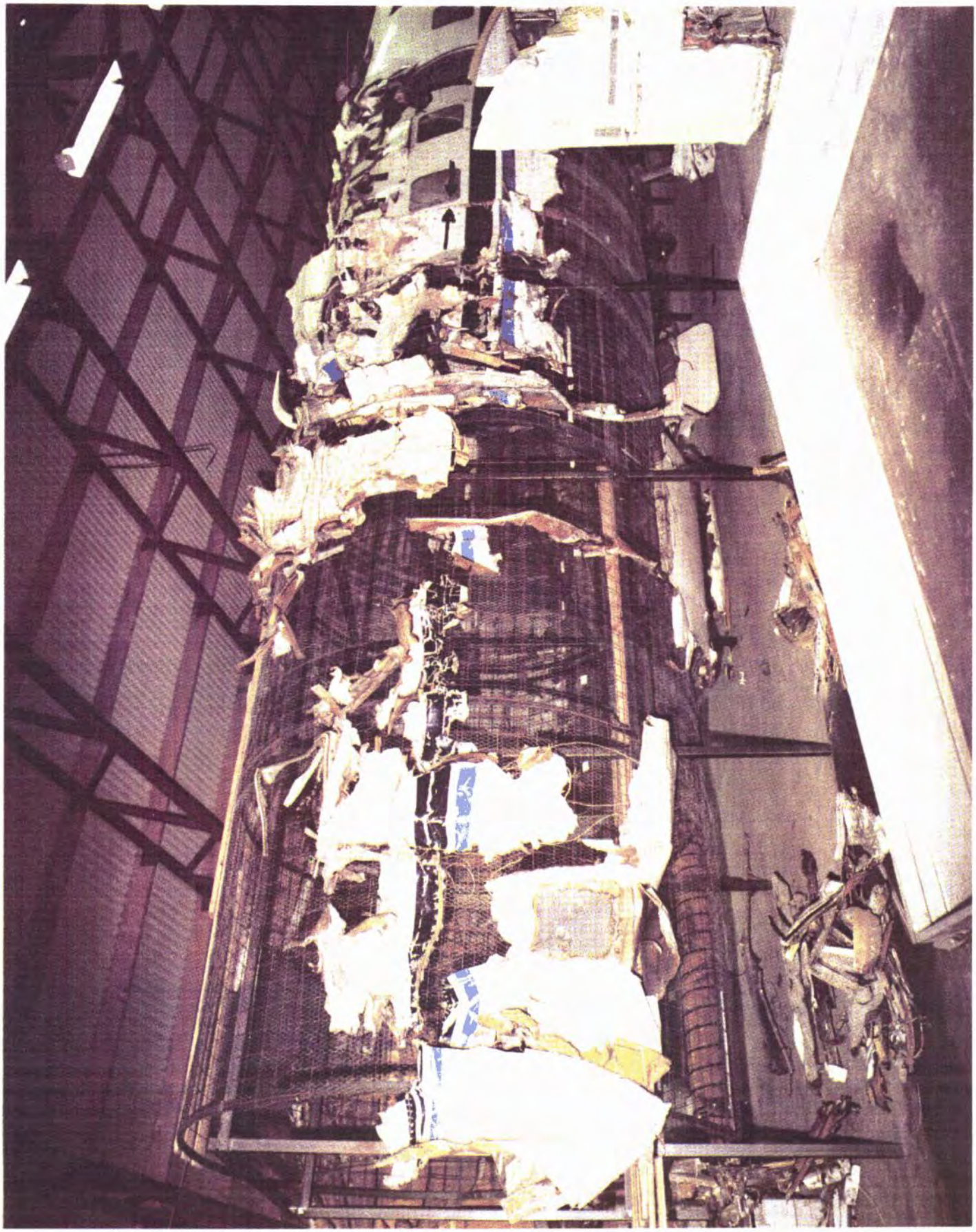


PHOTO (FOTO) 5A

FORWARD, LEFT SIDE OF THE FUSELAGE
ARROWS POINT AT STA 261
(VENSTRE SIDE AV SKROGET, FREMRE DEL
PILENE VISER STA 261)

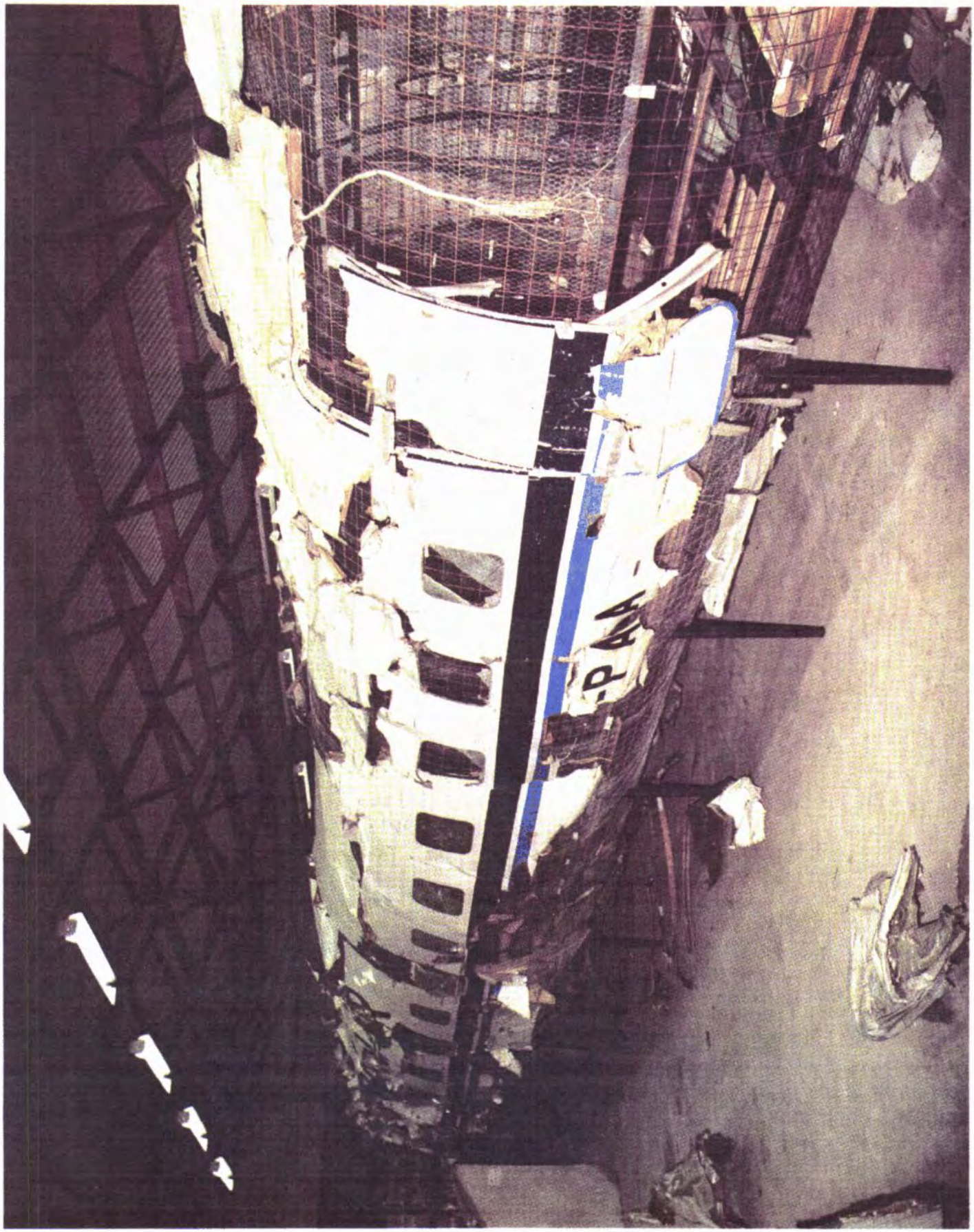


PHOTO (FOTO) 5B AFT, LEFT SIDE OF THE FUSELAGE
(VENSTRE SIDE AV SKROGET, BAKRE DEL)

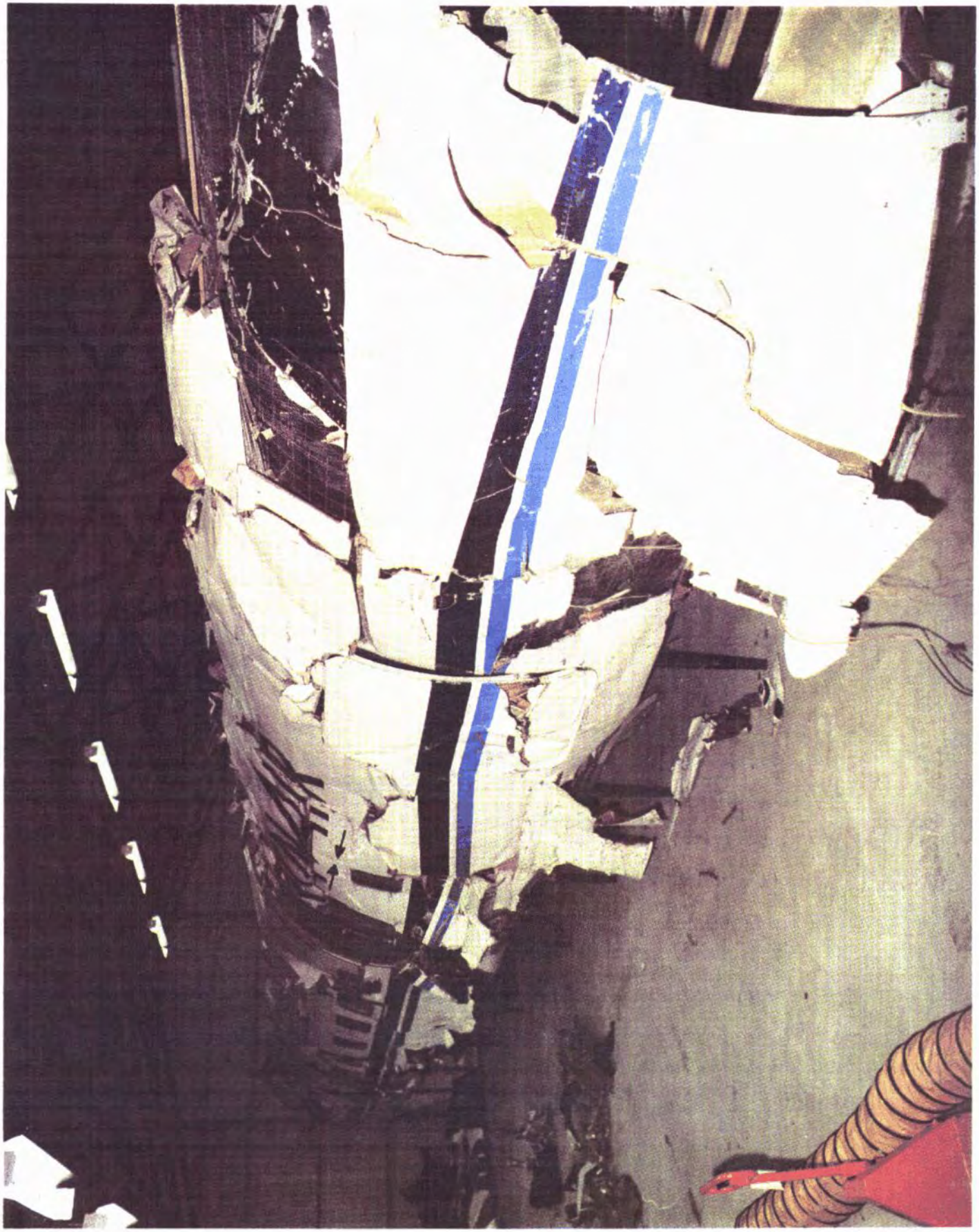


PHOTO (FOTO) 6

FORWARD, RIGHT SIDE OF THE FUSELAGE
ARROWS POINT AT STA 261
(HØYRE SIDE AV SKROGET
PILENE VISER STA 261)

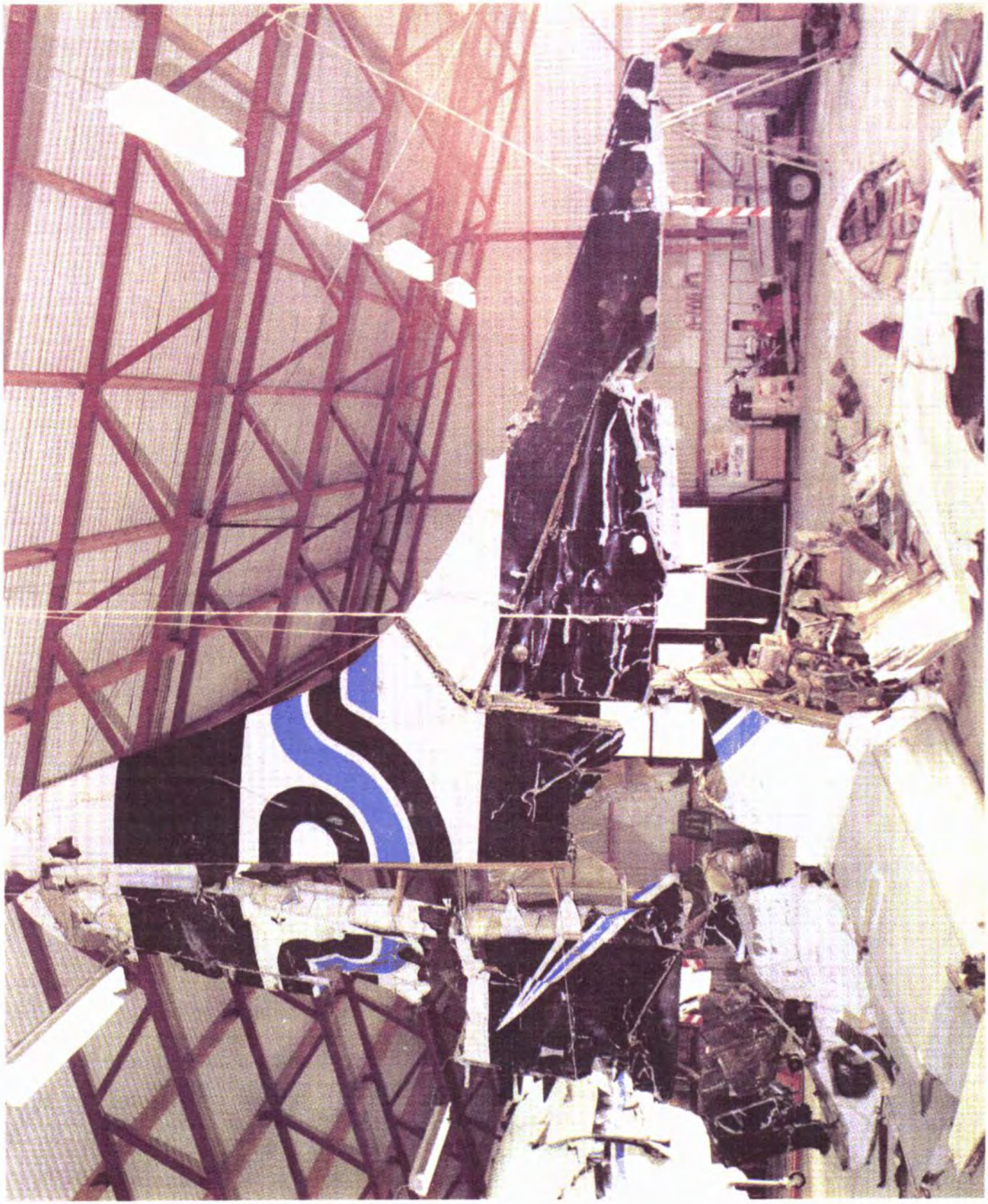


PHOTO (FOTO) 7 RIGHT SIDE OF THE TAILSECTION
(HØYRE SIDE AV HALESEKSJONEN)

PHOTO (FOTO) 8 LEFT SIDE OF THE TAILSECTION
(VENSTRE SIDE AV HALESEKSJONEN)

PHOTO (FOTO) 9 LEFT TAILPLANE INCLUDING ELEVATOR
(VENSTRE HALEFLATE M/HØYDEROR)

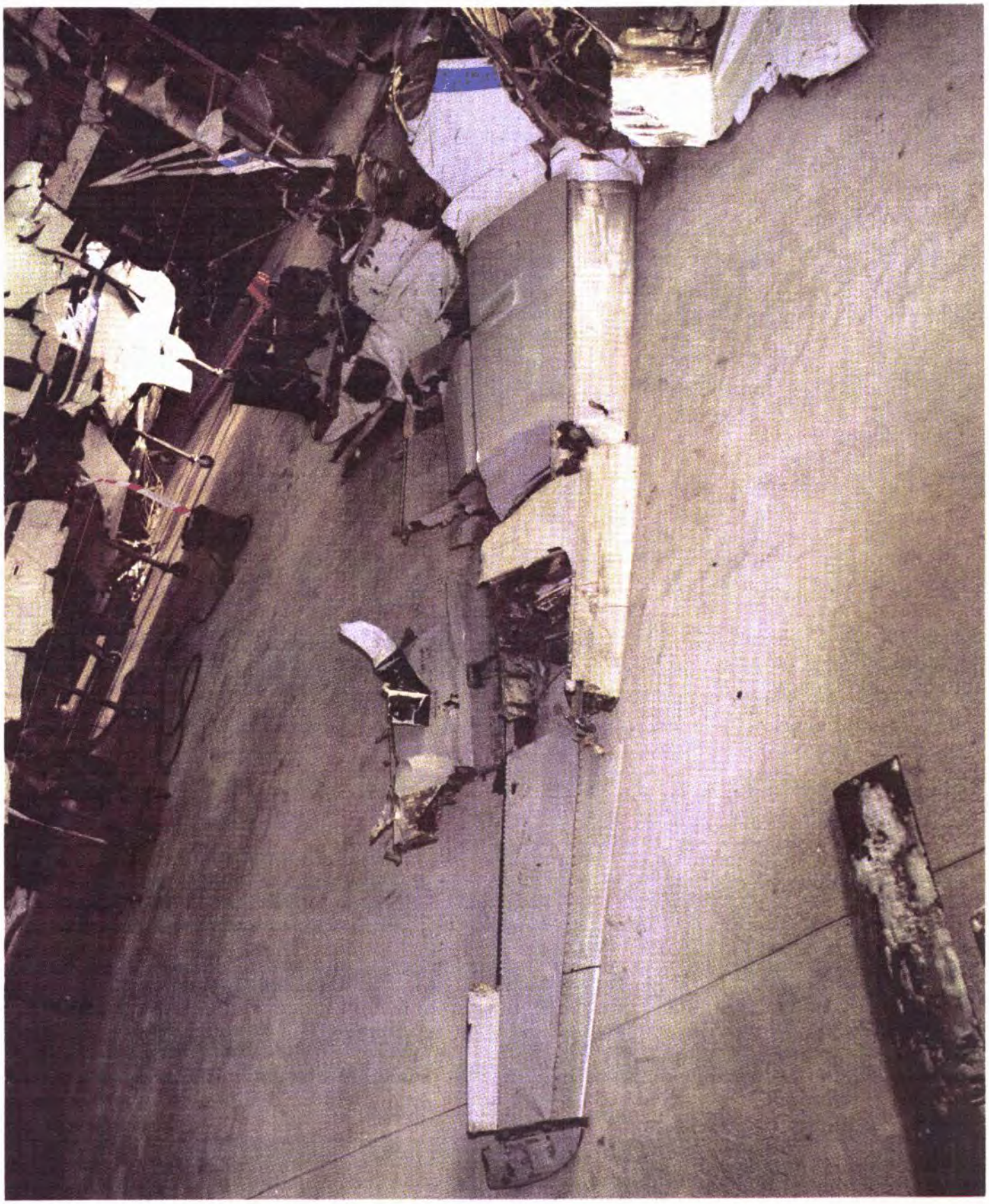


PHOTO (FOTO) 10 RIGHT TAILPLANE WITH PIECES OF ELEVATOR
(HØYRE HALEFLATE M/RESTER AV HØYDEROR)

manner characteristic of water damage. The radome, which was found floating in the water, was practically intact with only minor damage to its left side.

The damage to the right side of the fuselage was less extensive. Some of the cockpit construction and cockpit windows were salvaged. The windshield frame was recovered sometime later by a trawler. The rest of the fuselage was divided into larger and smaller pieces. All the essential parts were salvaged. There was a distinct difference in the damage pattern fore and aft of station 261, especially on the left side (photos 5 and 6).

1.12.3.2.2 *The cockpit*

Parts of both the pilots' cockpit chairs and of the cockpit jump seat were salvaged. The same applied to a part of the cockpit floor. Parts of the control columns were also found. Parts of the radio and electrical equipment, installed behind the pilots, were also salvaged, but these were substantially deformed. The fixed oxygen bottle which had been located adjacent to the co-pilot's seat was not found, most likely because it was hidden in the mud on the sea bed. The instrument panels were in fragments, although some of the instruments were found entangled in the electrical wiring which had been torn loose when the aircraft crashed.

1.12.3.2.3 *The tail section*

The tail section had been broken into many large and small parts. These parts were found some distance from each other. The tail section was mainly broken up as follows:

- vertical fin
- rudder
- elevators (several parts)
- left horizontal stabiliser
- right horizontal stabliser (many small parts)

- tail cone with the APU
- rear section of the fuselage, from the front part of the horizontal stabiliser to the tail cone, including the inner part of the right horizontal stabiliser (photos 7 - 10)

The elevator hinges were found to be severely damaged. The front APU fitting had a fracture which had occurred before impact with the water. The attachment pins and sleeves of the vertical stabiliser had abnormal wear. In addition, the rear left pin and sleeve were loose in the bushings. The vertical stabiliser had only minor deformations in the skin, but the rudder and the top fairing had been torn off. The shroud doors, which covered the gap between the rudder and the fin, were torn to pieces. The middle layer in the honeycomb construction was separated from the skin over large areas. Marks on the remains of the shroud doors show that the rudder balance weights had pounded against them in such a way that they had been torn to pieces.

The rudder had broken up into several pieces.

The tail surface had symmetrical fractures as a result of alternating loads. The skin on the remaining parts of the tail was deformed, with diagonal wave-like wrinkles. This is a certain indication of reversing torsional loads. The outer part of the right elevator is still missing. The condition of parts of the control surfaces is described in para. 1.16. This also applies to the APU's air pressure and ventilation ducts.

1.12.3.2.4 *Interior and seats*

The AAIB/N reconstructed the cabin floor. There was a distinct difference in the damage pattern on either side of the junction in the floor panel closest to station 261. The rows of seats on the right side were reconstructed and could be properly located. Two seats were found to be missing on the left side. Four seats were in such a

condition that it was uncertain as to where they were originally positioned. The galley was crushed from the outside, which corresponded to the water damage in front of station 261. Two of the service trolleys were only slightly damaged. The portable oxygen bottles from the cabin were also salvaged.

1.12.3.2.5 *The wings*

The broken-off outer parts of the wings, which were approximately 7 m long, were only slightly damaged, aside from the right wing tip, which had been torn off. The fractures in the respective wing parts were quite similar in both the right and left wings. There was no water damage on the wing surfaces. Both fractures were caused by tensile loads on the skin and stringers on the top side, and compression loads on the skin and stringers on the underside. The conclusion of the investigation was that the wings failed in negative G.

The centre section of the wings was torn loose from the fuselage. With the exception of one attachment, the brackets were still fixed to the corresponding parts of the fuselage. There was significant water damage, especially to the front left part of the inner wing.

Both engines were torn loose from their supports. Consequently, the wings were damaged in the nacelle area. The centre section of the wings broke up into several large parts. This part of the wing was built to withstand heavier loads than were the other parts of the wing. Nevertheless, the skin and ribs were torn apart. A few parts are missing, but all the important parts of the inner wings were salvaged.

1.12.3.2.6 *Undercarriage*

All three undercarriage struts, together with their respective wheels, had broken off from the aircraft. These

parts were severely damaged. The assessment of the damage to the undercarriage and its respective components showed that it had been up and locked at impact.

1.12.3.2.7 *Propellers and engines*

The left propeller and part of the reduction gear box were found approximately 275 m south south-east of the left engine. All four blades were attached to the hub. The hub was attached to the shaft and the front part of the reduction gear box. The rear part of the reduction gear was found together with the left engine. Blade No. 2 was bent backwards at its hub fitting. The fitting was damaged in such a way that the blade could rotate freely about its longitudinal axis. None of the blades had the usual torsional deformations which occur when a propeller hits water while the drive shaft is still transmitting power.

The right propeller was found with the right engine. Two of the blades were still attached to the hub. The other two blades had been broken off and were found in the same area as the rest of the propeller. The propeller hub was attached to the drive shaft and the reduction gear. The gear box was torn loose from the engine, but it was not damaged in the same way as the left engine.

The left engine was found approximately 100 m south-west of the area where the aircraft's centre section, right engine and other heavy parts were found. The engine, which was positioned over the wheel well, had exterior damage, showing that the aircraft's main wheels had been pushed upwards with great force. The engine showed no signs of fire or other abnormal conditions which could have occurred before impact.

The right engine was found to have the same exterior damage as the left engine, i.e. no trace of fire or other signs of abnormal operation. The indentations caused by the main wheels were somewhat less pronounced than on the left

engine.

The propellers, the reduction gear boxes and the engines were disassembled and inspected. The examinations were carried out with the assistance of Allison Gas Turbine Division, Pacific Propeller Inc., Hamilton Standard, Veritec and RNoAF Air Materiel Command. The results of these tear-down inspections are to be found in para. 1.16.5.

1.12.3.2.8 *The instruments*

- Temperature indicators

The Turbine Inlet Temperature (TIT) Indicators from both of the engines were found and examined.

The indicators were of an electromagnetic type, with a magnetic tape approximately 2 m long, the position of which varied according to the temperature. The tape is transferred alternately between two spools and remains in the last position when the electrical power to the instrument is cut off.

The examination of the left engine TIT indicator resulted in the following findings:

P/N BH 183, S/N 559.
The gauge reading was unreliable due to mechanical damage. The digital reading was in the range 563°C - 674°C, while the analogue reading was in the range 700°C - 900°C. The warning flag was also missing. 61 cm of the servo-potentiometer tape was on the driving side and 126 cm of it was on the receiving side.

Right engine TIT indicator:

P/N BH 183, S/N 539.
There was no visible mechanical damage which could have affected the meter reading. The digital reading was 853°C while the analogue reading was 850°C. The servo-potentiometer tape was 62 cm on the driving side and 126 cm on the receiving side.

Similar tests with an undamaged gauge of the same type showed that the distribution of the tape between the two spools in a 61/126 ratio corresponded to a reading of 850°C. This is a normal temperature in relation to a cruising speed power setting.

- The torquemeter on the right engine was found and examined. The instrument was of an electromechanical type with a potentiometer as the driving unit for the indication mechanism. The potentiometer remains in the last position when the electrical power is cut off.

  The instrument's measurement range is from -1,000 hp to +6,000 hp. The indicator mechanism was found to be 3.75 rotations from the minimum position. The total range is 10 rotations. This position corresponds to a reading of 1,625 hp.

- Both of the fuel flow meters were found and examined but the examination revealed no significant findings.

- An airspeed and a vertical speed indicator were found and examined. Air pressure-operated flight instruments seldom give reliable readings of flight conditions before or during an accident. The examination of these instruments revealed that they had suffered mechanical damage, which made all findings unreliable.

- Cabin Pressure Controller, P/N 102088-416-1, S/N

95-277, was found, disassembled and examined.

Two cracks were found in the control unit rubber diaphragm. There were also signs of brittleness and ageing. When tested in a pressure chamber a crack was found which had caused leakage in the control unit regulating bellows. It could not be determined for certain whether or not these cracks were a result of the accident or whether they had occurred during normal operations. The control unit was last overhauled on May 25, 1982.

A leakage in the rubber diaphragm would cause the cabin pressure to vary at the same rate as did the external air pressure. Rate control would therefore not correspond to the position selected on the control unit.

A leakage in the bellows would cause the cabin pressure to go directly to maximum differential pressure. According to the maintenance records this was adjusted to 4.02 psi (8.27" Hg). The normal maximum differential pressure for the CV-340/580 is 4.16 psi, with the emergency outlet valve set at 4.21 psi. The pressure cabin was constructed to withstand an ultimate differential pressure of 8.9 psi. When the correct setting is used, sea level pressure in the cabin is maintained up to a flight altitude of 8,900 ft. At an altitude of 22,900 ft the cabin pressure would correspond to 10,000 ft of altitude.

1.12.5 <u>Preliminary results from the technical investigations</u>

1.12.5.1 The preliminary technical investigations resulted in additional technical investigations in the following areas:

- damage to the elevator hinges
- wear/corrosion/damage to the attachment pins and sleeves which connect the vertical stabiliser to the

fuselage
- propellers and engines
- fracture in the front APU support
- APU air ducts and fire extinguishing equipment
- possible failure in the left AC-power system
- weaknesses in the fuselage as a result of cracks in frames and stringers, or faults in the cabin windows
- damage to the vertical stabiliser and the dorsal fin, as well as to the rudder

These investigations are summarised in para. 1.16.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

1.13.1 The AAIB/N's medical expert participated in the initial process of identification of the victims in a quayside warehouse in Hirtshals. Further identification was made and autopsies performed at the Department of Pathology at Hjoerring Hospital and at the Institute of Forensic Medicine at the University Hospital in Aarhus. The expert's report to the AAIB/N was based on comprehensive hospital reports.

1.13.2 <u>The victims</u>

All of the crew members were found and positively (that is to say, unambiguously) identified. 45 of the 50 passengers were found and positively identified.

A short time after the accident 31 of the persons on board were found floating in the sea. Since the pathological findings in this group differed somewhat from those for the other victims, they have been categorised as Group I.

The majority of the other victims were categorised as Group II. These victims were found in the course of the weeks during which salvaging took place. Some were found on the sea bed during the search for wreckage parts. Some drifted ashore and were found on nearby beaches. This group

consisted of the 3 crew members from the cockpit and 16 passengers. The last person in this group was found and identified 8 months after the accident.

1.13.3 Group I

Group I consisted of the 2 female flight attendants and 20 male and 9 female passengers. All died immediately as a result of multiple injuries. Investigations were carried out to look for signs of injuries caused by combustion or explosion, or for lesions caused by propeller fragments, but no such injury patterns were found. Neither were there any significant findings with regard to intake of alcohol or medication. An analysis of stomach contents revealed that passengers had eaten (or were in the process of eating) a light meal at the time of the accident.

15 of the 31 passengers (but not the 2 crew members) had skin impressions from the seat belts, indicating that they must have experienced a sudden deceleration while in their seats. Two of the victims had small puncture-like lesions on the upper torso, apparently caused by a shower of small X-ray dense particles. These findings were also analysed by police experts. They do not interpret these injuries as being a result of a detonation or explosion, but rather as a shower of metallic fragments from the break-up of the fuselage.

Over ¾ of the victims in this group sustained an injury pattern previously observed in free-fall accidents.

1.13.4 Group II

This group comprised the 3 cockpit crew members and 16 of the passengers (11 men and 5 women) who were found weeks or months after the accident.

At the time of impact both the pilots and the mechanic were sitting in their respective positions in the cockpit. Their

injuries corresponded to the forces of impact acting on this part of the aircraft. The co-pilot in the starboard chair sustained severe injuries to his right hand. These injuries corresponded to those commonly seen in persons gripping aircraft controls at impact. An unbroken toothpick with both ends pointed was found in his stomach. It is assumed that the only way to swallow such an object is by reflexive action caused by sudden shock or surprise. It is therefore assumed that the crew experienced a sudden deviation from normal flying conditions.

1.13.5 The expert's conclusion

1.13.5.1 There were no traces of carbon monoxide, alcohol or medication in any crew member. There were no signs of prior illness or failing health. There were also no injuries related to on-board explosions (for example from the aircraft's oxygen bottle installed in the cockpit).

1.13.5.2 All persons in Group II, both crew and passengers, died instantaneously as a result of severe internal lesions. Injuries suffered by these passengers were on the whole less extensive than for passengers in Group I. This fact, plus technical findings regarding clothing, etc., seem to indicate that these persons went down with the aircraft.

1.14 FIRE

There were no signs of fire on board.

1.15 SURVIVAL ASPECTS

It was not possible to survive this accident.

1.16 TESTS AND RESEARCH

1.16.1 Summary of technical investigations carried out by institutes other than the AAIB/N

1.16.1.1 *Investigations carried out by Veritec*

Report No.	Title	Date issued
VT 333 (letter)	Visual inspection of the fractures on the outer part of the wings	16 NOV 1989
89-3480	Examination of fuselage section from wrecked a/c Convair C 580, LN-PAA	17 JAN 1990
89-3506	Examination of propellers from the wrecked a/c Convair C 580, LN-PAA	02 FEB 1990
90-3015	Examination of main engines from wrecked a/c Convair C 580, LN-PAA	07 MAR 1990
90-3123	Examination of five fragments found to have penetrated the skin of human bodies, a/c accident, LN-PAA	04 APR 1990
91-3012	Examination of cabin floor panels, seat position rails and passenger seat installations from wrecked a/c Convair 580, LN-PAA	04 MAR 1991
91-3040	Examination of the tail section and the empennage installations from the wrecked a/c Convair CV 340/580, LN-PAA Volume I - Text Volume II - Figures	18 JUN 1991
91-3074	Examination of the main wing attachment towards the fuselage for the wrecked a/c Convair CV 340/580, LN-PAA	19 SEP 1991
91-3083	Estimation of the vertical downward motion and water impact velocity for the Cock-pit Voice Recorder (CVR) of the a/c Convair	

	580, LN-PAA	21 FEB 1991
91-3089	Examination of fracture surfaces and weld repair performances for the broken APU bleed air duct, wrecked Convair C 580, LN-PAA	17 APR 1991
91-3286	Examination of fractures found at the lower front spar attachment of the L/H horizontal stabilizer, Convair CV 340/580, LN-PAA	20 SEP 1991
91-3295	Examination of fragments found in soft drink cans from the wrecked a/c Convair CV 340/580, LN-PAA	03 DEC 1991
91-3487	Visual examination of the wing breakage for the wrecked a/c Convair 340/580, LN-PAA	31 DEC 1991
91-3488	Examination of bushing for the connecting bolts of the vertical stabiliser, Convair CV-340/580, LN-PAA	18 NOV 1991

Verbal reports with photo documentation:

Examination of indentation damage found on the main entrance stairway installation, Convair 340/580, LN-PAA	09 MAY 1990
Examination of indentations and deformation damage located on the co-pilot's sliding window, Convair 340/580, LN-PAA	26 APR 1991

1.16.1.2 *Investigations carried out by The Foundation for Scientific and Industrial Research, Trondheim*

Report No.	Title	Date issued
STF34F90064	Fracture in engine fitting	07 APR 1990
Not applicable	Investigation of welding in the exhaust pipe	05 MAR 1991
STF34F90040	Fracture in attachment	12 MAR 1990

1.16.1.3 *Investigations carried out by RNoAF Air Materiel Command*

Report No.	Title	Date issued
891010.010	Planet gear, fracture	10 OCT 1989
891011.005	The propeller fittings, cracks	11 OCT 1989
891012.001	Partnair accident, preliminary report on engine parts	12 OCT 1989
891017.004	Combustion chamber, cracks	17 OCT 1989
891020.037	Gear, crack	20 OCT 1989
891212.017	Investigation of plastic-like substance	12 DEC 1989
900307.004	Electrical wires	07 MAR 1990
900314.001	Identification of paint	14 MAR 1990
901319.001	Electrical wires, Partnair	19 MAR 1990
900321.004	Electrical wires, Partnair	21 MAR 1990
900417.001	Electrical wires, Partnair	17 APR 1990
900424.002	Mechanical fuel shut-off valve, Partnair	24 APR 1990
900530.005	Investigations of fractures in the front and rear APU supports, Partnair	30 MAY 1990
900622.002	Fracture in the window frame locking mechanism	22 JUN 1990
901126.003	Mechanical fuel shut-off valve, Partnair	26 NOV 1990
901126.005	Analysis of plastic-like substance	26 NOV 1990
901203.001	Electrical wires, Partnair	03 DEC 1990
910214.011	Fracture in duct connected to the APU	14 FEB 1991
910304.001	Fracture in duct connected to the APU	04 MAR 1991
910615.001	Analysis of foreign objects in the APU compressor, Partnair	15 JUN 1991

1.16.1.4 *Investigation performed by Statoil's petro-chemical laboratory, Bamble*

Report No.	Title	Date issued
901126.005	Analysis of plastic parts, aircraft supplementary report	13 NOV 1990

1.16.1.5 *Investigation by the Foundation for Scientific and Industrial Research, S.I., in Oslo*

Report No.	Title	Date issued
430-1411	Identification of a fuel sample from the aircraft by means of chemical analysis	26 OCT 1989

1.16.1.6	BSCE 20/WP35	Investigation carried out by the Zoological Museum, of Oslo	1990

1.16.2 Damage to the elevator hinges

Technical investigations revealed that the inner right-hand elevator hinge was severely damaged. The hinge pin was not found. The anchor nut the pin had been screwed into was torn off in such a way that the threaded portion had disappeared with the pin. The hinge bracket was examined in detail at the Veritec laboratory. There were signs that the bracket had been exposed to strong vibrations in both holes since the hinge pin bushing holes were severely deformed. The material had been substantially compressed in such a way that the holes had changed to an oval shape towards the end of the deformation process (See photo 11).

In the inner sections of the left part of the elevator, which the AAIB/N received in the summer of 1992, both the hinge bracket and the hinge pin were missing. The anchor

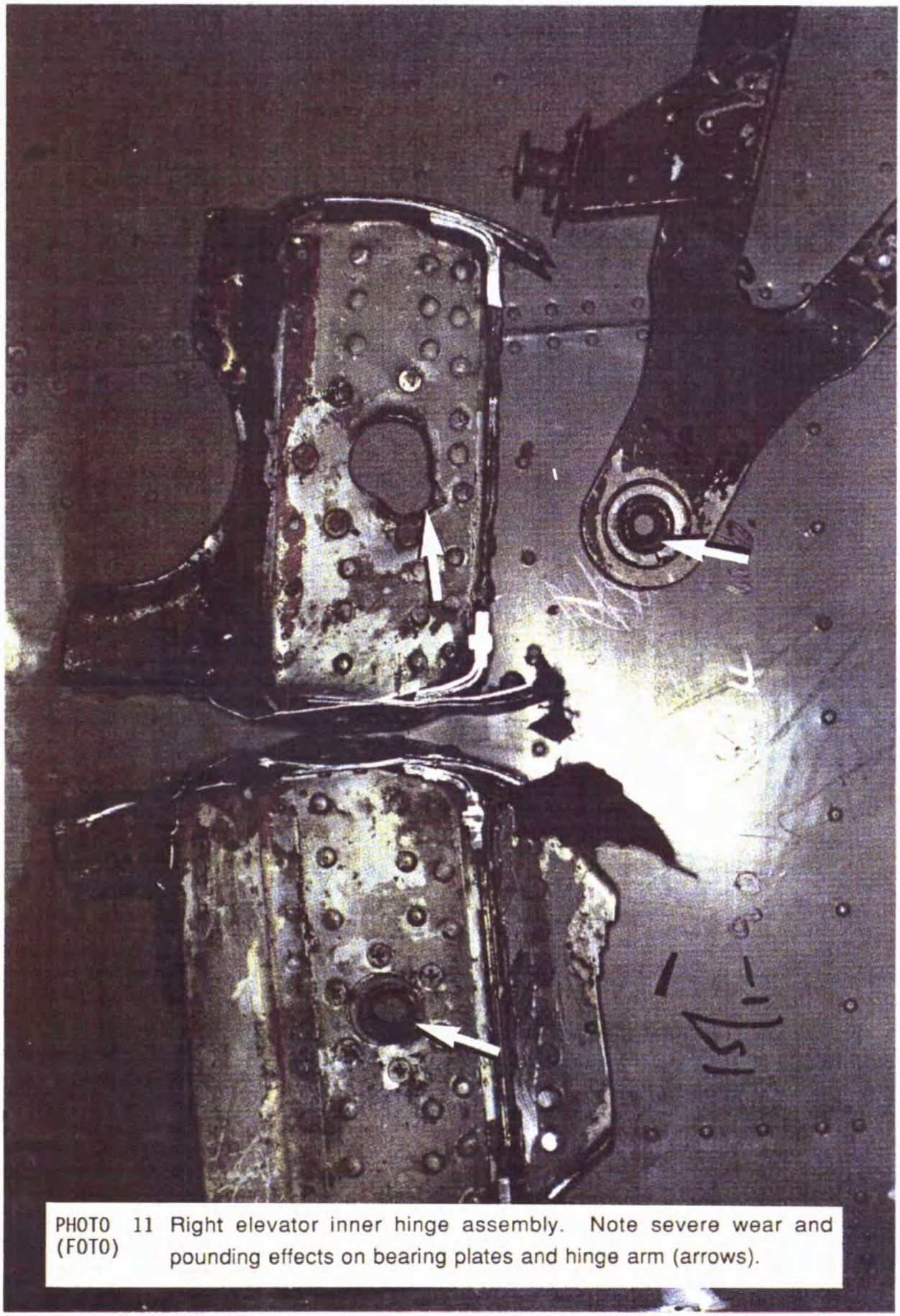


PHOTO 11 (FOTO) Right elevator inner hinge assembly. Note severe wear and pounding effects on bearing plates and hinge arm (arrows).

nut on this side had also been torn off in such a way that the threaded portion was missing.

It is a well-known fact that elevator hinges are a problem area on this type of aircraft. A review of available documentation and information received from the manufacturer resulted in the following findings:

- In 1954, General Dynamics, Convair Division, issued Newsletter No. 247, which compelled users to inspect and repair hinges where necessary.

- A review of various service reports revealed that the CV-340/440 piston-engine aircraft never had vibration problems due to worn elevator hinges. All findings of abnormal wear were revealed at maintenance.

- Service reports on turbine engine-powered aircraft showed that all findings of abnormal wear were a result of reported vibration problems during flight. The vibrations always occurred at high airspeeds and always ceased at lower airspeeds.

- In one reported case, the vibrations were so severe during acceleration to cruising speed from the airspeed maintained during climb that the Pilot-in-Command was afraid these vibrations might result in damage to the aircraft's structure. The Pilot-in-Command at first suspected that the vibrations came from one of the engines. He shut down one of engines, but this did not improve the situation. He restarted the engine and decided to return to the airport of departure. When engine power was reduced and the airspeed decreased to approximately 170 knots the vibrations ceased.

- 15 out of 18 reported cases stemmed from faults in the left elevator hinges. In two cases the actual elevator was not mentioned. In one case abnormal wear was

reported in the right elevator hinges.

It is known from previous experience that the hinges on the left side are exposed to the greatest amount of strain owing to turbulence caused by the air stream from the propellers.

Because of these vibration problems it was of great interest to ascertain what had been done with these hinges during the last D-check at KFC. A review of the maintenance documents revealed that both elevator and rudder hinges had been inspected. The work was checked and signed for on July 18, 1989 at TAT 36,883 hrs. In addition, the following was written on the document: "No defect found/noted".

On the relevant SID inspection card there was a remark written under the entry "Elevator and rudder hinge support structure attach flanges", saying: "No defects found". The maintenance documentation described the inspection as being a sight inspection.

1.16.3 Examination of wear/corrosion/damage to the attachment between the vertical fin and fuselage

1.16.3.1 The vertical fin had come loose from the fuselage because overload fractures had occurred in the four aluminium angle sections to which the fin fittings were connected. The fractures had occurred 40-60 cm above the fittings. The rear right-hand bracket was also broken off at the fittings. The three other brackets were still connected to the steel bracket on the fuselage. During the general examinations of the fuselage it was ascertained that the rear left-hand fitting was completely loose and showed signs of abnormal wear. This initiated a more thorough examination of all four attachments. These investigations were carried out by Veritec and AIR.

1.16.3.2 Each attachment comprised an aluminum bracket on the fin bolted to a steel bracket on the fuselage. The aluminum

bracket had two lugs fitted on either side of a steel bracket lug (figure 3). Both types of brackets may be equipped with inside steel bushings. On this aircraft only the aluminum brackets were fitted with such bushings. The fastening bolt consisted of a conical steel pin with a matching steel sleeve. The inside of the sleeve had a conical shape corresponding to that of the pin. The external shape was cylindrical. In addition, the sleeve had a longitudinal slit facilitating expansion when the pin was drawn into the sleeve. The purpose of this design was to provide a tight fitting for the attachment, thereby eliminating all movement when connecting the fin to the fuselage.

1.16.3.3 The investigation carried out by Veritec revealed that the rear left-hand attachment showed signs of fretting corrosion between the pin and the sleeve. The outside of the sleeve was also severely worn. Moreover, the sleeve material did not satisfy Convair's hardness specification of 390 (HV5). The rear right-hand attachment sleeve was, however, of the correct hardness.

Later examinations by AIR also revealed that the two front attachment pins, as well as their respective sleeves, did not satisfy the specifications. The hardness was between 200 and 230 (HV5). A hardness of 200 - 230 corresponds to a tensile strength of approximately 100,000 psi. Convair's specification for hardness corresponds to a tensile strength of 160,000 to 180,000 psi.

A check carried out on the bushings installed in the aluminum lugs on the rear right-hand attachment bracket showed a considerable discrepancy between the dimensions in the front and rear bushings. The difference between the outer diameters was approximately 0.013 inches while the difference between the inner diameters was approximately 0.018 inches (figure 4). In the production of these bushings the maximum allowable deviation is 0.001 inches.

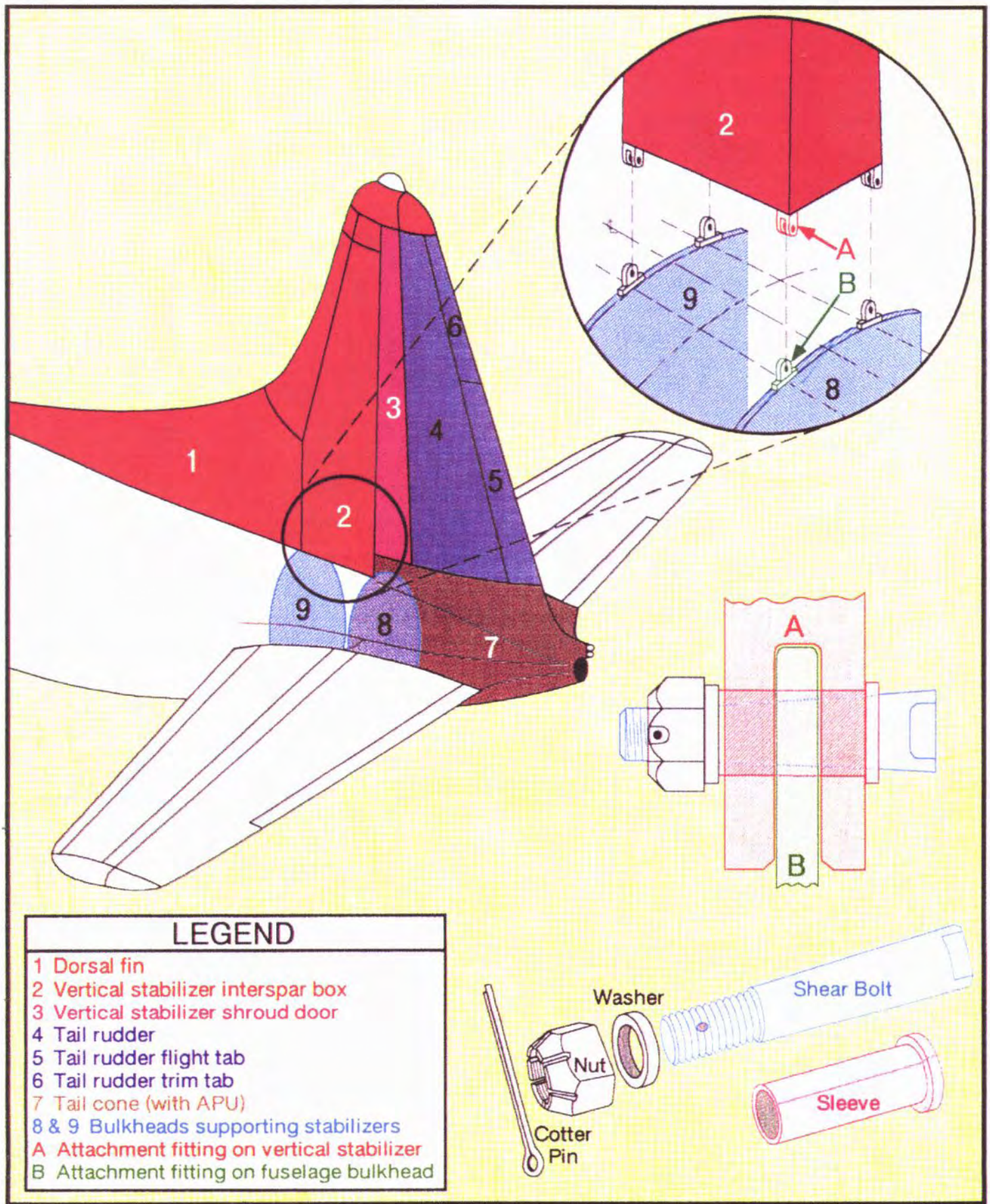
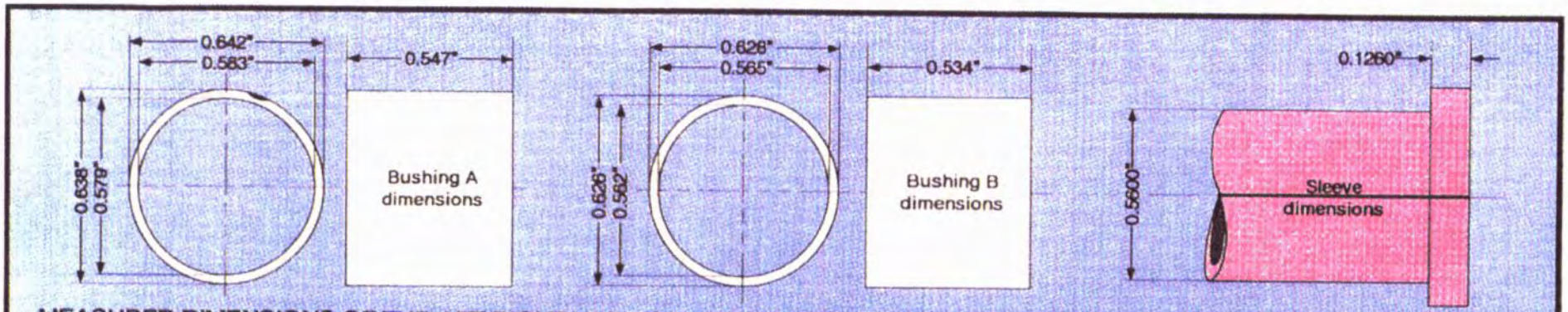


FIG. 3

TAIL & FIN ATTACHMENT SKETCH
PARTNAIR CONVAIR 580, LN-PAA



MEASURED DIMENSIONS OF THE AFT RIGHT VERTICAL STABILIZER ATTACHMENT BUSHINGS AND SLEEVE FROM LN-PAA

BUSHING REQUIREMENTS FROM THE CONVAIR OVERHAUL MANUAL

1. All forward fitting holes are of equal dimensions and all aft fitting holes are of equal dimensions
2. One or both stabilizer fitting lugs may be reamed over-sized and bushed
3. Make bushings from SAE 4130 steel, heat treat 125,000 to 140,000 psi and cadmium plate per Federal Specification QQ-P416. Dimensions to be met after plating
4. I.D. and O.D. of bushings to be parallel and concentric within 0.003"
5. Length of bushing to be 0.010±0.005" less than thickness of fitting
6. Break all sharp edges 0.015 inch and install bushings with wet prime
7. See Table for minimum oversize hole permissible. Increased hole sizes may be made in increments of 0.010 inch up to values shown for maximum oversize permissible

FITTING		MINIMUM OVERSIZE PERMISSIBLE			FIT: BUSHING TO FITTING		MAXIMUM OVERSIZE PERMISSIBLE
		REAM	BUSHING DIAMETER				
			OUTSIDE	INSIDE	MIN	MAX	
FORWARD	STABILIZER	0.8125 +0.0005 -0.0000	0.8140 +0.0000 -0.0005	0.7500 +0.0005 -0.0000	0.0005	0.0015	0.8405
	FUSELAGE	0.8125 +0.0005 -0.0000	0.8140 +0.0010 -0.0005	0.7500 +0.0005 -0.0000	0.0005	0.0025	0.8130
AFT	STABILIZER	0.6250 +0.0005 -0.0000	0.6250 +0.0000 -0.0005	0.5625 +0.0005 -0.0000	0.0005	0.0015	0.6530
	FUSELAGE	0.6250 +0.0005 -0.0000	0.6250 +0.0010 -0.0005	0.5625 +0.0005 -0.0000	0.0005	0.0025	0.6255

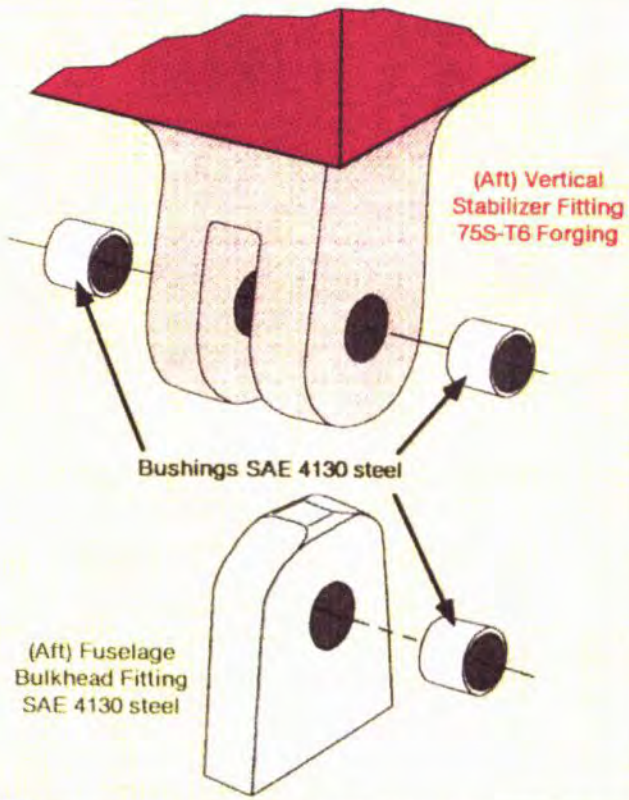


FIG. 4

VERTICAL STABILIZER BUSHING & SLEEVE DIMENSIONS & SPECIFICATIONS SKETCH; PARTNAIR CONVAIR 580, LN-PAA

The rear right-hand sleeve showed signs of fitting tightly on the inside of the steel bracket. The outside area showed signs of fretting corrosion. The other three sleeves also showed signs of fretting corrosion on the outside. Fretting corrosion was again found in the central area of the front right-hand sleeve, which was wider than the thickness of the steel bracket to which it was mounted (photo 12).

The examinations carried out by Veritec revealed that the four attachment bolts had sustained overloads from different directions. The front right-hand pin had a plastic deformation resulting from torsional forces transferred from the attachment.

1.16.3.4 The maintenance documents revealed that the pins and sleeves were changed in accordance with the Allegheny Airlines Airframe Overhaul Manual 55-50-301 before PAS took over the aircraft in 1986. The work was carried out by KFC. No additional work was done on the vertical fin attachments until the aircraft returned to KFC for maintenance in 1989. However, ordinary routine maintenance was carried out.

The maintenance documents did not state the origin of the parts that did not meet the specifications. When the AAIB/N queried this KFC stated that the workshop did not have a registration system prior to 1987 which would make it possible to trace the suppliers of these parts. In 1987 the workshop initiated a system which made it possible to trace mounted parts to both production series and suppliers. From 1984 onwards the workshop used pins and sleeves from five different suppliers. It is a requirement that the pins and sleeves be produced in compliance with the manufacturer's drawings and specifications for materials, dimensions, surface treatment, hardening and tensile strength.

1.16.3.5 The examination of the rudder control linkage in the tail section was carried out by both Veritec and AIR. Both examinations concluded that the elevator must have oscillated violently - far in excess of the normal range

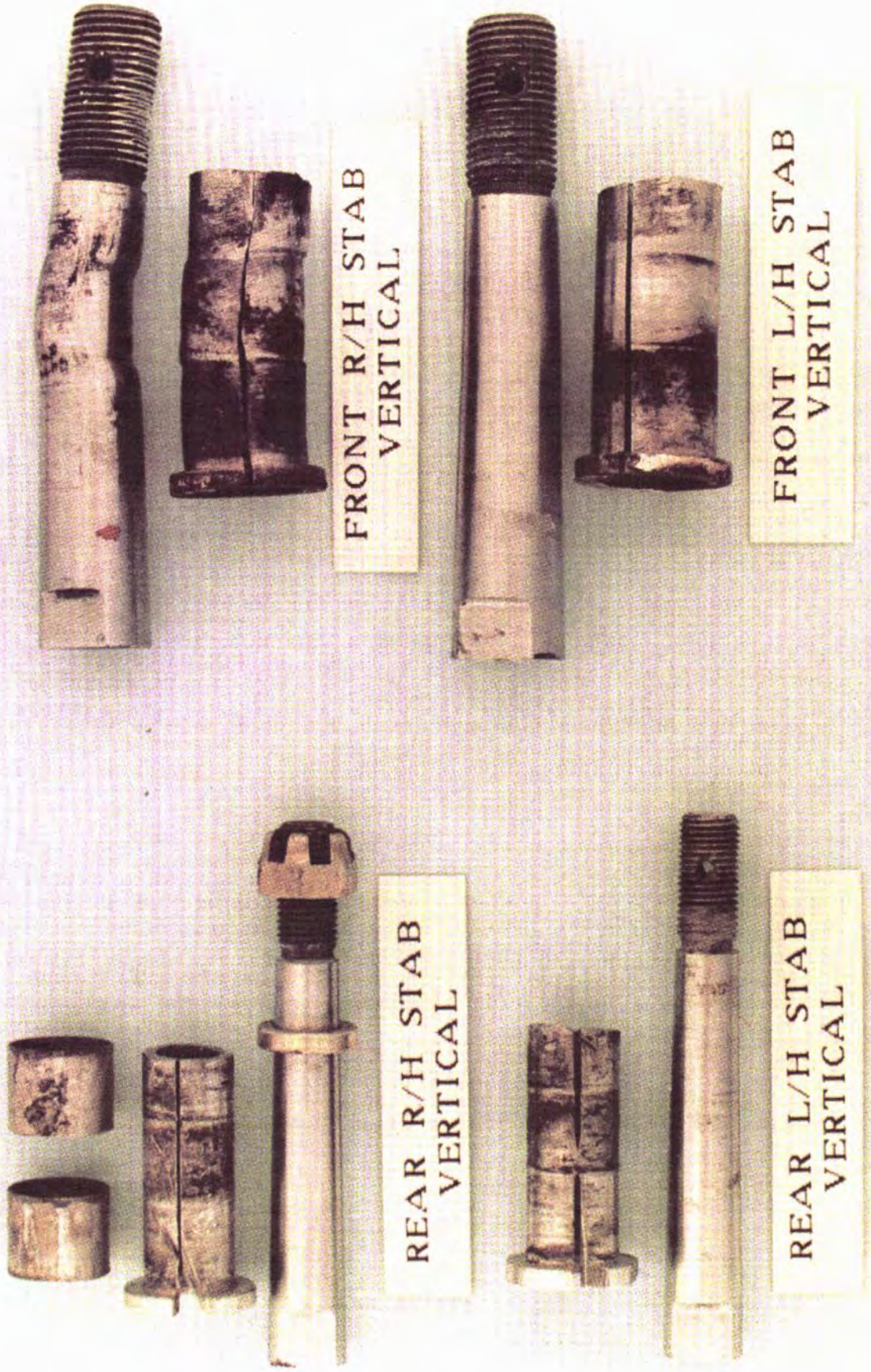


PHOTO (FOTO) 12

SHEAR PINS, SLEEVES AND BUSHINGS FROM LN-PAA FOR VERTICAL STABILIZER ATTACHMENT (BOLTER,HYLSER OG FORINGER FRA LN-PAA FOR FESTE AV VERTILKALFINNEN TIL SKROGET)

movement. It was stated that these movements must have lasted more than 40 seconds. This was calculated from the assumed frequency and the number of visible grinding marks on the torque tube (photos 13 and 14).

1.16.4 Possible weakening of the fuselage due to cracks in the frame, stringers and windows

1.16.4.1 Quite early on in the technical investigations of the fuselage weakening of the structure was evaluated as a possible factor in the accident. The basis for this assumption was the age of the aircraft and its various operators. Besides this, the aircraft logs showed, amongst other things, that cracks had been found in the frames and stringers on the fuselage during D-check No. 3 in 1989.

Veritec was given the task of examining the parts of the fuselage in which the quality of repair work had apparently been inferior. Veritec Report No. 83-3480, of January 17, 1990 revealed that some repair work did not comply with Convair's documentation (for example SB 53-15, regarding hole damage, plugging and riveting).

1.16.4.2 None of the areas where unsatisfactory repair work had been discovered showed signs of fatigue.

It was not possible to determine which repairs were carried out as a result of the findings made during the D-check in 1989 and which repairs dated from earlier maintenance work. However, it is certain that most of the repairs had been carried out at an earlier date.

The AAIB/N is therefore unable to ascertain who had carried out the respective repairs or when they were done.

1.16.4.3 During discussions on the weakening of the fuselage, theories were put forward to the effect that the windows in the passenger cabin on an aircraft of this type could be a weak point. The reconstruction of the fuselage revealed

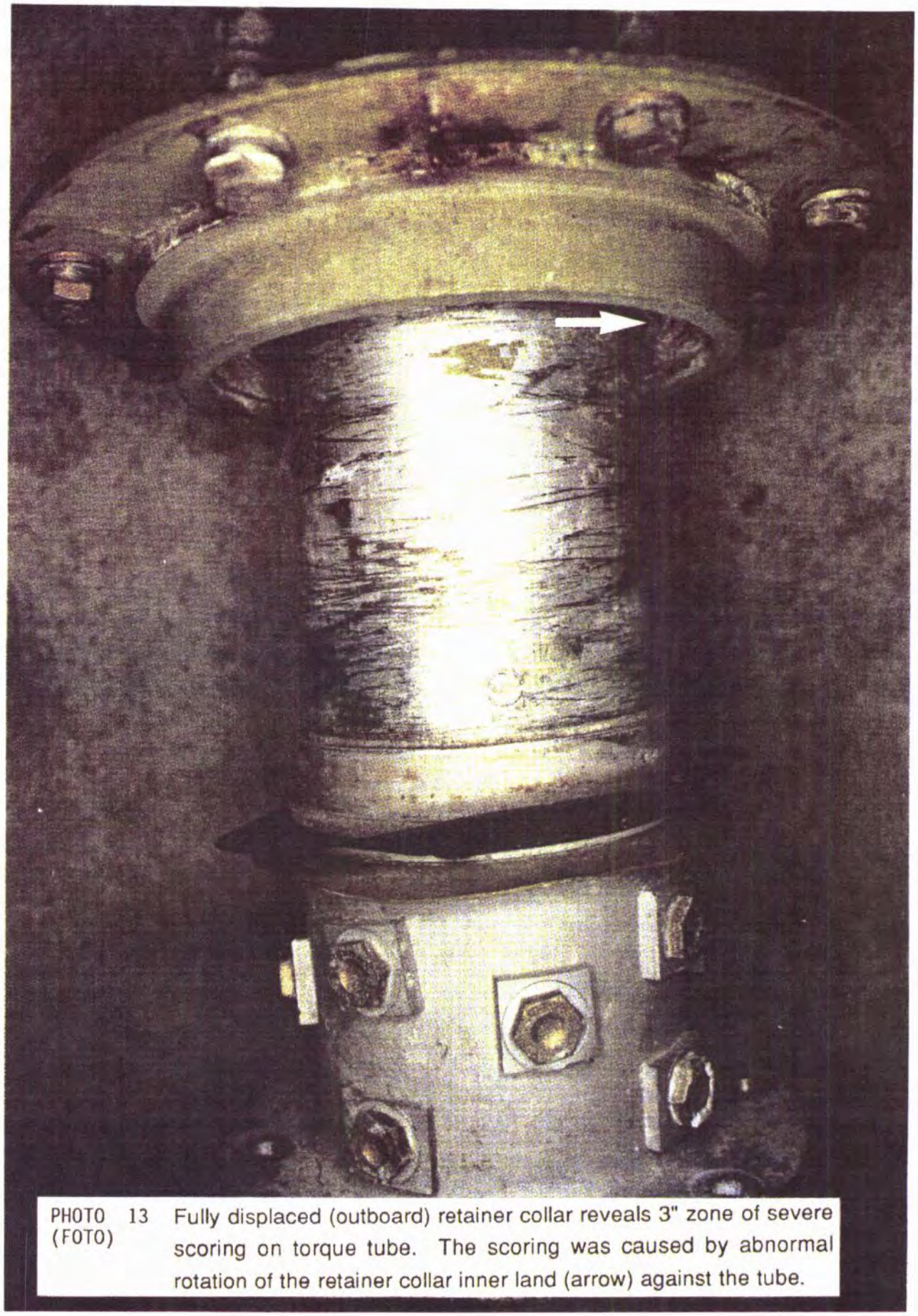


PHOTO 13 (FOTO) Fully displaced (outboard) retainer collar reveals 3" zone of severe scoring on torque tube. The scoring was caused by abnormal rotation of the retainer collar inner land (arrow) against the tube.

PHOTO 14 (FOTO) Clearly exhibits the extensive scoring. Note the circumferential length and angles of the score marks well in excess of the normal 35° of elevator travel. Some marks are up to 90° of the circumference.

that most of the windows had cracked, and in some cases they had been broken into pieces in such a way that parts of the glass were still in their frames.

It was therefore important to know how much internal pressure a window of this type could withstand before it would break. The Board also wanted a reference which could tell them something about which pattern the cracks would form when exposed to internal pressure of too great a magnitude.

A suitable window and frame were obtained from a scrapped Convair 440. RNoAF Air Materiel Command prepared a fixture where the frame and window were mounted and subjected to an internal hydraulic pressure which could then be measured.

The test revealed that this window withstood 19 psi before it broke. The Board believes that this was representative of how much pressure the windows in LN-PAA could withstand. The pattern of cracks in the tested window was different from the pattern seen on LN-PAA. The test pattern had a circular form, whereas the accident aircraft's windows had linear, diagonal cracks. This indicates that the forces acting during the accident and those acting during the test were essentially different.

1.16.5 Examination of the propellers and engines

The examination was carried out by the AAIB/N with the assistance of RNoAF Air Materiel Command, Veritec, the Foundation for Scientific and Industrial Research, Allison, Hamilton Standard and Pacific Propellers. The object of the examination was to reveal possible faults which could have led to malfunctioning, and to be as precise as possible in determining the conditions at the time of impact. The required disassembly check on relevant components and systems, sight inspections and metallurgical analyses, was carried out.

1.16.5.1 When the left engine's compressor and turbine were disassembled, damage was found to cover only an approximately 60° sector of the rotor blades. Corresponding damage to the stator showed that damage had occurred in the lower part of the engine only.

The front end of the turbine axle was connected to the compressor through splines which transmitted the torque between the turbine and compressor and the reduction gear. The axle was deformed in the area where the splines engaged. The deformation was caused by a torque overload in a positive direction of rotation, i.e. energy had been transferred from the turbine to the compressor and reduction gear.

The main gear in the reduction gearbox showed overload marks on 42 out of 101 teeth. Most of the marks were on the last 18 teeth before the gears disengaged. The marks were caused by abnormal pressure between the pinion gear and the main gear.

The safety coupling, which was supposed to free the propeller from the engine upon transfer of energy from the propeller to the engine, had not disengaged.

The torquemeter transmitter had damage on the teeth caused by rotation under abnormal strain over a short period of time. At final impact the teeth made distinct marks that did not show signs of rotation.

No signs of mechanical or thermal faults or strain, which would have prevented the engine from operating normally, were found.

The electrical actuator for the engine's fuel shut-off valve was found in a closed position.

1.16.5.2 The right engine compressor and turbine had damage on the blades over the entire circumference of the rotor. The

bottom sector of the stator was damaged. The blade damage was moderate in that the bending was in the opposite direction to the direction of rotation, the angles of the bending being from 30° to 90°. None of the blades had been torn off. In one sector, the lower one, as a result of the way the rotor was jammed into the stator, the blades were bent in both directions. There were also blades with double bending.

The main gear in the reduction gearbox had overload marks on approximately 1/3 of the teeth. Smearing of the material indicated that there was movement in the gears at the time the marks were made.

The safety coupling between the propeller and the engine had not disengaged. The torquemeter transmitter had marks made by teeth which were in motion at the time of impact.

No signs of mechanical or thermal faults or strain, which would have prevented the engine from operating normally, were found.

The electrical actuator for the engine's fuel shut-off valve was found to be in the closed position.

1.16.5.3 The left propeller, which was found with all the blades attached to the hub, was disassembled in order to ascertain its condition at the time of impact. All four blades were bent in the opposite direction to the direction of flight. The blade angles were measured as they were found. The impact marks were also measured in order to check the corresponding blade angles.

	As found	At impact
Blade No. 1	36.4°	41.9°
Blade No. 2	0.0°	46.3°
Blade No. 3	37.3°	41.4°
Blade No. 4	41.3°	50.2°

The damage to Blade No. 2 allowed the blade to rotate freely on its spindle. There were also some impact marks corresponding to a blade angle of 0°. These marks were found to stem from secondary impacts, while the angle of 46.3° corresponded to the first impact.

1.16.5.4 The right propeller was found with two blades missing from the hub. The condition of all the blades was as follows:

Blade No. 1: This was attached to the hub and was slightly deformed. There was a small bend on the front side of the blade, which was about 45 cm from the tip of the blade.

Blade No. 2: The blade had been torn off, but had all but retained its original form, with only minor damage to the front side of the blade.

Blade No. 3: Similar to Blade No. 2.

Blade No. 4: The blade was attached to the hub. It had a double bend forward on the outer part, about 45 cm from the tip of the blade, and another on the inner part, about 75 cm from the axial point of the blade.

Veritec's metallurgical analysis of the torn blades concluded that they had failed in a single cycle overload. The overload was in a rearward direction and the fracture area started on the front sides of the blades. The impact marks corresponded to the following blade angles:

	As found	At impact
Blade No. 1:	36.3°	41.8°
Blade No. 2:	39.9°	42.0°
Blade No. 3:	33.4°	42.1°
Blade No. 4:	35.4°	39.6°

1.16.5.5 The propeller control mechanisms were disassembled and checked. At disassembly all findings corresponded to the position of the propeller blades at impact and as found after the accident (33.4° - 42.1°). The control mechanism was AC-operated. When power is cut off the blades remain in the approximate position they were in at that point in time.

A blade angle of about 40° is in the upper range for flight operation, with engines at cruise power and an indicated airspeed of about 200 knots.

1.16.6 Examination of the APU

1.16.6.1 There were pieces of melted plastic found in the APU's turbine section. The plastic pieces were identified by means of IR spectography, and had the same composition as the material used in the cabin interior.

1.16.6.2 The APU had a total of four attachments to the aircraft structure. The two main supports were intact. The other two were fractured. Metallurgical examinations revealed that the rear support had failed in overload while the front support showed signs of fatigue failure. The front support was of a design and manufacture which did not conform to the manufacturer's specifications. The support end fitting, which is normally a rod end with an internal spherical bearing, had been replaced by a locally-manufactured design. This consisted of a square piece of iron and a threaded rod which had been welded together (figure 5). The quality of the welding was poor and the wrong type of material had been used. The fatigue fracture was caused by a fault in the welding. The method used to make the support and the choice of material did not conform to the standards used in aircraft parts. The support had signs of repeated loads having been applied to it after the fracture took place (photos 15 and 16).

1.16.6.3 The stator and rotor in the APU turbine had considerable

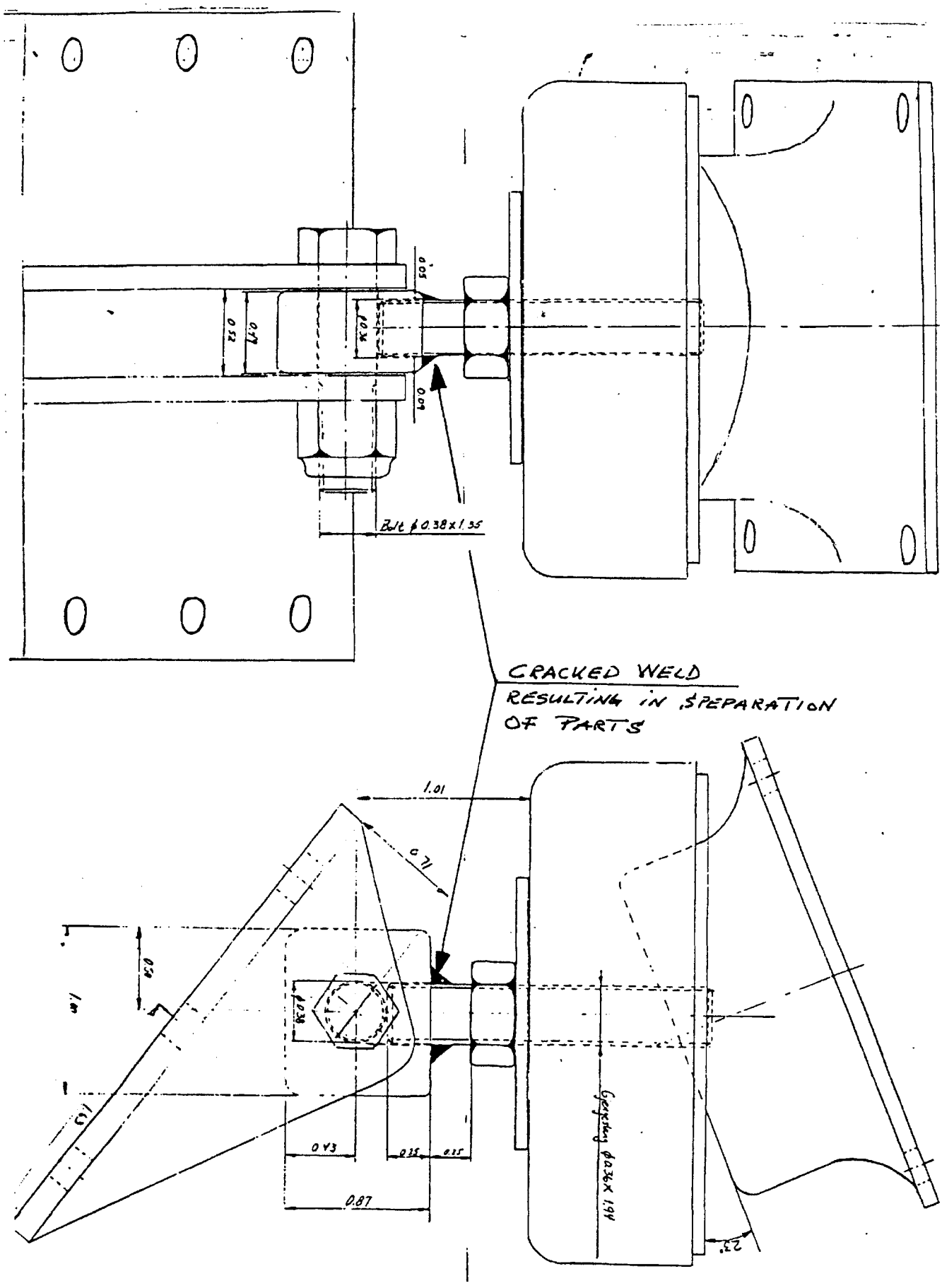


FIG. 5 FORWARD MOUNT FOR THE APU (AS FOUND)
FREMRE MONTERINGSFESTE FOR APU (SOM FUNNET)

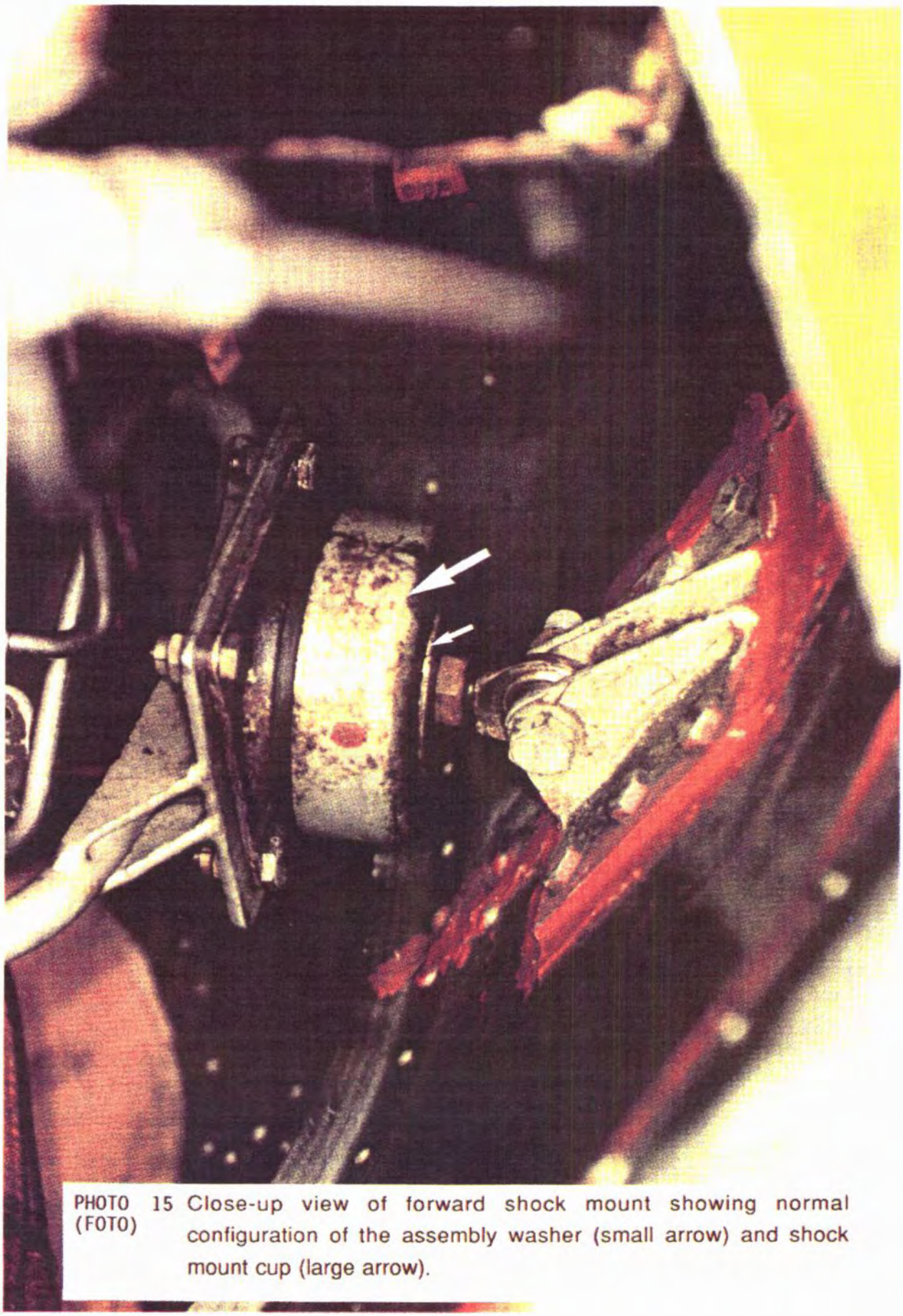


PHOTO (FOTO) 15 Close-up view of forward shock mount showing normal configuration of the assembly washer (small arrow) and shock mount cup (large arrow).

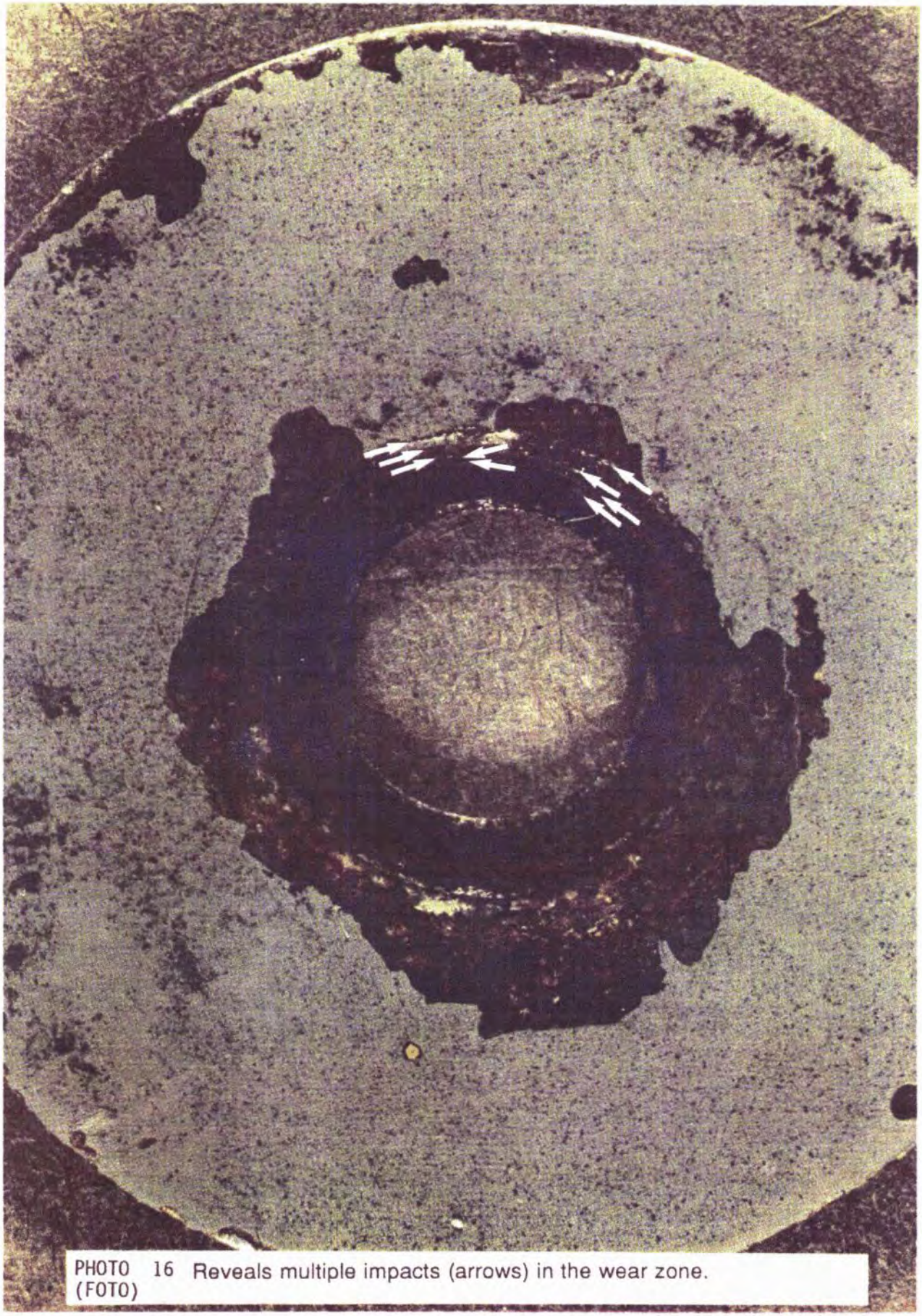


PHOTO 16 Reveals multiple impacts (arrows) in the wear zone.
(FOTO)

heat damage. The guide vane ring had circumferential cracks in a 180° sector. The surfaces of the cracks were oxidised and corroded. This indicated that the APU was in operation subsequent to the cracks being formed. The formation of the cracks changed the clearance between the rotor and stator. A 120° sector showed signs of damage caused by rubbing.

1.16.6.4 A diode had short-circuited in the AC generator mounted on the APU. Both this diode and the other two on the same side had been overloaded. This overload had caused melting of the tin soldering and had burnt the insulation on several cables in the circuit.

1.16.6.5 The APU fire extinguisher bottle and its squib were not mentioned at all in the maintenance documents. According to PAS' Component Change Card No. 204, a change was due in October 1989. According to Snag Card No. 026 for the bottle and No. 027 for the squib, both were changed by KFC in July 1989. The reason for the change is not stated on the snag cards.

The squib, which releases the APU fire extinguisher, was found to have been triggered. The squib is fired electrically. Tests have shown that an applied voltage of about 15 V DC is enough to trigger a charge of this kind.

The extinguishing agent pressure chamber outlet valve, which is released when the squib is fired, was found to be in the closed position. The valve is of a design where the valve is forced into the open position by the pressure in the container. The design does not allow for the valve to close again once it has been forced into the open position. According to an expert on the system, this means that when the squib was fired there was no extinguishing agent under pressure in the container. In addition to the outlet valve, the container has two other possible outlets - the filling valve and the manometer. It was ascertained that both were tight.

1.16.6.6 The air pressure duct leading from the APU to the ventilation and starting systems had had repairs carried out on them which were not up to standard as regards method and technique. Several joint weldings and repairs were imperfectly done. They contained slag and pores, and some of the basic material had been only partly melted. This, amongst other things, had resulted in a fatigue crack about 70 mm long appearing in the duct between the APU and its outlet and regulating valve.

1.16.6.7 The technical manuals, operating description, maintenance requirements and maintenance documentation have all been examined. FAA Form No. 337 showed that the modification (STC SA-1343) for installation of the APU in the aircraft tail section was carried out as prescribed by Hayes International Corporation, Dothan, Alabama, on August 27, 1979. The modification, however, was not written into the maintenance requirements used by later operators. The maintenance documentation shows that up until the time of the accident the requirements for the previous configuration were used, i.e. with the GTC installed in the right wheel well of the aircraft. The AC generator mounted on the APU is not mentioned either. The aircraft was actually equipped with three identical AC generators. Lack of documentation makes it impossible to determine the extent of the maintenance that the unit had received before the accident. Therefore there are neither indications as to who installed the unit's front support nor as to who was responsible for its manufacture.

The MEL in the company's FOM does not show that the aircraft was equipped with an APU with an AC generator installed, nor does it show the APU being connected to the ventilation system. The procedures for use of the APU in the air were not incorporated in the handbooks delivered to the Board.

1.16.7 Examination of possible defects in AC system No. 1

1.16.7.1 Because of the problems which occurred in the left AC system on the flights prior to the accident the AAIB/N decided to examine the electrical system, as far as it was possible to do so. Since changing the AC generator did nothing to correct the fault and no faults were found in the replacement generator, it is most likely that a system fault prevented the left AC generator from connecting up to the left system. An examination of the remains of the system and a check of its parts did not produce results which could explain why the problem occurred.

1.17 ADDITIONAL INFORMATION

1.17.1 Operation handbooks, maintenance material and documentation

1.17.1.1 There were more modifications carried out on LN-PAA than on most of the other CV-340/580 aircraft that were, and still are, in service. These modifications resulted in further changes being made to several systems and in amendments and changes be made to a number of the aircraft's documents. These were:

- APU
- APU fire warning and extinguishing systems
- Heating and ventilation
- AC system
- Inverter system
- Radio equipment
- Autopilot
- Flight Director
- Flight Data Recorder
- Cockpit Voice Recorder
- Mach/Airspeed Indicator
- Underwing Fuel Pressure Refueling
- Fuel Dumping
- 50,000 lbs Zero Fuel Weight

- Interior and exterior lighting
- Galley installation
- Normal Checklist
- Minimum Equipment List

1.17.1.2 Several documents were affected by the modifications mentioned in 1.17.1.1. In the following documents and handbooks handed over to the AAIB/N revisions were not made in accordance with the LN-PAA configuration:

- Maintenance Schedule
- FOF work card (See para. 1.6.4.3)
- Maintenance Manual (Allegheny)
- Allison Parts Catalogue
- Flight Manual with check lists
- Minimum Equipment List

1.17.1.6 Use of the check lists is referred to in the Company's FOM para. 4.2.1. where it is stated that the Normal Check List and the Emergency Check List shall be kept on board and used during flight. It is also stated that the other check lists and the Expanded Check Lists should be included in the Company's Flight Training Manual.

1.17.1.7 The pilots had two check lists available on board for normal use. One with rolling text mounted in the cockpit and another in plastic covers as a reserve. Both were given Reference No. 00460 and were dated September 1, 1988.

These check lists were based on information found in Allison Flight Manual, Vol. I, last revised on July 16, 1975; Vol. II, last revised on January 21, 1974 and in the Pilot's Handbook, issued by Allegheny Airlines, dated April 1, 1976.

The check list system complied with normal standards.

According to the Normal Check List, the APU should be switched off prior to departure.

1.17.1.8 The Company's FOM, para. 4.2.1, states that both the Normal Check List and the Expanded Check List were to be found in the Flight Training Manual. The Training Manual was issued in November 1982, before the Company began operating the CV-340/580. The manual had not been revised since then. The Company informed the AAIB/N that the manual was in the process of being revised when the accident occurred. The new CV-340/580 chief pilot presented the Board with a draft of the new training manual, which also included this aircraft type.

1.17.3 Radar

1.17.3.1 The AAIB/N was given access to information from the following sources:

- Oslo ACC radar
- Military radar at Maakeroey
- Military radar at Skagen on Jutland
- Radar data from Skagen which was transmitted to Maakeroey
- A NATO AWACS aircraft which circled north of Sjaelland, approximately 120 nm (220 km) from the accident site
- Two Swedish military radar stations
- Approach radar at Aalborg airport
- Copenhagen ACC radar

The times stated in the radar information are in UTC.

1.17.3.2 Shortly after the accident the RNoAF provided the Board with the radar data recorded at Maakeroey. This information was essential in establishing the search for the wreckage on the sea bed. The Air Force also provided a systems consultant to assist the AAIB/N. The consultant supported the AAIB/N's interpretation of the available radar data from Norway, Denmark and AWACS' NATO base in Geilenkirchen.

1.17.3.3 The Board found that all the recorded data on the LN-PAA

track correlated. There were minor differences due to inaccuracies in the radar systems, as well as differences in the recording methods.

1.17.3.4 The AAIB/N received information indicating that the time recordings at Maakeroey were correct. The recordings from Skagen radar were 15 seconds late and AWACS' recordings were 15 seconds early. These were therefore adjusted to Maakeroey times. The Swedish time recordings were within plus/minus 1 second of Maakeroey time.

The observation of the primary echo from the approach radar at Aalborg lasted from 1457 hrs to 1520 hrs. Copenhagen ACC established radar contact at 1423:30 hrs and registered "something" 40 nm nord of Aalborg at 1445 hrs.

1.17.3.5 LN-PAA was tracked by radar shortly after its departure from Fornebu at 1359:50 hrs. There were no abnormal recordings during take-off and climb to cruising level at FL 220. At 1416 hrs Oslo ACC informed LN-PAA that there were strong westerly winds, and suggested a 10° right heading correction which would give a direct track to AAL VOR/DME. It can be seen from the read-out that the crew followed the recommendation.

From 1431:07 hrs until 1432:18 hrs Skagen radar recorded a change of direction to the left, from 195.5° to 188.3°. After a slight change in a westerly direction another change to the left occurred between 1433:53 hrs and 1435:27 hrs, i.e. from 190.2° to 179.0°.

1.17.3.6 From 1436:39 hrs to 1437:02 hrs, the aircraft turned sharply to the right, heading north west, followed by a sharp turn to the left, heading south west at 1437:14 hrs and in a southerly direction at 1437:26 hrs. From then until 1438:38 hrs the computer only recorded hits from the radar beam on each alternate antenna rotation. The distance between the accepted radar hits indicated a marked change in altitude in this area. The aircraft turn could not have

been any wider, as figure 6 shows, owing to the characteristics of the radar system. The last recording of acceptable quality was made at 1438:49 hrs. The last recording by AWACS was made at 1438:08 hrs. At 1437:43 Swedish radar monitored LN-PAA for the last time. The radar recording ended abruptly on the Swedish radar screen, which, according to Swedish experts, indicated a steep descent.

According to the Norwegian system consultant, the monitoring of the aircraft track by Skagen radar was the most accurate. The Board therefore chose to go by Skagen radar's recordings (figure 6).

1.17.3.7 In addition to the aircraft track, one of the Swedish radars recorded one or several objects at 1438:23 hrs. LN-PAA had by then disappeared from the radar screen. This recording lasted until 1509:36 hrs. During this period of time the object travelled a distance corresponding to an average speed of 15 knots, and moved on a steady course of 080°. This implied that the average wind direction and speed was 260°/15 knots, which corresponded to the aftercast of the wind direction in the area.

1.17.3.8 The approach radar at Aalborg airport was also used to search for LN-PAA. The air traffic controller and his assistant observed an apparently stationary object in the position, radial 360° 16 nm from Sindal airport. This position differed by only 1 nm from the Swedish recording. The object was observed from about 1457 hrs to 1520 hrs.

Another interesting fact was that Copenhagen ACC radar registered "something" 40 nm north of Aalborg, at 1445 hrs. This correlates with the position of the object registered by the approach radar at Aalborg airport.

1.17.3.9 The aircraft's transponder recordings in mode C, made by the AWACS, was somewhat sporadic. At 1422:26 hrs the altitude was 21,700 ft and at 1423:25 hrs it was 21,800 ft.

PARTNAIR CONVAIR 580, LN-PAA

Plot based on Skagen radar.

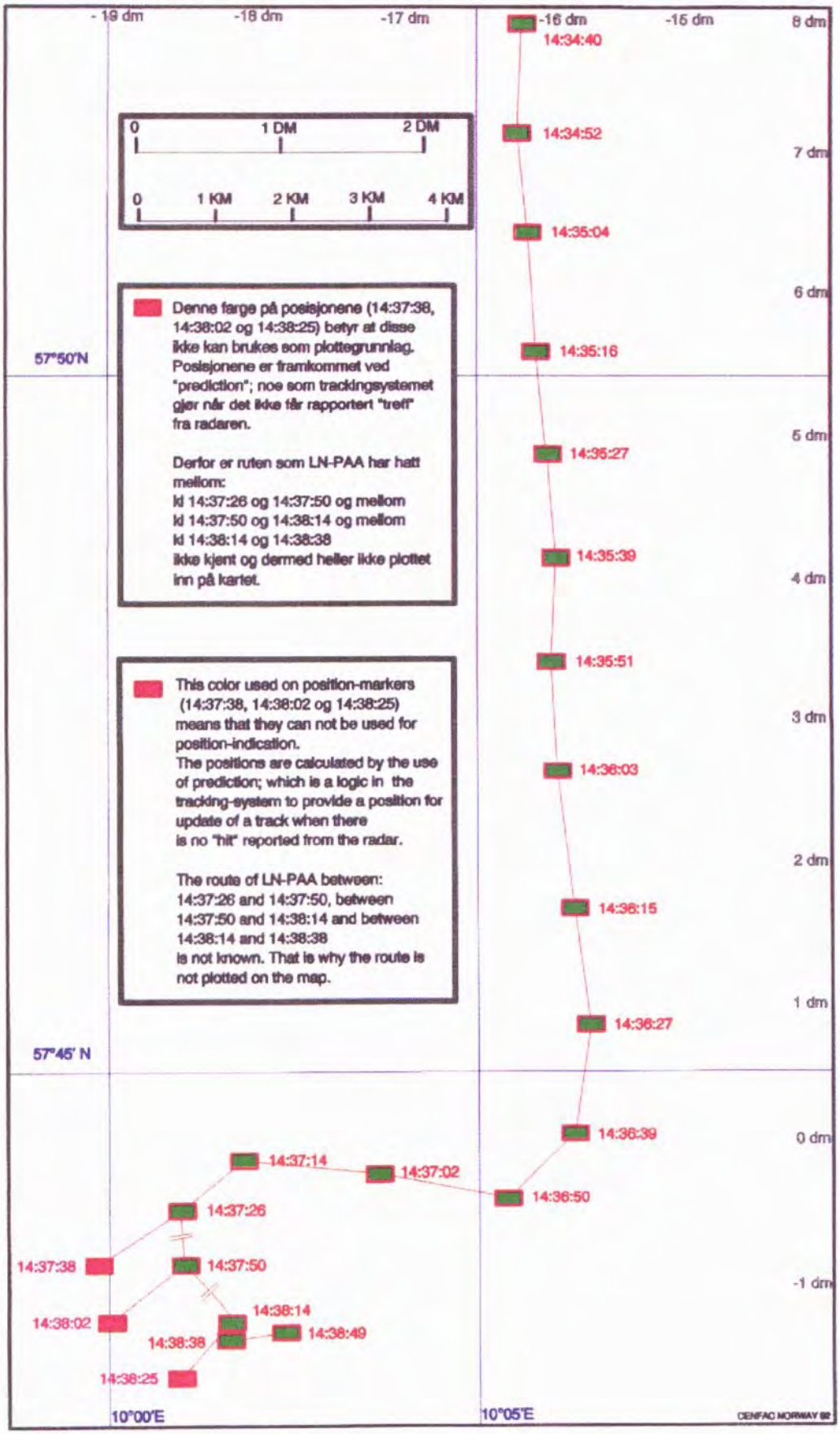


FIG. 6

From 1428:00 hrs to 1432:36 hrs there were several recordings of 21,900 ft. Twenty seconds later the mode C recording was 21,800 ft. There was a subsequent interval until 1438:03 hrs, when the final recording was made. The altitude of the aircraft was then given as 11,200 ft.

1.17.3.10 An evaluation of AWACS' 3D radar showed that the steady recording of altitude ended at about 1437 hrs. This indicated that a marked drop in altitude began at this time.

1.17.3.11 The source of Skagan radar's altitude recordings was the secondary radar system (mode C). The recordings indicated that the aircraft maintained cruising altitude from 1422:35 hrs until 1435:39 hrs. The recorded altitude ranged from 21,900 ft to 21,800 ft. Two antenna rotations later, at 1436:03 hrs, the recording was 300 ft higher, i.e. 22,100 ft. Three rotations after that, at 1436:39 hrs, 21,000 ft was recorded. The final altitude recorded by Skagen radar was 21,100 ft at 1437:02 hrs.

1.17.3.12 Swedish military radar did not record the altitude of the aircraft. It was stated that the aircraft must have been at or above an altitude of approximately 5,000 m (16,400 ft) at 1437:43 hrs. The object recorded at 1438:23 hrs was judged to be at an altitude of no less than 5,000 m. When the object disappeared from the radar scope the altitude was judged to be approximately 400 m (1,300 ft).

Based on local weather conditions that day, air traffic controllers at Aalborg airport judged that the observed object on the approach radar had disappeared at an approximate altitude of 2,000 ft.

1.17.3.13 Swedish radar recordings after 1638:23 hrs (figure 7)

The AAIB/N placed emphasis on trying to determine what exactly Swedish radar had recorded once the PAR 394 radar hits had disappeared. The line of thought was that the

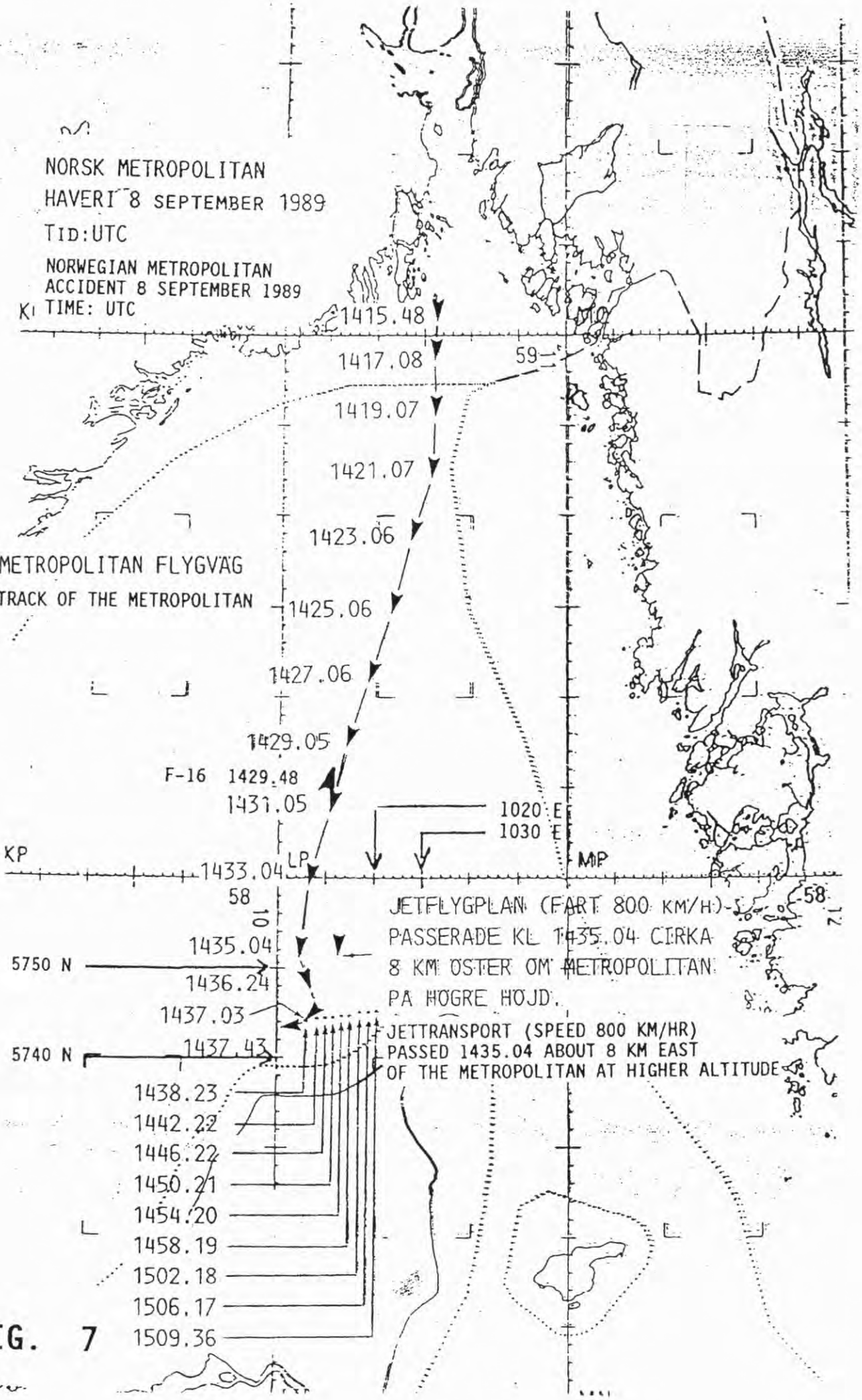

NORSK METROPOLITAN
HAVERI 8 SEPTEMBER 1989
TID:UTC
NORWEGIAN METROPOLITAN
ACCIDENT 8 SEPTEMBER 1989
TIME: UTC
1415.48
1417.08
1419.07
1421.07
1423.06
1425.06
1427.06
1429.05
F-16 1429.48
1431.05
1433.04
1435.04
1436.24
1437.03
1437.43
1438.23
1442.22
1446.22
1450.21
1454.20
1458.19
1502.18
1506.17
1509.36
59
58
KP
LP
MP
1020 E
1030 E
5750 N
5740 N
METROPOLITAN FLYGVÄG
TRACK OF THE METROPOLITAN
JETFLYGPLAN (FART 800 KM/H)
PASSERADE KL 1435.04 CIRKA
8 KM ÖSTER OM METROPOLITAN
PÅ HÖGRE HÖJD.
JETTRANSPORT (SPEED 800 KM/HR)
PASSED 1435.04 ABOUT 8 KM EAST
OF THE METROPOLITAN AT HIGHER ALTITUDE

FIG. 7

object must have been small and very light. It must also have excellent radar reflection properties. The object was recorded for 2,473 secs (41 mins and 13 secs) from a minimum height of 5,000 m until it disappeared at a height of 400 m. This corresponds to a minimum sink rate of 1.86 m/s. Since the radar hit of the object could have been blocked by the radar hit of the aircraft, the maximum possible height could have been 21,100 ft (6,431 m). This corresponds to a maximum altitude loss of 6,031 m during the same time span. The maximum possible sink rate was thus 2.4 m/s. Both maximum and minimum values pointed to the fact that the object must have been very light. Owing to the characteristics of the radar signal the experts judged the object to be quite small.

1.17.3.14 The RNoAF was consulted about the wave lengths of the actual radars, because the shape and size of a radar target in relation to the radar wave length determine the target's reflection properties. A careful inspection of the aircraft's structure, interior and loose objects resulted in the conclusion being drawn that the only material which could satisfy the criteria was the metallic honeycomb in the shroud doors on the vertical fin.

In order to determine the reflective properties with certainty the Norwegian Defence Research Establishment was contacted. The Defence Research Establishment informed the Board that the reflective properties of metallic honeycomb were 100%. Reconstruction of the aircraft wreckage showed that some of the honeycomb was missing from several areas of the shroud doors on the vertical fin.

As this honeycomb was the only material from the aircraft which could satisfy the requirements of low weight per unit of area and of perfect reflection of radar energy, the AAIB/N concluded that the object recorded by Swedish radar and Aalborg approach radar must have been one or more pieces of honeycomb in the shroud doors on the vertical fin.

1.17.4 Other air traffic

1.17.4.1 In addition to LN-PAA, other air traffic in nearby airspace consisted of a B-737 Braathens SAFE passenger flight (Flight No. BRA 405) en route from Fornebu to Billund and a Norwegian F-16 fighter aircraft en route from Aalborg to Rygge under civilian air traffic control. The two aircraft had established their respective cruising levels when they passed LN-PAA. LN-PAA maintained FL 220, BRA 405 maintained FL 290 and the F-16 maintained FL 240. According to radar information, all the aircraft were identified as friendly, i.e. known traffic (figure 8).

1.17.4.2 LN-PAA and the F-16 passed each other at 1429:28 hrs. Danish radar recordings showed that LN-PAA passed to the east of the F-16 at a lateral distance of approx. 1 nm. Swedish radar data showed that LN-PAA passed to the east of the F-16 at a lateral distance of approx. 0.5 nm. LN-PAA was observed by the pilot and passenger in the fighter aircraft. The pilot confirmed that the Partnair aircraft passed to the right, but he believed it to be closer than 1 nm. He could not, however, give an accurate distance. The difference in altitude was 2,000 ft. The speed of the F-16 in the three-minute period during which it passed LN-PAA, based on available data, was calculated as being approx. M.87. In an interview in November 1989 the Pilot-in-Command of the F-16 stated to the Board that the speed had been between M.85 and M.90. The speed of M.87 lies within the economical area of the cruising range in this aircraft type. Nothing unusual was observed while passing LN-PAA.

1.17.4.3 BRA 405 flew in the same direction as LN-PAA and caught up with LN-PAA at 1434:52 hrs. According to radar recordings, the lateral distance was 3 nm and the difference in altitude was 7,000 ft. The BRA 405 crew did not observe LN-PAA.

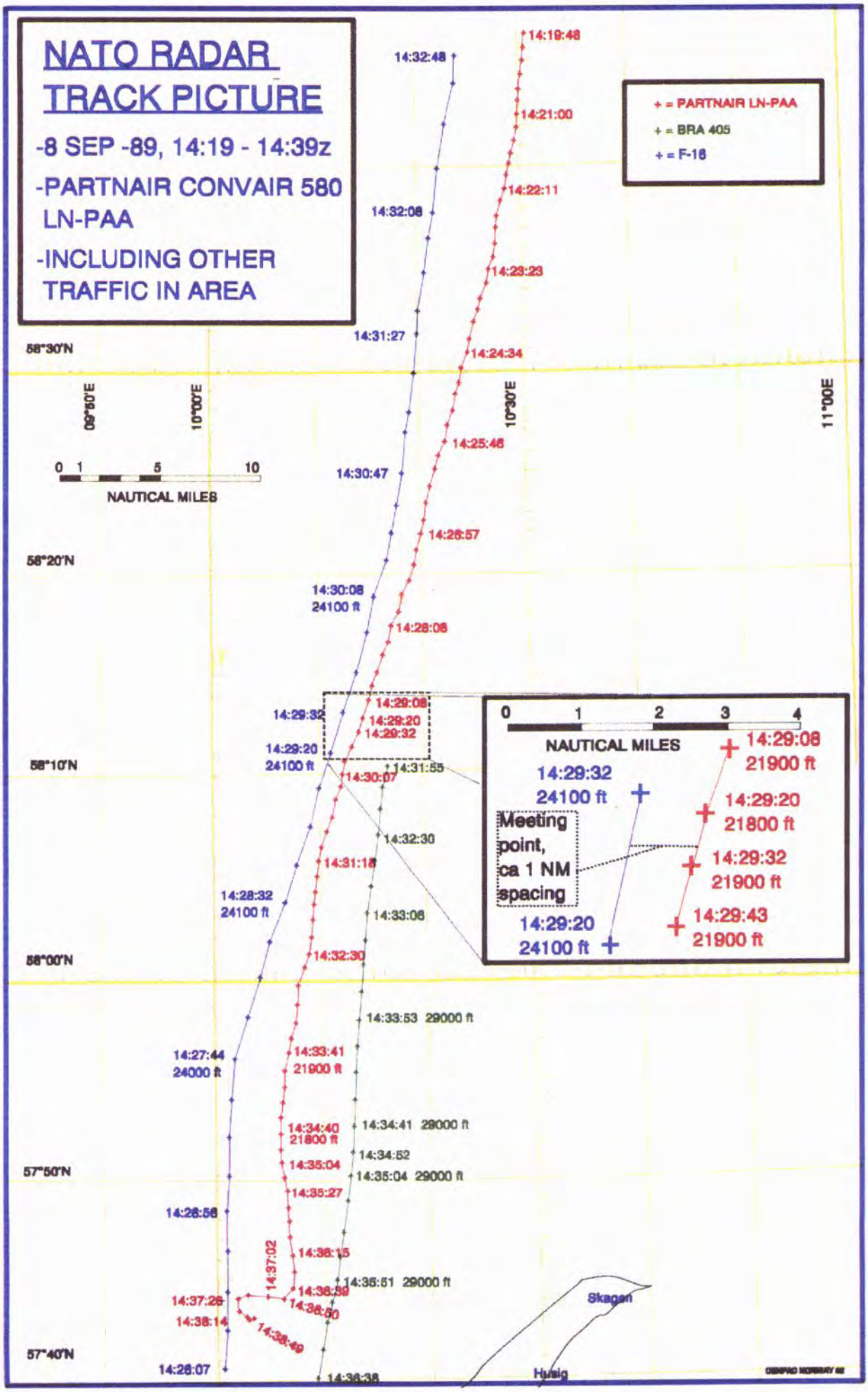

NATO RADAR TRACK PICTURE
-8 SEP -89, 14:19 - 14:39z
-PARTNAIR CONVAIR 580 LN-PAA
-INCLUDING OTHER TRAFFIC IN AREA
+ = PARTNAIR LN-PAA
+ = BRA 405
+ = F-16
58°30'N
58°20'N
58°10'N
58°00'N
57°50'N
57°40'N
09°50'E
10°00'E
10°30'E
11°00E
0 1 5 10
NAUTICAL MILES
14:19:48
14:21:00
14:22:11
14:23:23
14:24:34
14:25:46
14:26:57
14:28:08
14:29:08
14:29:20
14:29:32
14:30:07
14:31:15
14:32:30
14:33:41
21900 ft
14:34:40
21800 ft
14:35:04
14:35:27
14:36:15
14:36:38
14:36:50
14:37:02
14:37:26
14:38:14
14:38:49
14:32:48
14:32:08
14:31:27
14:30:47
14:30:08
24100 ft
14:29:32
14:29:20
24100 ft
14:28:32
24100 ft
14:27:44
24000 ft
14:26:56
14:26:07
14:31:55
14:33:06
14:33:53 29000 ft
14:34:41 29000 ft
14:34:52
14:35:04 29000 ft
14:35:51 29000 ft
0 1 2 3 4
NAUTICAL MILES
14:29:32
24100 ft
Meeting point, ca 1 NM spacing
14:29:20
24100 ft
14:29:08
21900 ft
14:29:20
21800 ft
14:29:32
21900 ft
14:29:43
21900 ft
Skagen
Hvalø

FIG. 8

1.17.5 Military activity

1.17.5.1 The "SHARP SPEAR" NATO exercise was in progress at the time LN-PAA crashed. The exercise involved sea and air forces, and was conducted partly in exercise areas covering Denmark and adjacent waters and air space. The areas to be covered were announced to airmen in NOTAM Nos. 71/89 and 72/89, issued by the Norwegian Civil Aviation Administration.

1.17.5.2 After the accident there were rumours and allegations that LN-PAA could have been shot down by participants in the aforementioned exercise. Headquarters Defence Command Norway, however, denied any such allegation in press releases, etc. The AAIB/N nevertheless received information from the public to the effect that the aircraft could have been shot down during a military exercise. The AAIB/N sent a letter to the Headquarters Defence Command requesting clarification as to whether or not there had been any military activity in the accident area which could support allegations that LN-PAA was shot down. The AAIB/N subsequently received a statement from the Headquarters Defence Command, in which, amongst other things, rumours of the aircraft having been shot down were rejected.

1.17.5.3 The Norwegian fighter aircraft which met LN-PAA approximately 9 minutes before the crash did not participate in the NATO exercise. Rumours also circulated that this fighter aircraft could have shot down LN-PAA. The rumours were rejected in writing, both by the Headquarters Defence Command and the pilot in question. The pilot also expressed to the Board that it was rather onerous to be the subject of such allegations. He also pointed out that the Air Force had strict rules regarding the carrying weapons into other countries, and that his aircraft was not armed. The radar recordings of the F-16 aircraft showed that it maintained a steady course and altitude over the actual time span.

1.17.6 Investigation into the explosion theory

1.17.6.1 The police carried out investigations to clarify whether there could have been an explosion in the form of a detonation of explosives on board LN-PAA. The police applied for assistance from well-known international experts in this field of investigation. The AAIB/N also assisted the police by providing flight technical expertise for identification and examination of the wreckage parts.

Two British experts who had taken part in investigations into the sabotage of the Pan Am aircraft over Lockerbie, Scotland, in December 1988, scrutinised all wreckage parts, equipment and personal belongings from LN-PAA. They concluded that they could find none of the signs they would have expected to find subsequent to an explosion.

1.17.6.2 The conclusions of the police, based on extensive investigations carried out were as follows:

- "In our examination of the wreckage parts from the accident aircraft and the baggage and clothes of the victims, there were no signs of detonation usually associated with explosives.

- Investigations carried out by Walter Korsgaard of the FAA and by the RARDE Laboratory in England produced no signs or analysis results which might lead to the conclusion that the aircraft had been blown up. The minimal amount of RDX military explosive found on an aircraft part* could have been caused by contamination, either before the accident or through the handling or storage of the wreckage parts subsequent to the accident.

- In conclusion, it is our opinion that there were no signs to indicate that the accident was caused by an explosion on board the aircraft".

*) 23.5 cm x 76 cm part of a ventilation duct in the passenger cabin.

1.17.6.3 The AAIB/N noted the conclusions arrived at by the police. The Board's own technical investigations carried out on available wreckage parts correspond to these conclusions.

1.17.7 Witnesses

1.17.7.1 The police in Hjoerring, Denmark received witness statements from 16 persons regarding the accident. All of them had heard sounds that could have been from LN-PAA. The statements were mainly to the effect that they had heard sounds which they associated with aircraft engines at very high rpm, followed by sounds described by them as "crash - boom - bang - bump - thunder" etc. The time of the accident coincided in the main with the time periods or points in time given by the witnesses. The witness statements supported each other, in that all of them had heard the sounds from the direction of the accident site, north of Hirtshals. There were no eye witnesses to events which could be connected to the accident.

1.17.7.2 A total of 24 persons contacted the Norwegian police and the AAIB/N regarding experiences they connected to LN-PAA and other CV-340/580 aircraft. Seven of the statements were observations linked to the actual accident flight. These observations were mainly the sound of engines functioning abnormally and of an aircraft with abnormal smoke emissions from its engines. In one case, the person in question claimed to have heard cannon-like booms coming from the direction of the accident site. The other 17 statements mainly concerned experiences witnesses had had as passengers on LN-PAA and/or other CV-340/580 aircraft. The witnesses mentioned difficulties in closing doors, one emergency exit which opened upon landing, as well as fog in the cabin before landing. In some cases movements of and dents in the skin of the wings and engine cowlings, an apparently uncentered propeller spinner, as well as

vibrations, were observed. Two of the statememts were from pilots who had flown the route in question some time before LN-PAA did so. These witnesses described the weather conditions along the route.

1.17.7.3 The police questioned those persons who had carried out the security check on the passengers and their baggage, as well as those responsible for the handling of the aircraft. Those questioned declared that there had been no unusual circumstances, aside from the fact that the Company's credit had been suspended by the CAA/N and the catering company.

The police questioned 27 PAS and FOF employees who had had some connection with LN-PAA. In general, the statements implied that the aircraft had had a normal operational and technical standard. Some witnesses were of the opinion that LN-PAA, subsequent to maintenance work carried out by KFC in 1989, had had a few more minor problems than the other two CV-340/580s operated by the Company. Amongst other things, difficulties were noted in the closing of the main door and there were problems with the tightening strip around the service door. During one period of time there were problems in starting the engines. It was also mentioned that it had been difficult to regulate the heat in the passenger cabin, and that occasionally condensation (grey, scentless fog) formed in the cabin during approach. One witness stated that LN-PAA vibrated more than other aircraft of the same type. Two witnesses stated that they felt there was more noise in this aircraft than in the others. Other witnesses did not notice any abnormal vibrations or sounds.

In some statements it was said that PAS had, at times, had financial problems.

1.17.7.4 The AAIB/N, in addition, compiled comprehensive information by interviewing quite a few members of staff from PAS and FOF.

1.17.8.1 *Airworthiness Certificates*

1.17.8.2 Norway is a member of the International Civil Aviation Organisation (ICAO). This organisation has based on the 1944 Chicago Convention, compiled a set of regulations that member states are obliged to adhere to, unless they have notified differences. The regulations contain, amongst other things, standards for airworthiness and how a airworthiness is to be confirmed. These apply both to the issuance of an airworthiness certificate and to how such certificates should be evaluated across national borders (for example, with regard to one country selling to another). The regulations, which cover the subject of airworthiness, are compiled in Annex 8, Airworthiness of Aircraft, and are reflected in the Norwegian regulations. Norway has not notified ICAO of any differences to Annex 8.

1.17.8.3 In a letter to the Board, the CAA/N states:

> "The system is entirely based on work being carried out in accordance with an approved maintenance programme and by a qualified organisation that is approved in correlation with regulations of that state and ICAO's standards, and also that both the organisation and the aircraft are subject to supervision by the authority. The Airworthiness Certificate which the export country issues and renews if necessary, is a confirmation of this."

In the same letter, it is also stated that both bilateral and multilateral agreements have been established regarding mutual acceptance of airworthiness certificates among certain countries. There are some countries that Norway does not have such an agreement with, for example, Canada. In such cases, any imports from these countries would have a condition that the regulations for airworthiness in that particular state should correspond to the regulations governing imports from the USA or a member state of the European Civil Aviation Conference.

1.17.8.4 When an aircraft is imported to Norway it will always be subject to international standards and any agreements which

are the basis for the issuance of a Norwegian Airworthiness Certificate. There are more detailed requirements in the Norwegian Air Regulations (BSL).

1.17.8.5 The Transport Canada Aviation issued an Airworthiness Certificate for C-GKFT on May 15, 1986. On the basis of an application from PAS regarding the issuance of an Airworthiness Certificate for LN-PAA, the Canadian certificate was validated the day after, on May 16, 1986, by an endorsement given by the Norwegian CAA, which had a validity of 30 days. This validation was given in Canada as part of an admission check to the Norwegian Civil Aircraft Register. Later, when the aircraft arrived in Norway, a Norwegian Airworthiness Certificate was issued.

1.17.9 Minimum Equipment List

1.17.9.1 Regulations regarding MEL, BSL D 2-6, which were established by the CAA/N on April 16, 1986, states:

> "To commence a flight the aircraft, including instruments, equipment and systems shall be airworthy, in accordance with valid airworthiness requirements.
>
> A flight may, however, commence with instruments or systems which do not function within the framework of a MEL system approved by the authorities."

The MEL system is to be approved by the CAA/N. There are several requirements which must be fulfilled in order for such approval to be given, inter alia:

- There shall be a MEL for each aircraft type concerned and for any special version of it. The lists shall include those systems/components which may be non-functional as well as the conditions under which the aircraft may be operated.

- Dealing with inconsistencies and location of these in handbooks and system revisions.

- Objective with regard to the MEL system.

- A description of how technical and operational responsibility for the MEL system is administered, giving lists of personnel who are technically and operationally responsible for the preparation, revision and use of the system. (The fundamental rule is that the Flight Operations Manager is responsible for the MEL system, in consultation with the Technical Manager).

- A system for issuance of airworthiness release.

1.17.9.2 Partnair's MEL system was approved by the CAA/N on May 9, 1987. In a letter from the CAA/N, it is stated that the regulations in BSL D 2-1 is the basis of the approval, and that the Flight Operations Manager is responsible for the system. In an internal memo, comments were made by the Airworthiness Department of the Aeronautical Inspection Division, CAA/N regarding requirements in the MEL Regulation, BSL D 2-6, not mentioned in the CAA/N letter. Furthermore, the letter did not discuss FOF's role as the company technically responsible for the PAS CV-340/580 aircraft.

Minimum Equipment List Standards are found in ICAO Annex 6, Operation of Aircraft.

1.17.10 Flight Manual

1.17.10.1 The design requirements of the country originally undertaking type certification require that a Flight Manual for the aircraft type be issued (referred to as the Aeroplane Flight Manual in ICAO Annex 8). This is an operation handbook primarily designed for use by flight crew, but is formally connected to the concept of airworthiness. It is required that certain sections of this handbook be approved by the authorities. For the type of aircraft involved in this investigation, the original

authority was the American FAA. Upon issuance of a Norwegian Airworthiness Certificate the part of the Flight Manual to be approved by the authorities is validated by the CAA/N by the issuance of an authorisation page. The page is then placed in the handbook. For LN-PAA the Airworthiness Certificate was validated on May 16, 1986, while the Flight Manual was authorised by the CAA/N on May 27, 1986. The aircraft was then en route to Norway.

1.17.10.2 ICAO Annex 8, Airworthiness of Aircraft, part 3, 9.5, contains a description of the Flight Manual:

> "An aeroplane flight manual shall be made available. It shall identify clearly the specific aeroplane or series of aeroplanes with which it is related. The aeroplane flight manual shall include at least the limitations, information and procedures specified in this chapter."

1.17.10.3 In the Norwegian regulations pertaining to the Flight Manual, the following is stated in BSL B 3-2, 8.4.5:

> "Should repairs or modifications of an aircraft or changes in equipment cause a change to occur in its operational limits or to the operating procedures or performance data included in the aircraft's flight manual, the person responsible for the aircraft's airworthiness after such work has been carried out should ensure that the necessary approved changes are included in the flight manual, along with respective check lists and, if necessary, corrections to the table of contents.
>
> Note 1: The procedure for the correction of the flight manual is indicated in BSL B 1-5, Flight Manual and Check List for the aircraft."

BSL B 1-5 is listed in the table of contents in BSL B, but has not been issued (in the course of compilation).

1.17.10.4 The FAA in the USA has ruled that the documentation requirements for manufacturers possessing a Type Certificate (TC) also apply to manufacturers who submit modifications with a Supplemental Type Certificate (STC). This implies that modifications based on an STC, which are of importance to the operation of the aircraft require

relevant supplements to be included in the authorised Flight Manual.

1.17.10.5 The Flight Manual for LN-PAA which was on board was not recovered after the accident. The Flight Manual which the AAIB/N received from the Company was inconsistent with many of the systems that were installed in LN-PAA. When questioned, the Company's new Flight Operations Manager stated that the Flight Manual on board the aircraft had the necessary supplements for the systems that were particular to LN-PAA, including the APU installation. There is no requirement in the regulations for a master copy of the Flight Manual for a specific aircraft type, with up-to-date revisions and supplements of modifications or type versions, to be available at the operator's main base. The Company's FOM, para. 2 of 1.7.5, which refers to the Airplane Flight Manual, states, however, that one copy of the Flight Manual is to be kept in the company's technical office and one copy is to be kept on board each aircraft.

2 ANALYSIS

GENERAL

A considerable part of the investigation led to negative findings, i.e. no findings of anomalies that could be related to the sequence of events leading up to the accident.

In addition to those investigations resulting in positive findings, those which resulted in negative findings led to the conclusion that circumstances outside the aircraft did not affect the outcome of the final flight.

2.1 The investigation did not reveal signs of deficient crew performance. Medical and technical findings revealed that the crew did their utmost to control the aircraft. Both pilots were highly experienced and reputably competent in their profession.

2.2 Meteorological data from the area, as well as reports from other aircraft and observations at sea level, all led to the conclusion that the weather could not have affected normal flight operations.

2.3 The independent liability investigation conducted by police authorities excluded the possibility of demolition by an explosive charge. This conclusion was corroborated by the fracture pattern revealed during the technical investigation carried out by the AAIB/N.

2.4 Headquarters Defence Command Norway informed the AAIB/N that no military activity in the area could have posed any threat to flight operations. All information available about the northbound F 16 passing to the west of and at a higher level than LN-PAA gave no indication of any

irregularity connected with this event.

2.5 The technical investigation excluded the possibility that operations were affected by abnormal propeller or engine performance. Findings in the recovered engine instruments indicate normal cruise power settings at the time the AC power failed. Other findings showed that the aircraft was out of control and a catastrophic failure of the tail structure was in progress when AC power was lost. The propellers were in upper cruise range blade angle position when power was lost.

2.6 The investigation revealed some reliable findings which were quite significant. The findings were of such importance that the AAIB/N has used them as a basis for its analysis of the accident. These findings were from the following sections of interest:

- Wing fractures
- Fracture pattern and observed marks in the empennage
- APU
- Radar data
- FDR recordings

2.6.1 The fact that the wings failed symmetrically from a downward overload led to two conclusions. The negative load must have been somewhat symmetrical around the longitudinal axis of the aircraft, and the onset of load must have been very rapid. Failure of one wing would have led to an instant unloading of the opposite wing, hence the failure of both wings must have occurred simultaneously or within a very short time span. To achieve this, the load must have increased at a high rate.

It is most unlikely that any action by the crew or a failure in the flight control systems between the cockpit and the flight control surfaces could have led to such an overload. The only logical explanation is that the aircraft

was out of control when wing failure occurred. Loss of control and stability to the point where wing structure was overloaded would indicate the pre-existence of a partial or complete empennage control surface malfunction.

2.6.2 The diagonal wrinkles found on the fixed and mobile tail surfaces were indicative of the cyclic, reversed, torsional and bending loads resulting from classic flutter. All surfaces can be subject to flutter if the airspeed exceeds established limits. The margin between normal operating speed and the flutter limit must satisfy certification criteria. Not all flutter margins were calculated in the Supplementary Certification process for this aircraft type. As an approved alternative, high speed dives were performed to demonstrate sufficient margins on all components affected.

This procedure, which is approved by the FAA, is simple and economical, and is considered to achieve the same level of flight safety as calculated limitations. What is not revealed with high speed dive tests, is an individual flutter margin for the components affected by aerodynamic loads.

The investigation brought to light a history of elevator hinge problems for this aircraft type. The installation of turbine engines gave these problems a new dimension, as more powerful engines increased the vibratory loads on the empennage and its components. The vibrations are caused by turbulent air from the propeller slipstreams impinging on the tail surfaces. Several cases of elevator oscillations caused by defective hinges have been reported. In at least one case the oscillations were such that, if they had been allowed to continue, they could have damaged the tail structure.

Investigation of the elevator remains from LN-PAA, including the elevator torque tube, indicated that at one stage in the accident sequence the elevator had been

subject to violent oscillations. The elevator hinges were found to be in a defective state. A metallurgical analysis of the hinges, the right-hand in-board hinge in particular, indicated that deformation was caused by a limited number of cycles in overload rather than long-term wear and tear. This makes it unlikely that the elevator hinges initiated the process of abnormal vibrations in the tail.

2.6.3 Since the left-hand main AC generator system could not be brought on line it was decided to keep the APU running throughout the flight to Hamburg. This information stems from the Flight Log, and is corroborated by technical evidence. The APU front support was not the standard shock absorber specified for this installation. The support failed before impact, evidenced by indentations from vibratory loads on and around the fracture. The APU turbine section had deteriorated as a result of heat erosion and cracks. The turbine rotor had rubbed against the stator vane ring. Cracking along the circumference of the stator vane ring over a 180° sector had cocked the stator in relation to the rotor, thus eliminating the clearance between the stator and the rotor on one side. The turbine rotor rotates at more than 40,000 rpm during steady state operation. If the rubbing had initiated any vibrations the frequency would have been very high. It therefore seems highly unlikely that it was the APU which initiated the cyclic stress exerted on the surfaces of the empennage.

However, it is a strong possibility that the APU, with its weight located at the very end of the tail, and the gyroscopic effect from the rotating mass, could have affected the general vibration pattern of the empennage. The witness marks found on the failed front APU support indicated oscillations around the lateral axis. Elasticity in the main supports, located on each side of the APU, allowed a limited degree of motion. If this situation were to be combined with an external energy source the APU could serve as a catalyst in transforming and transmitting vibration between reacting components in the empennage.

2.6.4 The investigation revealed rudder oscillations beyond the normal maximum limit of travel. When this occurs, the rudder balance weights interfere with the shroud doors covering the gap between the vertical stabiliser and the rudder. When the shroud doors were destroyed, sheets of honeycomb were torn away from the door structure. The investigation established that only this material, aluminum honeycomb in sheet form, could have given the radar echo registered by Swedish military radar and by Aalborg Approach Radar. There were no other sources for this material externally on the aircraft other than the rudder/fin shroud doors.

Radar observations indicated the release of the slowly falling object at high altitude, probably at cruise level. When an aircraft travels at cruising speed excessive force is needed to force the rudder against the stops. The control system is normally not strong enough to transmit this power to the rudder. This leads to the conclusion that the oscillations could not have been initiated by the crew or auto-pilot, or by an internal failure in the control system itself.

For the rudder to have made full travel excursions at cruise speed it must have been affected by abnormal aerodynamic forces in possible combination with a mechanical force transmitted from the vertical stabiliser via the hinges. The investigation established that the vertical stabiliser had abnormal clearances in its attachment fittings to the fuselage structure, and thus had a certain degree of freedom to move laterally. The movement would be in the order of less than 1 mm at the fittings. Owing to the geometrical shape of the tail the movements in the upper section of the tail could have been magnified by a ratio of 10 to 15. The tail's elasticity and the aerodynamic effects could have increased the vibrations by a greater factor. The vertical stabiliser was exposed to torsional stress. This is evidenced by the front right-hand

attachment, where the sleeve had a wider area of wear than the corresponding surface in the attachment fitting. In order for the sleeve to have been worn down in this manner the sleeve and pin must have had a rocking motion caused by stabiliser load.

It is the opinion of the AAIB/N that movement in the vertical stabiliser reached a level where the rudder was affected both aerodynamically, through air flow disturbances, and mechanically, via the rudder hinges. This initiated rudder oscillations to a degree higher than the dampening capacity of the rudder balance weights. When the shroud doors failed, the conditions were further aggravated by turbulence from the then exposed gap between the fin and the rudder.

2.6.5 Analysis of the FDR foil provided information from two separate areas:

- Flight parameters
- Indications of abnormal vibrations

2.6.5.1 Prior to the accident the FDR had increasing operational problems. For some time it had only been recording three flight parameters, as the G-parameter was unserviceable. On the accident flight, pressure altitude, airspeed and heading were recorded. The FDR stopped 36:29 mins after take-off (rotation). This corresponds to 36:01 mins FDR time, since it was found that the FDR was running approximately 50 seconds slow per hour. The three working parameters recorded values compatible with normal operations for the first 34 minutes of FDR time. A total assessment of the recordings from the last 2 minutes leads one to the conclusion that the crew began losing control of the aircraft at between 34 and 36 minutes FDR time. The change in heading at 34 minutes FDR time, which followed after several minutes of stable conditions, was in itself insignificant, but seemed to have been unintentional. It coincided with a change in airspeed,

which also seemed unintentional at that time. Since operations preceding 34 minutes FDR time were extraordinarily stable it was concluded that the aircraft was operating on auto-pilot when the first disturbance occurred at 34 minutes FDR time. It is probable that heading and altitude had been selected as guiding parameters.

The variations in altitude over that period were all minor and compatible with normal operations. The radar data from this segment of the flight matched the altitude deviations measured over that period and thus contributed to the correlation between actual time and FDR time.

At approximately 35 minutes FDR time there was a new heading deviation to the left, coinciding with a significant drop in airspeed. The recorded increase in airspeed, which started at approximately 35:45 mins FDR time, was in excess of normal aircraft performance. This meant that the FDR was affected at that time by erroneous sources not present during normal operations, which could have resulted from extreme yaw or pitch changes causing turbulence at static air pressure inlets.

Immediately before the FDR ceased operation it recorded a heading turn to the right for about 3 seconds, followed by a reverse to the left at an extremely high rate of more than 500°/min. To understand the significance of this recording the AAIB/N based its analysis on information received from the FDR manufacturer. In four reported accidents where this type of FDR was installed and recorded similar heading indications, a roll was observed by eye witnesses or was established from the relative positions of wreckage components. The manufacturer's representative, who also participated in the design of this type of FDR, commented that an analytical assessment of the FDR and its sub-systems led to the conclusion that one would have expected a radical heading change to have been recorded when the aircraft rolled. Based on this information the

AAIB/N is of the opinion that the aircraft went into an uncontrolled roll to the left at that time.

2.6.5.2 The AAIB/N concluded that the double altitude trace recorded on the FDR foil was an indication that the FDR had been subject to an abnormal level of vibration. The conclusion was based on information gathered from four separate areas:

- Analytical assessment of the FDR design, mechanical characteristics, known failure mechanisms, and information from a manufacturer/design source

- Correlation between recordings and records of FDR maintenance

- Correlation between recordings and maintenance history of a potential vibration source

- Conformity between recordings and phase of flight where vibration level in the empennage is highest

2.6.5.2.1 The empennage is generally subject to high vibration levels. This is particularly the case in propeller-driven aircraft where a high output of power creates an energy-rich slipstream, exposing the tail to turbulence. The FDR, which is normally installed in the tail, was designed to withstand vibrations. According to specifications, this FDR type had been tested to specified energy levels defined by frequency range and maximum amplitudes. Since no known internal failure mechanisms could have resulted in the dotted double lines, the FDR must have been subject to external sources in the form of vibrations which exceeded the test criteria level. The fact that abnormal recordings were found mainly on one parameter and not all three was taken into consideration. The mechanical properties of the FDR registration arms is of significant importance in this case. Each arm is individually mass-balanced by means of an adjustment screw which varies the distance between the

hinge axis and the centre of gravity. This means that there are individual variations in resonant frequency. In order for an arm and its recording knife edge to vibrate enough to jump back and forth on the recording medium it must be excited by energy pulses of a frequency in harmony with its own natural frequency. This makes it rather unlikely that more than one arm at a time could be subject to such oscillations. The shape of the arms and the registrations as they appeared on the foil indicate low frequency vibration.

2.6.5.2.2 By examining the maintenance records for the FDR and recordings from past operations it is evident that the FDR frequently malfunctioned and that the number of breakdowns increased prior to the accident flight. In addition to the anomalies registered by the altitude arm, the heading parameter had showed erroneous readings on a number of flights in the past, and the G-parameter had been out of service for extended periods. This could be interpreted as a result of the FDR being exposed to abnormal enviromental stress.

2.6.5.2.3 In the immediate vicinity of the FDR installation, at station 820.950, the investigation revealed conditions which most certainly led to an increase in the vibration level as operating time increased. This condition was brought about by the worn pins and sleeves in the vertical stabiliser attachment fittings. By studying the maintenance records for the pins and sleeves and comparing these with the development of the vibration pattern as it occurred on the FDR, a definite connection between them was established. The change in the recording pattern seen at the time heavy maintenance was carried out in July/August 1989 was of particular importance. Prior to the maintenance overhaul, abnormal registrations were recorded with increasing frequency until they occurred on almost every flight. During the final 10 hours before the maintenance the FDR was only partially operational. As a result of a sight inspection the rear right-hand vertical stabiliser

attachment was disassembled, inspected, and a new pin and sleeve installed. The other three attachments were not disassembled. Of the following 9 flights, after the maintenance work had been carried out, abnormal readings were recorded on only one flight. These abnormal readings reappeared thereafter with increasing frequency. Double lines were registered on 15 out of the final 24 flights. On the accident flight the double lines appeared earlier in the flight than ever before. The distance between the two lines was longer than it had been previously and this reading was recorded as long as the FDR was operational.

2.6.5.2.4 An analysis of the abnormal readings, with regard to the phase of flight in which they occurred, strongly supports the hypothesis of empennage vibrations being the source of the FDR anomalies. Vibrations in the empennage are generally caused by turbulence affecting tail surfaces. The level of vibration is mainly determined by the energy of the passing air flow, angle of attack, surface finish and atmospheric turbulence. The energy of the air flow is determined by airspeed, but can be substantially influenced locally by the propeller slipstream. This effect is not symmetrical for an aircraft where both propellers rotate in the same direction. For this type of aircraft it has been seen from service experience that there was more stress applied to the inner left-hand elevator hinge than to the other five elevator hinges. Since the effect of the air flow from the propellers is not symmetrical it can be assumed that the vertical stabiliser is exposed to lateral pressure pulses, particularly when there is a combined effect resulting from high airspeed and high engine power settings. This occurs in the phase of flight where there is a transition from climb to cruise and the climb power settings are maintained during level-off in order to accelerate to cruise speed. All of the preliminary readings of an abnormal altitude line in the FDR occurred during level-off and lasted into the first part of the cruise phase, where they again disappeared. In other words, they disappeared when engine power was reduced to cruise

setting. Later readings started earlier in the climb phase and lasted longer into the cruise portion of the flight. On the accident flight the readings started shortly after take-off, coinciding with a situation where airspeed increased temporarily from 190 to 217 knots, and climb power was apparently being maintained.

2.7 Based on the findings from the investigation and on the analytical conclusions drawn from the findings, the AAIB/N judged that the sequence of events leading to the accident could, with all probability, be described as follows:

2.7.1 The aircraft had been in operation for an extended period with abnormal vibrations in the empennage. The oscillations were convergent because the energy level was not high enough to overcome rigidity in the tail structure. The vibrations were such that they could not be distinguished from the natural vibration pattern in the empennage, and thus did not alarm the crew or passengers.

2.7.2 On the accident flight it was decided to keep the APU in continuous operation. At an altitude of approximately 1,400 feet the climb rate was temporarily reduced. This led to an increase in airspeed from approximately 190 to 217 knots. After a few seconds the climb rate was again increased and the airspeed was reduced to approximately 200 knots. This manoeuvre initiated the same vibration readings on the altitude trace in the FDR, previously recorded only at later stages of flight. These abnormal readings were more pronounced than on previous flights.

2.7.3 At 22:30 mins. FDR time, Flight Level 220 was reached and level-off was performed. During climb, the airspeed fluctuated between 182 and 217 knots. After level-off the airspeed gradually increased until it culminated at 215 knots. This probably coincided with a reduction in engine power to cruise setting. The speed then gradually decreased, stabilising at 200 knots at 32 mins FDR time. During the next 2 mins, from 32 to 34 mins FDR time, all

three operational flight parameters indicated stable values. This led the AAIB/N to believe that the auto-pilot had been selected at that time. From the readings it appeared that the heading and altitude modes had been set to auto-pilot. The vibration level in the tail section was probably not high enough to alarm the crew at that point.

2.7.4 At between 34 and 36 mins FDR time the vibrations in the tail section assumed catastrophic dimensions and started to affect the lateral stability of the aircraft. The oscillations could not be dampened by the tail structure and became divergent, i.e. their amplitude increased with each cycle. The reason for this must have been increasing energy levels, in the form of larger or added energy sources, supporting the oscillations. It is known that the APU was in operation, that its front support had failed, and that it was oscillating around its lateral axis.

There is, with all probability, a connection between the APU vibrations and the fact that the elevator oscillated around its hinge line. Which of these two energy sources triggered the other cannot be determined. When the oscillations began large amounts of energy were available from the turbulent air flowing from the propellers. The tail control surfaces were subject to loads in excess of design limitations, and the control linkage to the cockpit was overloaded and failed.

2.7.5 At this point it must have been evident to the crew that something had happened to the tail section, and this may explain why the APU fire extinguishing system had been triggered, resulting in fuel starvation in the APU, but had had no influence on subsequent events.

The AAIB/N has discussed the possibility that control of the aircraft would have been regained at that point by a rapid reduction in the engine power settings so as to reduce airspeed. Comments from pilots who have experienced vibrations resulting from worn elevator hinges indicate

that it is extremely difficult to identify the source of such vibrations. The findings from the investigation indicated that loss of control occurred suddenly and without due warning.

2.7.6 The oscillating rudder travelled to its maximum limit on both sides. The rudder balance weights on its leading edge hit the shroud doors and knocked these partially off. Sheets of aluminum honeycomb were released and created the source for the radar echo observed by Swedish and Danish radar stations.

At 35:40 mins FDR time the rudder became jammed in a maximum left-hand deflection. The rudder locked owing to a hinge line deformation resulting from vertical stabiliser bending. The rudder failed and was partially torn from its hinges after introducing enough yawing moment to initiate rapid roll to the left.

2.7.7 The findings from the examination of the wreckage and radar data gave numerous indications of the subsequent sequence of events. In general, this included loss of control around the lateral axis resulting from loss of horizontal surfaces in the tail, followed by a rapid onset of negative G load which broke off both wings.

Findings of plastic particles from the cabin interior in the APU turbine section, the aircraft wreckage pattern, medical findings and the damage pattern on beer cans, indicated a loss of cabin integrity prior to impact with the surface of the water. Some of these findings have been of value to the investigation.

The slowly-falling object observed by Swedish radar stations gave reliable indications of the wind direction being 260° at all altitudes. Parts of the horizontal tail surfaces were found scattered over a wide area in a pattern consistent with the established track and sequence, indicating failure at an early stage in the accident

sequence. Examination of the APU generator indicated a short circuit in the electrical systems while the APU was still in operation. Direct current from the battery must have been available when the last Mode C signal was transmitted from the transponder. Witnesses on the north coast of Jutland made observations which were probably related to the accident.

A detailed description of the final stages of the accident would be based on a number of assumptions. There would not be an exact reproduction of the events, and since this part is of minor importance in explaining the causal factors, the AAIB/N has refrained from carrying out an extensive analysis of the final stages of the accident.

2.8 To appraise the conditions leading up to and influencing the final outcome the AAIB/N decide to place the findings from the investigation in chronological order and to divide them up into four time periods:

- Maintenance visit at KFC 1985-86
- Operation and maintenance 1986-89
- Maintenance visit KFC 1989
- Operation and maintenance Aug. 27 - Sep. 8, 1989

2.8.1 In the maintenance work carried out at KFC in 1986, three separate events were of importance:

- The pins and sleeves in the vertical stabiliser attachments were replaced

- The APU was reinstalled with a front support of inferior design and unknown origin

- The aircraft was prepared for transfer to Norwegian registration and for operation by a new operator, with incomplete maintenance inspection requirements.

2.8.1.1 Maintenance records show that all four pins with matching sleeves, connecting the vertical stabiliser to the fuselage

structure, were replaced during maintenance carried out in 1986. The investigation further revealed that all four sleeves plus the two front pins did not conform to the specified hardness. Their actual hardness yielded a tensile strength of little more than 50% of the specified value. The composition of the material in the pins and sleeves, as well as their dimensions did, however, conform to specification. This indicated problems in the heat treatment of the parts, resulting from a probable lack of hardening after they had been machine-worked.

2.8.1.2 The APU installation in 1986 was a re-installation. The same APU had been removed and shipped to an overhaul facility before the aircraft went into storage in 1984-85. When the APU was re-installed in 1986 the original supports were used, according to KFC. This may have contributed to the fact that the front support was not properly inspected before installation.

2.8.1.3 The maintenance instructions used for the maintenance work carried out in 1985-86 did not cover all the modifications that LN-PAA had undergone. These modifications made this aircraft unique as compared with the other two CV 580s that PAS already operated. The modifications were carried out mainly on the APU installation and the aircraft systems affected by this installation. These maintenance instructions were used for the aircraft in all subsequent maintenance work carried out. The Norwegian Civil Aviation Act requires that an aircraft is "maintained in accordance with safety requirements".

Availability of adequate maintenance documentation must be considered a basic requirement in establishing satisfactory maintenance instructions.

Defective parts and components installed in the aircraft could only have been corrected by a precise, target-oriented inspection. Normal preventive maintenance does not reveal such deficiencies until the resulting symptoms

develop.

2.8.2 From May 1986 to July 1989 the aircraft was operated by PAS and maintained by FOF. The investigation revealed that wear in the vertical stabiliser attachments progressed at an abnormal rate. The wear created clearances in the joints, allowing the vertical stabiliser to vibrate when exposed to turbulent air. The vibrations occurred with increasing frequency and lasted longer and longer into each flight as the wear progressed. At no point did the vibrations reach a level sufficient to alarm the crew. No indications of abnormal conditions were evident to maintenance personnel. Not until July 1989, when the aircraft was in for inspection at KFC, was any sign of abnormal wear evident. The defective APU front support passed through several maintenance inspections without any comments being recorded in the maintenance records. The reason for this may have been that the current maintenance instructions were incomplete. Some updating of the maintenance documentation was carried out over this period, but had not been completed when the accident occurred.

It should be pointed out that the increasing operational problems with the FDR ought to have been noticed and that there ought to have been reason for concern. There should have been concern about the cause of the problems and about the stipulated requirement to carry out a "running check on all readings".

2.8.3 One part of the maintenance work carried out at KFC in July/August 1989 was of major interest in the light of subsequent events. This was the inspection of the vertical stabiliser attachments, the findings of the inspection, and the corrective action taken based on these findings.

As part of the SID programme it had been planned to inspect the vertical stabiliser attachments for cracks. The inspection was supposed to be carried out with the pins and sleeves removed so as to have access to the interior

surfaces of the pin/sleeve holes. If this disassembly had been carried out as planned it would have revealed unacceptable wear on all four pin/sleeve combinations. The maintenance organisation, KFC, chose to use ultrasonic equipment for the inspection without removing the pins and sleeves. This procedure did not comply with the relevant maintenance instructions, and when the operator's representative, an appointed inspector, became aware of the situation, he did not approve the inspection. It was decided to postpone the inspection until the aircraft had returned to Norway. This was acceptable, according to AD Note 88-22-06 which made the SID programme mandatory.

The remaining maintenance requirements did not include any inspection of the vertical stabiliser attachments. The total operating time between replacements of pins and sleeves had not been finalised in the relevant maintenance instructions. However, according to manufacturer recommendations and maintenance intervals established by other operators, this could be as high as between 10,000 and 20,000 hours of operating time.

Through a sight examination of the attachments it was found that the rear right-hand pin and sleeve had rotated in the attachment and black oxide and wear particles were "weeping" from the installation. This observation led to the replacement of the bolt and sleeve in the rear right-hand installation. The accident investigation revealed conditions indicating that sub-standard routines were being followed during the replacement. At this point unacceptable levels of wear must have been present in all four attachments, although wear was not outwardly visible in the other three. The manufacturer, GDCV, describes the procedures for the replacement of the pin and sleeve in its Maintenance Manual. The procedure requires the replacement of only one pin and sleeve set at a time, leaving the other three installed while removing it. With normal levels of wear this is sufficient to keep the attachment being worked on fixed in the correct position. In this case, with

abnormal wear in all four positions, the vertical stabiliser would have had to be unloaded and its weight taken off the mounts to ensure that it was in the correct position. Maintenance records did not reveal any details as to how the work had been carried out, but there is reason to believe that the stabiliser was not unloaded. If this is the case, with the stabiliser attachment sagging in relation to the fuselage attachment, the holes would not have been concentric and there would have been problems measuring the actual diameters of the holes with the steel bushings installed. The fact that the holes were not concentric would also make it difficult to install the new pin and sleeve correctly.

The actual degree of wear in the replaced parts cannot be determined, as the parts were scrapped before the accident. If one should judge from the wear found on the identical installation in the rear left-hand side subsequent to the accident, where there were supposedly no evident outward signs of wear at the time of inspection, the actual wear on the right-hand side must have been considerable. Regardless of the degree of wear, it must be considered a departure from correct aviation maintenance standards to replace only one of four identical components in a vital structural system where abnormal conditions occur. The investigation clearly demonstrated the importance of this fact. Replacement of one pin/sleeve set resulted in a change in the structural rigidity. This, in turn, changed the natural frequency of the system of which the vertical stabiliser and its attachments were a part.

At that point the pins and sleeves had only been used during approximately 10% of maximum operating time.

The replacement of one pin and sleeve set changed the vibration pattern in the empennage. On the flights immediately following maintenance it appeared to be an improvement, registering vibrations on the FDR foil on only 1 in 9 flights. On subsequent flights, however, this

development took a serious turn for the worse. These same vibrations were registered on 15 of the final 24 flights. This seems to indicate that the replacement of one pin/sleeve set actually aggravated the situation by changing the natural frequency of the stabiliser.

Apparently there was no reaction to the fact that the maintenance documentation still did not cover the inspection of the APU positioned in the tail section.

2.8.4 Information gathered from maintenance records from the final few days before the accident took place indicates certain departures from established routines. These routines included: the apportioning of responsibility and communication to the operator, PAS and to the maintenance organisation, FOF; preparation of aircraft for flight; and the reporting of malfunctions in incoming aircraft. During the final few days before the accident took place the LN-PAA's scheduled flight programme had a negative effect on its maintenance programme. PAS' strong desire to complete as many flights as possible resulted in a delay in the correction of reported faults. The reason for this may have been the operator's critical financial situation.

2.9 The fact that the aircraft crashed without having been affected by either external conditions or operation outside its normal flight envelope, must give rise to questions regarding the aircraft's airworthiness. This made it necessary for the AAIB/N to evaluate at what stage the aircraft was no longer airworthy and the reason for this.

2.9.1.1 When PAS applied for a Norwegian Certificate of Airworthiness for LN-PAA, the aircraft and its documentation were subject to an acceptance inspection by the CAA/N. One element in this acceptance procedure was the Canadian Certificate of Airworthiness which was proof of airworthiness. The Canadian Certificate of Airworthiness was issued on May 15, 1986, and was validated by the CAA/N the following day, with a validity period of 30 days.

2.9.1.2 Since Norway and Canada do not have a mutual agreement to accept each other's Certificates of Airworthiness, the basis for such acceptance must be found in other circumstances. These circumstances are, in particular, that both nations have ratified the Chicago Convention and that both have similar legal requirements regarding airworthiness.

2.9.1.3. It is thus clear that the formal basis for airworthiness was the Canadian Certificate of Airworthiness with which the aircraft was approved for operations in Norway. It is also evident that the Canadian authorities based their acceptance on an application from the owner, Kelowna Flightcraft. The application should have included, among other requirements, a maintenance document.

The maintenance carried out was based on maintenance instructions provided by PAS. These instructions had not been updated to include LN-PAA's current configuration.

Based on these facts it is questionable whether the Canadian authorities would have been led to issue the Certificate of Airworthiness on an unsound basis.

2.9.1.4 The decision to accept the aircraft in spite of the malfunction in the left-hand A/C generator system on September 8, 1989, was based on a review of the MEL for this aircraft type. The review concluded that the aircraft would be airworthy with the APU in continous operation and the APU A/C generator supplying power to the left-hand main A/C system. The fact that the MEL had not been updated, and thus did not take into consideration that LN-PAA had a third A/C generator, raised questions after the accident about this interpretation of the MEL and about the legality of this decision.

Since it is not clear how the MEL would have been written had it been updated, the legality of the decision to issue

a maintenance release is hypothetical. What is clear, however, is that the MEL is considered to be a formal requirement of airworthiness. Based on these facts, it is unacceptable for an aircraft to be in service for more than three years with a MEL which does not correspond to its actual configuration.

Regulations and requirements for setting up and maintaining a MEL system are given in Norwegian Civil Aviation Regulations (BSL D) which indicates that the authorities view the MEL primarily as an operational requirement. The MEL must necessarily include a considerable element of technical and maintenance-related considerations. BSL D directs the Flight Operations Manager to cooperate with the Maintenance Manager in setting up a MEL system. The maintenance agreement between PAS and FOF did not include a MEL. The AAIB/N felt it was unfortunate that FOF, who was responsible for the maintenance of this aircraft, was not involved in the work on the MEL system.

The authorities responsible for supervision of operators and operations may be criticised for their handling and acceptance of PAS' MEL system.

2.9.1.5 The Flight Manual is considered to be an airworthiness requirement. The FM on board LN-PAA was not recovered. Copies provided by the operator after the accident had not been updated to include the current configuration of all the systems on LN-PAA.

The AAIB/N was informed that the FM on board LN-PAA contained additional pages with relevant descriptions of components and systems, including the STC for the APU installation.

With regard to documentation, it would have been beneficial to have a requirement for the operator to keep an identical copy of the on-board FM on file. This would have made it possible to determine whether or not the crew had been

issued adequate operating instructions.

2.9.2 The installation of vital components which did not comply with the manufacturer's specifications led to loss of airworthiness. The pins and sleeves installed in the attachments on the vertical fin in 1986 did not satisfy the requirements on which the manufacturer based his calculation of structural integrity. The APU's front support did not satisfy airworthiness requirements. All this leads to the conclusion that the aircraft was not airworthy after May 1986.

2.9.3 For the period LN-PAA was in service in Norway, which was over three years, responsibility for its maintenance was split between PAS (the operator) and FOF (the maintenance organisation), both of which were under the supervision of the CAA/N. The AAIB/N has considered the possibility that the working relationship between the three organisations could have played an important part in the aircraft's state of maintenance deteriorating to a point where it caused an accident.

The operator is responsible for operations, which includes maintenance. In this case the operator had contracted the responsibility for maintenance out to FOF, which was approved by the CAA/N. After the accident it was revealed that the parties involved had differing opinions on how responsibility had been administered. Owing to lack of capacity FOF was forced to sub-contract maintenance work out to KFC, which was also approved by the CAA/N.

On the whole, this situation gives a picture of an arrangement in which heavy demands were made on planning, administration, communication and control.

Assessment of these circumstances leads one to the conclusion that in order to have aircraft with the same status as LN-PAA operating safely, responsibility, resources and information should not be split up and given

to several parties.

An extra effort is also required on the part of the authorities to improve regulations and provide more vigilant supervision.

It was the opinion of the AAIB/N that in this case there was a clear connection between factors which did not individually cause the accident but which together led to catastrophe through mutual influence and the accumulated effect of this.

2.9.4 The AAIB/N is also of the opinion that discrepancies and ambiguities in the regulations stipulated by the CAA/N have a greater effect on aircraft which have undergone extensive modification, such as LN-PAA, than on other aircraft, and where the aircraft no longer conforms to its initial type acceptance. The AAIB/N also considers regulations are not sufficiently stringent in vital areas such as acceptance inspections which, in this case, had a negative effect on the maintenance instructions, the MEL system and the FM.

2.9.7 During the investigation the AAIB/N reported to the CAA/N on all findings of importance with regard to air safety. The operator is no longer in business, and aircraft of this type are no longer operated by any Norwegian airline.

To satisfy both the national and international interests of flight safety, all recommendations will be submitted to the CAA/N.

3 CONCLUSIONS

3.1 FINDINGS

a. The crew members were properly licensed, medically fit and qualified to conduct the flight.

b. LN-PAA was first listed in the Norwegian register on May 30, 1986. The Certificate of Airworthiness was last renewed on May 22, 1989, was valid until May 31, 1990.

c. Maintenance instructions in use for LN-PAA did not reflect the current aircraft configuration (causal factor).

d. The operator's MEL system for CV 340/580 was not adjusted to reflect the actual configuration of LN-PAA.

e. The Flight Operations Manager decided that the aircraft could be operated with the APU generator used as a substitute for the inoperative left-hand main A/C generator.

f. The Pilot-in-Command accepted the responsibility of operating the aircraft with the APU generator used as a substitute for the inoperative left-hand main A/C generator prior to departure.

g. The CVR became inoperative after an upshift in the engine rpm prior to departure.

h. The FDR registered three out of the four parameters (pressure altitude, heading and airspeed). It also registered that it was subject to vibrational forces from external sources.

i. The events were not influenced by other activities or traffic in the air.

j. The events were not influenced by weather conditions.

k. The events were not influenced by military activity.

l. The flight was not the subject of sabotage.

m. The aircraft's propellers and engines were operating normally.

n. All horizontal tail surfaces and the rudder were subject to violent oscillations or flutter.

o. Vital parts of the tail structure failed and caused loss of control of the aircraft (causal factor).

p. The flight crew did not identify the problems in time to take corrective action.

q. The wings failed symmetrically under negative G load.

r. While the aircraft was still at high altitude sheets of honeycomb from the shroud doors between the fin and rudder were released and fell slowly into the water. This was the source of the radar echo observed by Swedish defence radar stations and the approach radar at Aalborg Airport.

s. The vertical stabiliser was attached to the fuselage with pins and sleeves which did not comply with the specified values for hardness and tensile strength, and were therefore not airworthy (causal factor).

t. The abnormal wear which had developed in the vertical fin attachments was not disclosed (causal factor).

u. The wear in the fin attachments led to vibrations developing into flutter (causal factor).

v. Undampened oscillations in the elevator contributed to the destruction of the empennage (causal factor).

w. The APU was installed with a front support of inferior quality and unknown origin (causal factor).

x. Faulty, out-of-date maintenance instructions and inadequate maintenance procedures left the problems in the APU's front support undetected (causal factor).

y. The airworthiness of the aircraft at the time it was transferred to Norway was based on the Canadian Certificate of Airworthiness. Owing to the fact that the maintenance instructions were incomplete, the basis on which this Certificate of Airworthiness was issued may have been unsound.

z. The airworthiness requirements for the aircraft were not met while it was in service in Norway as the MEL and maintenance instructions had not been updated to include systems and components currently installed in the aircraft.

aa. PAS had financial problems at the time of the accident and filed for bankruptcy shortly after the accident.

3.2 CAUSES

The accident was caused by loss of control due to the destruction of primary control surfaces in the tail section, which, in turn, was caused by aeroelastic oscillations initiated by abnormal clearances in the vertical stabiliser attachments to the fuselage structure. The condition of the attachments was a result of excessive wear in pins and sleeves used in this structural joint. The pins and sleeves were of an inferior quality and did not satisfy specified values for hardness and tensile strength. They had also been installed and inspected using sub-standard maintenance procedures. Undamped oscillations in the elevator contributed to the structural failure of the empennage.

The vibratory patterns in the empennage and the oscillations in the surfaces were affected by the fact that the APU was operating with a faulty front support which was of a non-standard design and of unknown origin.

(ref. causal factors para 3.1)

4. SAFETY RECOMMENDATIONS

GENERAL

The investigation revealed findings judged by the AAIB/N to be of importance in operating this type of aircraft safely and in accordance with regulations. In order to give the CAA/N, operators of similar types of aircraft and foreign aviation authorities the opportunity of taking appropriate action without delay, the following findings were reported:

- State of fuselage repairs (structural repairs)
- Damaged inner R/H elevator hinge
- Faulty APU front support
- Deviation from specifications for pins and sleeves in vertical fin installations
- Malfunction of CVR power supply

The AAIB/N has been informed that preventive flight safety measures have been introduced and hence, further recommendations related to these subjects should not be necessary.

The cause of the accident leads one to the conclusion that documented traceability is of importance in establishing the airworthiness of aircraft parts. JAR 21 "Certification Procedures for Aircraft and related Products and Parts" deals with this subject. JAR 21 is expected to be issued in the spring/summer of 1993. In addition to JAR 21, the JAA is working on regulations governing the manufacture of substitute parts by maintenance organisations. The regulations will be included in "JAA Maintenance Temporary Guidance", which is a supplement to JAR 145.

Based on the facts stated above, the AAIB/N finds it unnecessary to forward any recommendations on this subject.

PAS had financial problems at the time of the accident and

filed for bankruptcy shortly thereafter. The AAIB/N considers it important for aviation authorities to include financial considerations in their assessment of an operator's ability to operate safely. It is a possibility that financial instability may have a negative effect on flight safety.

Since the ECAC includes the operator's financial situation on its check list and the CAA/N, having assessed the situation, takes this point into consideration, the AAIB/N considers it unnecessary to forward any recommendation in this regard.

4.1 The AAIB/N recommends that the CAA/N considers adjusting the existing supervisory system to improve its ability to deal with aircraft requiring special attention.

Old aircraft and aircraft with a high number of operating hours may not necessarily require special attention if they have been properly maintained. Other decisive factors, over and above old age and a large number of operating hours, which may require special attention are:

- the aircraft has been operated and/or maintained by several owners and maintenance organisations with various operational arrangements

- the aircraft has been subject to a number of extensive modifications

- the aircraft has been in service in a corrosive environment

Included in this recommendation is a requirement for aviation authorities to follow up the introduction of a mandatory quality assurance system.

4.2 This investigation has revealed a history of vibration problems in the empennage on this type of aircraft which

was not known to all operators. In other cases it has been found that important information did not reach all those operators to which the information applied. The AAIB/N recommends that the CAA/N reviews the requirement for new operators to obtain access to an aircraft's operations and maintenance history. This requirement should apply when primary acceptance inspections are being carried out.

4.3 The AAIB/N recommends that the CAA/N considers establishing a requirement for operators to keep an updated "Master Flight Manual" at the aircraft's home base.

5. APPENDICES

1. Abbreviations
2. FDR print-out, in extenso
3. FDR print-out, final 9 minutes of accident flight
4. FDR print-out with four "event marks", last 7 seconds of accident flight

AIRCRAFT ACCIDENT INVESTIGATION BOARD/NORWAY

Fornebu, February 12, 1993

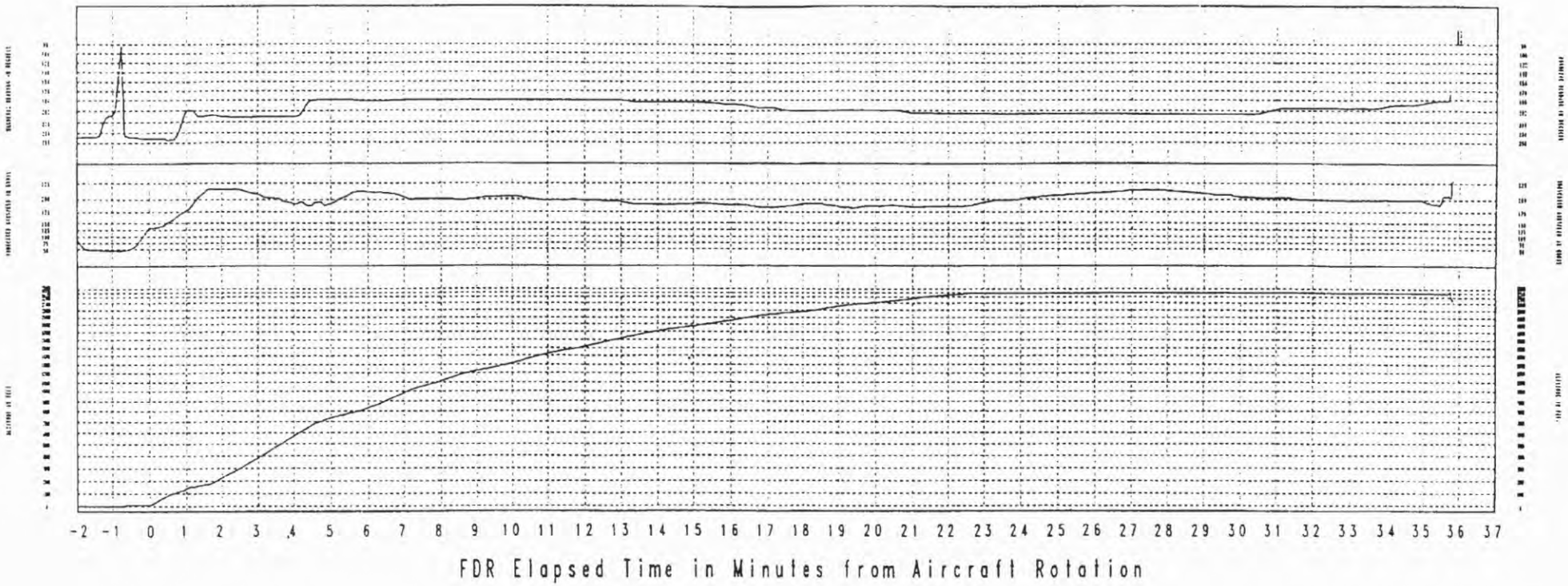
APPLICABLE ABBREVIATIONS

AAIB	Air Accidents Investigation Branch (UK)
AAIB/N	Aircraft Accident Investigation Board/Norway
AC	Alternating Current
ACC	Area Control Centre
ADF	Automatic Direction Finder
AD note	Airworthiness Directive
AFM	Aeroplane (Aircraft) Flight Manual
AIR	Accident Investigation & Research Inc
APP	Approach Control Office
APU	Auxiliary Power Unit
ATA	Air Transport Association (of America)
ATC	Air Traffic Control
ATS	Air Traffic Services
AWACS	Airborne Warning and Control Station
BOP	Block Overhaul Period
BSL	Bestemmelser for Sivil Luftfart (Norwegian Civil Aviation Regulations)
CAA/N	Civil Aviation Administration, Norway
CV	Convair
CVR	Cockpit Voice Recorder
DC	Direct Current
DI	Daily Inspection
DME	Distance Measurement Equipment
ECAC	European Civil Aviation Conference
EST	Estimate(d)
ETO	Estimated Time Over (significant point)
FAA	Federal Aviation Administration (USA)
FAR	Federal Aviation Regulations
FDR	Flight Data Recorder
FIR	Flight Information Region
FL	Flight Level
FM	Flight Manual
FOF	A/S Fred. Olsens Flyselskap (Fred Olsen Air Transport Ltd)
FOM	Flight Operations Manual
FPL	Filed Flight Plan

FT	Feet
G	Unit of acceleration of Gravitational force
GDCV	General Dynamics, Convair Division
GMC	General Motors Corporation
GPWS	Ground Proximity Warning System
GS	Ground Speed, or Glide Slope
GTC	Gas Turbine Compressor
HF	High Frequency
Hg	Mercury
HP	Horse Power
hPa	Hectopascal
HV5	Vickers Hardness, 5 kiloponds
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IR	Infrared
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
KFC	Kelowna Flightcraft Ltd
KM	Kilometer
LOC	Localiser
°M	Degrees Magnetic
MEL	Minimum Equipment List
METAR	Meteorological Aerodrome Report
MO	Major Overhaul
NATO	North Atlantic Treaty Organisation
NDB	Nor Directional Beacon
n	nautical
NTSB	National Transportation Safety Board (USA)
PAR	Partnair's 3-letter operational designator
PAS	Partnair A/S
PFT	Periodic Flight Training
P/N	Part Number
psi	pounds per square inch
QNH	Altimeter sub-scale setting
RFC	Radio Facility Chart
RNoAF	Royal Norwegian Air Force
SAS	Scandinavian Airlines System
SB	Service Bulletin

SI	Service Inspection
SID	Supplemental Inspection Document
SL	Service Letter
S/N	Serial Number
STA	Station
STC	Supplemental Type Certficate
TAF	Terminal Aerodrome Forecast
TAS	True AirSpeed
TAT	Total Aircraft Time
TBO	Time Between Overhaul
TC	Type Certificate
TIT	Turbine Inlet Temperature
TMA	TerMinal control Area
TSO	Time Since Overhaul
TWR	Aerodrome Control Tower
UTA	Upper Control Area
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirectional radio Range

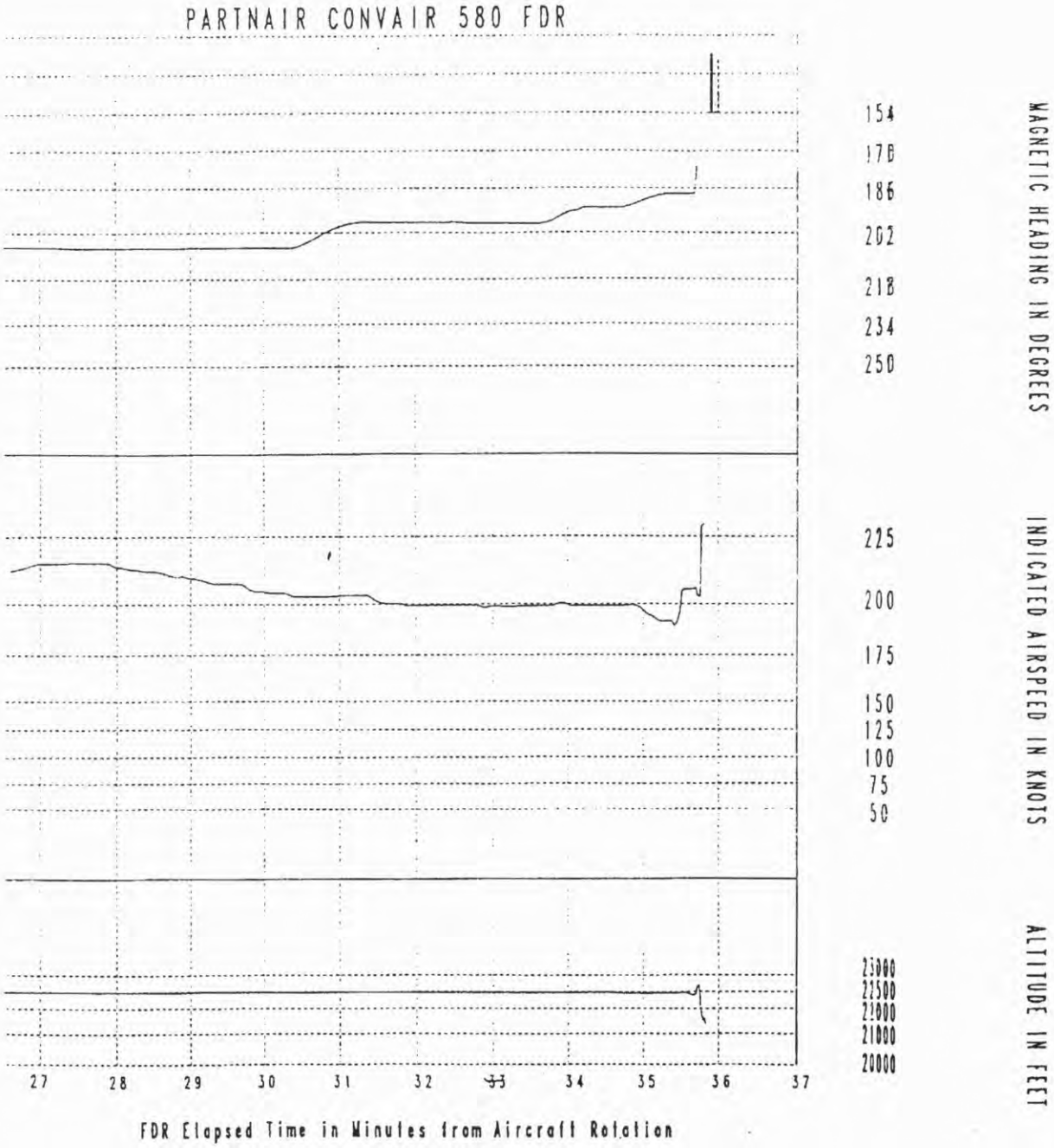
PARTNAIR CONVAIR 580 FDR



Complete FDR Readout for the accident flight, Convair 580, LN-PAA.

APPENDIX 2
(BILAG)

ACCIDENT INVESTIGATION AND RESEARCH

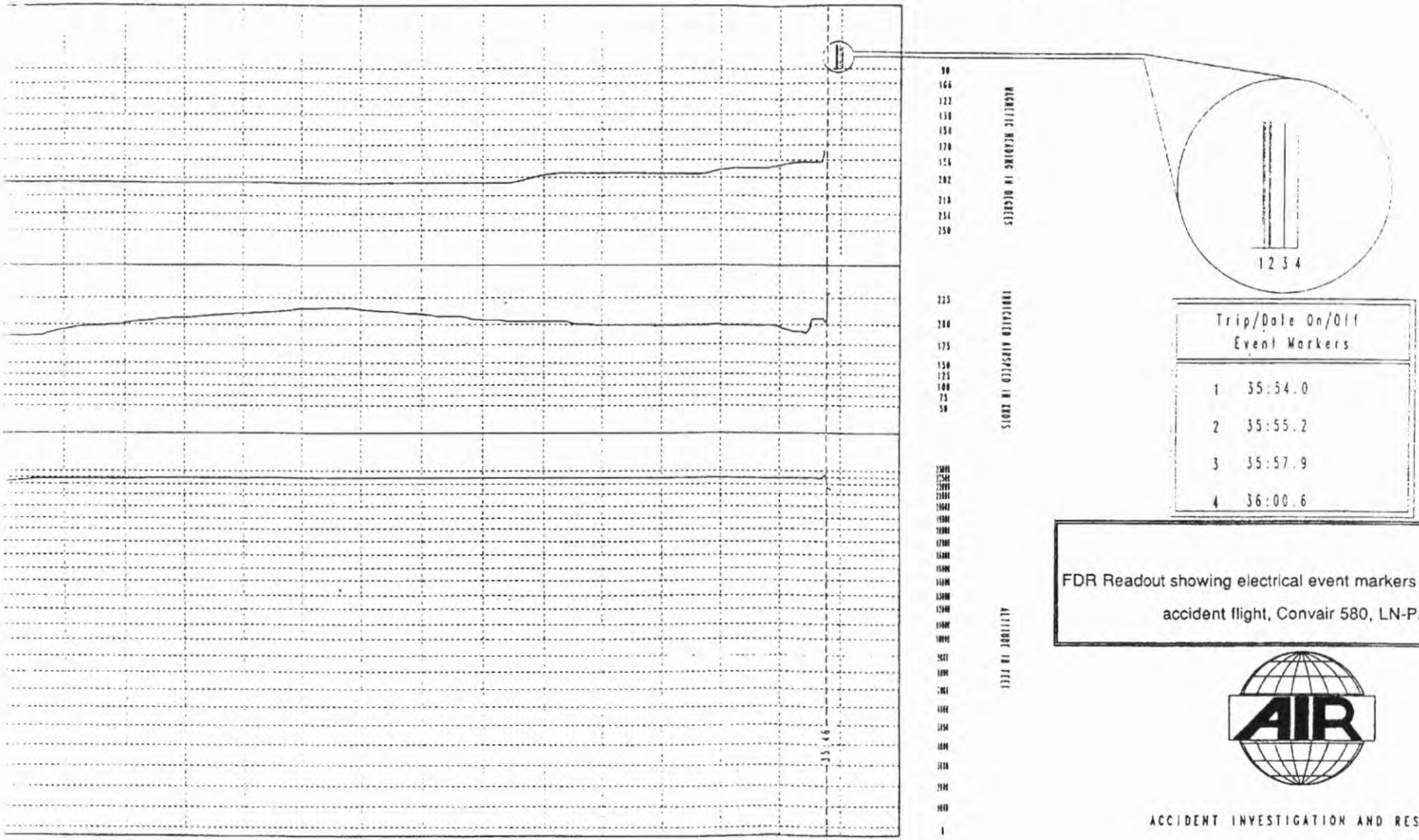


ACCIDENT INVESTIGATION AND RESEARCH

FDR Readout data for the last 9 minutes of the accident flight, Convair 580, LN-PAA.

APPENDIX 3 (BILAG)

PARTNAIR CONVAIR 580 FDR



Trip/Date On/Off Event Markers	
1	35:54.0
2	35:55.2
3	35:57.9
4	36:00.6

FDR Readout showing electrical event markers at the end of the accident flight, Convair 580, LN-PAA.

AIR

ACCIDENT INVESTIGATION AND RESEARCH

23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

FDR Elapsed Time in Minutes from Aircraft Rotation

APPENDIX 4
(BILAG)