RVDL 93-01

RAAD VOOR DE LUCHTVAART

Netherlands Aviation
Safety Board

AIRCRAFT ACCIDENT REPORT
93-01

THIS REPORT CONTAINS THE VIEWS OF THE
NETHERLANDS AVIATION SAFETY BOARD ON
THE ACCIDENT TO:

PALAIR FLIGHT PMK301,
FOKKER 100, PH-KXL,
SKOPJE, REPUBLIC OF MACEDONIA
MARCH 5, 1993

Ministerie van Verkeer en Waterstaat
Luchtvaartinspectie Bibliotheek

Reference: Final Report dated May 1993 published January 1996, of the Aircraft Accident Investigation Commission of the former Federal Republic of Yugoslavia.

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LIST OF APPENDIXES

- LIST OF ABBREVIATIONS -

AD	Airworthiness Directive
AFCAS	Automatic Flight Control and Augmentation System (NAV and PROF modes = Navigation and Profile modes)
AFM	Airplane Flight Manual
AFT	Aircraft Financing and Trading B.V.
AFTAS	AFT Aviation Services
AIIB	Accident and Incident Investigation Bureau of the NASB
AND	Aircraft Nose Down
ANU	Aircraft Nose Up
AOA	Angle Of Attack
AOC	Air Operator Certificate
AOM	Aircraft Operating Manual
APU	Auxiliary Power Unit
ATC	Air Traffic Control
BOM	Basic Operating Manual
C	Celsius
CT	Collector Tank
CVR	Cockpit Voice Recorder
DDG	Dispatch Deficiency Guide
DFDR	Digital Flight Data Recorder
EFIS	Electronic Flight Instrument System
F	Fahrenheit
FCC	Flight Control Computer
FD	Flight Director
FMS	Flight Management System
FOCA	Federal Office for Civil Aviation of Switzerland
FSE	(Swissair) Flying Station Engineer
GPWS	Ground Proximity Warning System
ICAO	International Civil Aviation Organization
IRS	Inertial Reference System
LH	Left Hand
LT	Local Time
M	Magnetic
MEL	Minimum Equipment List
METAR	Meteorological Aviation Routine Weather Report
MLG	Main Landing Gear
MPC	Maintenance Preflight Check
MT	Main Tank Compartment
N1	Low Pressure Rotor RPM
NASB	Netherlands Aviation Safety Board
NLG	Nose Landing Gear
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
PF	Pilot Flying
PFD	Primary Flight Display
PNF	Pilot Not Flying

QNH	Sea Level Atmosphere Pressure
RH	Right Hand
RLD	Rijksluchtvaartdienst (= Civil Aviation Authority of the Netherlands)
SAIC	State Accident Investigation Commission
SAT	Static Air Temperature
SNOWTAM	Snow NOTAM
SOP	Standard Operating Procedures
SPC	Special Check
TAF	Terminal Aerodrome Forecast
TAT	Total Air Temperature
TOW	Take Off Weight
UTC	Coordinated Universal Time
VOR	VHF Omnidirectional Radio Range
WS	Wing Station
α	Angle of Attack
C_L	Liftcoefficient
C_{Lmax}	Maximum Liftcoefficient
V_1	Take off Decision Speed
V_2	Safety Speed
V_{FR}	Minimum Flap Retraction Speed
V_R	Rotation Speed
V_{stall}	Stall Speed

SYNOPSIS

On March 5, 1993, Palair Flight PMK301, a Fokker 100 with registration PH-KXL, crashed shortly after taking-off from Skopje Airport, Republic of Macedonia, for a scheduled passenger flight to Zürich, Switzerland. Seventy-nine passengers and four crewmembers were fatally injured and thirteen passengers and one cabin crew member survived. The aircraft was destroyed by impact and fire. The weather conditions at the time of the accident were: visibility 1,000 meters in snow, temperature 0°C, dewpoint -1°C.

The accident was caused by loss of roll controllability due to contamination of the wings with ice. This situation resulted from an omission to carry out spraying of the aircraft with deicing or anti-icing fluid in meteorological conditions conducive to icing, due to a lack of ice-awareness of the flight crew and the Flying Station Engineer. Contributing factors were a lack of common background and procedures in a difficult multi-sources operational environment.

Safety issues addressed in the report include:

- Airline operating instructions as regards criteria for anti-icing as well as de-icing, taking into account variability of contamination conditions at temperatures around the freezing level, the presence of cold-soaked fuel and local effects of warmer fresh fuel depending on the aircraft fuel systems;
- flight simulator training to increase pilot awareness of how aircraft behaviour could be affected by wing contamination, with a view to early recognition and prevention;
- special attention for procedural consistency with start-up or lease operations that involve contracting of airline functions from multiple external sources.

Six safety recommendations are presented.

PREAMBLE

Immediately after the accident the Macedonian Government appointed a State Accident Investigation Commission (SAIC), chaired by the head of the Accident Investigation Department of the Ministry of Transport and Communications of the Federal Republic of Yugoslavia from Belgrade. The Kingdom of the Netherlands, being State of Registry and State of Manufacture, appointed an Accredited Representative who travelled to Skopje accompanied by a team of experts and advisors and participated in the investigation according to ICAO Annex 13. Representatives from the engine manufacturer Rolls Royce and from Swissair also assisted in the investigation.

The aircraft recorders DFDR and CVR were processed by the Bureau Enquêtes Accidents in Paris, France. At the closing of a collaborative on site investigation phase it was agreed that the DFDR and CVR data would be available to Fokker Aircraft B.V. (Fokker), to analyse the take off and to investigate the possible effects of wing contamination on the flight and handling characteristics. It was also agreed that Fokker would, based on previous research, present the results in the form of a flight simulator data model and demonstrate it to the SAIC in Fokkers engineering flight simulator. It was anticipated that this work would take some months to complete.

During this investigation phase it appeared that fuel temperature distribution effects associated with the particular way of flight preparation in this case could play an important role in the distribution of frozen contamination. On-aircraft testing was considered necessary to quantify the fuel temperature distribution resulting from adding small quantities of relatively warm fuel to a large amount of cold soaked fuel remaining from the previous flight. Also additional windtunnel model testing was done to investigate the aerodynamic effects of particular types of frozen contamination accumulated on cold fuel tanks and adjacent wing structure.

Furthermore, as the flight analysis showed the primary reason for the accident to be loss of roll controllability, it was considered necessary to develop an addition to the flight simulation software to represent the drastical changes to roll damping resulting from airflow separation ahead of the ailerons. Whilst this took considerably more effort than initially anticipated, most of it was ready for review by October 1993, it appeared extremely difficult to communicate with either Skopje or Belgrade on the progress and results.

Meanwhile the Accident and Incident Investigation Bureau (AIIB) of the Netherlands Aviation Safety Board (NASB) had conducted an inquiry among RLD, Fokker and AFT, addressing important aspects of the organization of the operation at Palair, supervision by the RLD and aircraft technical and operational characteristics, particularly in relation to operation in ground icing conditions. The results of this contribution to the investigation were made available to the SAIC in Skopje in September 1993.

Responding to media reports that the Chairman of the SAIC considered the investigation completed, apparently without taking any of the above into account, a meeting was arranged in Skopje in December 1993 with the Swiss and the Netherlands Accredited Representatives. During this meeting a Final Report was presented that had been produced by the Aircraft Accident Investigation Commission of the Federal Republic of Yugoslavia, dated May 1993, and had apparently been adopted by the Macedonian SAIC. The Accredited Representatives were requested to agree or to give the final comments of the delegations on that same day. In view of substantial disagreement and after explicit objection, the Netherlands being State of Registry as well as State of Manufacture was given the 60 days period for comments according to the provisions of ICAO Annex 13.

During a following work-meeting in January 1994 at the Netherlands Aviation Safety Board and AIIB in Hoofddorp, the Netherlands, with representatives of the Macedonian Directorate General of Civil Aviation (DGCA) and of Swissair, Fokker and AFT, the Netherlands' comments were presented and discussed. Because these comments would imply a timeconsuming redraft of the Final Report, and there appeared to exist in the Republic of Macedonia an urge to conclude and release the results of the investigation, an intermediate solution was agreed upon. A summary of the investigation including conclusions and probable cause was to be released to the press. This was considered possible because there was agreement in principle on issues such as wing ice contamination being a basic cause and the need for de-/anti-icing in the given circumstances. However, disagreement existed as regards several technical aspects of the sequence of events.

Furthermore, the Final Report did not pay attention to organizational aspects of the operation at Palair, nor to human factors issues surrounding the decision making regarding de-icing, nor did it take into account important developments in North America and Europe in the fields of de- and anti-icing procedures and technology. Completion of the Final Report would be allowed some more time to include the lessons learned in these regards, to present substantial analysis to support appropriate recommendations and to awaite the results of further testing and research by Fokker. The agreed summary was released to the press in Skopje in February 1994.
In the January 1994 work-meeting the results of the aerodynamic analysis were reported by Fokker to the Macedonian DGCA (representing the SAIC furtheron), and the reconstruction of the accident flight as well as prevention techniques were demonstrated in Fokkers Engineering Flight Simulator.

Because of the much wider scope of the Netherlands' position in this investigation than reflected in the (draft) Final Report, it was decided to present the Netherlands' comments in the form and format of a complete proposed report, while retaining as much of the original Final Report as suitable. This result was presented to the Macedonian DGCA in November 1994 with a proposal to have a further work-meeting to agree on the form and logistics of publication of the report(s). The Macedonian DGCA was also requested to allow provision of the Netherlands' proposed report to the Swiss Accredited Representative for their comments, however, this request was denied because the DGCA wanted to study the proposed report before further distribution.

Upon inquiry by the NASB as regards the completion status of the disposal of the Netherlands' comments on the Final Report, the Macedonian DGCA responded in January 1996 in writing that the (original) Report of May 1993 had now been formally adopted by the Republic of Macedonia and would be filed with ICAO shortly and should be considered as the Final Report, also suggesting that the Netherlands' report be published separately. The NASB considers that important information found in this investigation and included in the Netherlands' proposed report does warrant separate publication, but regrets the delay incurred.

This report contains the views of the Netherlands Aviation Safety Board presented as an (extensive) amendment to the May 1993 Report and essentially describes the status as of October 1994. It has been updated only to include comments from interested parties such as the Swiss Accident Investigation Board, Swissair, RLD and Fokker.

1 FACTUAL INFORMATION

1.1 History of the flight

[All times in this report are UTC unless otherwise stated]

On March 5, 1993 a Fokker 100, registration PH-KXL, operating as Palair 301 (PMK 301), crashed shortly after take off from runway 34 at Skopje Airport, Republic of Macedonia. The aircraft was on a scheduled flight from Skopje to Zürich and was flown by the company AFT from The Netherlands (Aircraft Financing and Trading B.V.) on the basis of a lease contract with the Macedonian airline company Palair Macedonian.

Palair Macedonian is an airline which operates scheduled and charter flights on the basis of a Macedonian Air Operator Certificate (AOC no. 13-207/2) and a Yugoslavian AOC. AFT is a company jointly owned by the N.V. Koninklijke Nederlandse Vliegtuigenfabriek Fokker and Rolls Royce and Partners Finance Ltd.

The AFT operation for Palair started in January 1993 with one Fokker 100 aircraft. Palair contracted AFT to operate some of their flights on a lease contract. The contract also incorporated crew training and ground support by AFTAS (AFT Aviation Services), a department of AFT. AFTAS provided route training captains, while Palair provided the first officer or candidate Palair captain and the cabin crew. The technical maintenance of the Fokker 100 was carried out by Swissair via a contract with Palair. Therefore a licensed Swissair Flying Station Engineer (FSE) accompanied the flights to stations other than Zürich, which is the home base of Swissair and was the maintenance base of the aircraft.

The aircraft arrived on a scheduled flight from Frankfurt to Skopje at 09:40 with 35 minutes delay and two maintenance complaints. One of the complaints was a flap position computer malfunction. The other complaint was a Ground Proximity Warning System (GPWS) fault. Both faults were written up in the technical log.

The aircraft was scheduled for departure to Zürich on 10:50. Enroute on the flight from Frankfurt, the incoming crew anticipated that the return flight to Zürich would violate the Work and Rest times Regulations and requested to be relieved. This was approved by the Director Flight Operations of AFTAS. He decided to make the flight to Zürich himself as a training captain and use the occasion to check the training progress of one of Palair's candidate captains.

The crew from the incoming flight went straight to the hotel. The FSE, who was on board on the incoming flight, stayed with the aircraft and performed the maintenance transit check and the exterior inspection for the next flight. From 09:55 - 10:00 the aircraft was initially refuelled with 2,000 litres of JP1 fuel to a company standard total amount of 6,803 kilogram (15,000 pounds).

The new crew arrived at Skopje Airport at approximately 10:30 and they went straight to the aircraft. It was snowing lightly. The temperature was 0° Celsius, dewpoint -1° Celsius.

Pilot A, the Director Flight Operations of AFTAS, was the pilot-in-command and was sitting in the right seat. He performed the first officer duties and was the pilot not flying (PNF). He was also giving route-instruction. Pilot B was the captain-under-training and was sitting in the left seat. He was acting captain and was pilot flying (PF), receiving route-training.

Upon arrival at Skopje airport, the AFT-dispatch officer from The Netherlands - who drove the new crew to the airport - proceeded directly to the meteo office on request of pilot A, to get the weather briefing for the flight crew. The dispatch officer stated that, upon arrival in the cockpit, pilot A specifically instructed him to brief pilot B - because he was the acting captain receiving route-training - about the weather enroute and on destination Zürich. Because of the weather, pilot A decided to add an additional 907 kg (2,000 pounds) of fuel, making the total amount of 7,711 kg (17,000 pounds) of fuel. According to the fuel slip, refuelling for the second time was performed between 10:35 - 10:45.

The dispatch officer stated that before he embarked to do the briefing to the flight crew, he looked for the presence of ice and snow on the wing leading edges. He felt by hand on both wing leading edges and confirmed for himself that both wing leading edges were not contaminated with ice or snow, but were only wet of melted snow.

With the new crew on board, the FSE performed the walk around and was accompanied by three Palair ground handling crewmembers. The ground handling crewmembers stated that the FSE performed a so called "tactile check" by hand on the right wing leading edge and in addition he looked over the right wing briefly, while standing on a baggage cart in front of the inner wing. Both actions were repeated by one of the ground handling crew. They stated that the leading edge was clean and some melted snow was noticed on the right wing. Furthermore the ground handling crewmembers stated that they had a brief discussion with the FSE about the weather and asked if the aircraft needed deicing. To support the question one of the ground handling members collected with one stroke of his hand a handful of snow from the right wing inner flap and showed it to the FSE, who in turn replied that deicing was not necessary and that any deposit would blow off the wing during take off.

One ground handling crewmember stated further, that during the abovementioned conversation, he walked from behind the right wing, under the belly, to the left wing and determined that a similar amount of snow was lying on the left inner flap. He estimated the thickness of the snow on both inner flaps to be approximately 5 millimetres. He also checked the bottom surfaces of both wings for contamination, which was a thin layer of frost and estimated the thickness of the contamination by touching with his thumbnail to be less than 1 millimetre.

After the dispatch officer disembarked the aircraft he went to the groundhandling office to report about the 2,000 pounds extra fuel and the weight of the baggage. The loadsheet was prepared by the airport handling agent and included 2 flight crewmembers and 3 cabin crew, 91 passengers and standard 15,000 pounds fuel. The handling agent changed the loadsheet accordingly for the extra fuel, to 17,000 pounds. At approximately 11:00 she went outside to the aircraft. She stated she gave the loadsheet to pilot B (PF and acting captain) to check. He corrected the take off weight and the landing weight, as a miscalculation by the handling agent had taken place. He did not correct the loadsheet for the weight of the FSE who was to make the flight sitting between the pilots on the cockpit observer seat.

The total time the aircraft remained on the ground at Skopje Airport was about 1 hour 35 minutes. At 11:02 the PNF contacted Skopje Tower and requested start-up clearance. At first he used the flightnumber 303 instead of 301, which gave some misunderstanding with the tower controller. At 11.05 start-up was approved but with the flight-number Palair 301.

While working on the after start checklist the PF selected engine anti-ice on, ignition to automatic, flaps were set at 8°. At 11:06 taxi clearance was requested and Palair 301 was approved to taxi to holding point runway 34. During taxying the airway clearance was given to Palair 301 and the aircraft was cleared to line up and hold on runway 34, which was acknowledged. When arming the Automatic Flight Control and Augmentation System (AFCAS) NAV and PROF mode, an aural alert was generated, because of the flap position computer failure, which generated a speed limit flag on the left hand Primary Flight Display (PFD). After lining up, both pilots briefly discussed the presence of the speed limit flag. After selection of the left Flight Control Computer (FCC) to alternate, the speed limit flag had disappeared from the left PFD.

In the meantime the radar controller from Skopje Approach asked the tower controller to give Palair 301 a reclearance and to hold the aircraft due to an aircraft flying inbound Skopje VOR. The reclearance was confirmed by Palair 301 and without knowing of the inbound aircraft the PNF said they needed one minute on the runway, which was approved. This time was needed to complete the Before Take Off checklist. The PF announced that they would use standard speeds V_1/V_R speed of 134 knots and V_{FR} speed of 146 knots, which were confirmed by the PNF.

During taxying of Palair flight 301 a YAK 42D from Vardar Air, which was standing on the apron, was de-iced with ARCTICA type I fluid. This was the first aircraft that day being de-iced. In the meantime the snowfall had increased to moderate. According to the Cockpit Voice Recorder (CVR), no discussion about the weather conditions took place by the pilots.

At 11:11 Palair 301 was cleared for take off, the wind was given as 010° with 3 knots. The tower controller stated that the visibility was 900 meters and it was snowing. She said she could not see the end of runway 34 from her position in the tower, because of the snow.

The CVR and the Digital Flight Data Recorder (DFDR) revealed that after the take off clearance was received, take off thrust was applied and 28 seconds elapsed until the PNF called: "V_1, rotate". The aircraft rotated normally and the PNF then called "positive", followed by the call "gear up" from the PF, which was confirmed by the PNF. Two seconds after lift off the aircraft experienced heavy vibrations followed by a sudden right bank to approximately 10°, immediately followed by approximately 50° left bank and 55° right bank in sequence within 2 seconds. The roll movements were counteracted by aileron and rudder input. The vibrations and the roll movements were confirmed by the cabin attendant, the only crewmember who survived the accident. Approximately 10 seconds before impact the PNF called "deselect" followed by sounds which were determined to be the auto pilot cavalry charge (twice) followed by the GPWS aural alert, "sink rate" (twice).

The aircraft's take off was seen by several witnesses, amongst others by the tower controller. She stated the aircraft took off normally at approximately 2/3 of the runway and disappeared in the snow. Another witness was a soldier on duty on a 10 meters high watch tower, located approximately 700 meters in Easterly direction perpendicular to the end of runway 34. He stated that he saw the aircraft taking off, while the aircraft was overflying the end of the runway at what he estimated as 30 meters high, he heard a loud noise and sensed at the same time a vibration which could be felt in the steel framework structure of the watch tower. He estimated the visibility to be about 1,000 meters and stated that it was snowing heavily. At 11:12 the tower controller instructed Palair 301 to contact Skopje Approach. No reply was received.

The aircraft right wingtip hit the ground 382 meters beyond the end of the runway with approximately 90° bank, the fuselage was more or less in a horizontal position. The right wing disintegrated towards the wing-fuselage attachment, followed by major impact of the fuselage, which broke up into three major parts, and the impact of the right engine and stabilizer. The right engine separated and subsequently impacted and penetrated the aft fuselage. The stabilizer and the upper part of the vertical tail plane also separated. Witnesses stated that explosions followed shortly after impact and several residual fires broke out on the debris.

Helicopter rescue started shortly after the crash as a United Nations (UNPROFOR) helicopter pilot, stationed at Skopje Airport, was alerted by the impact sound and offered his services. Fire fighting, police and hospital vehicles arrived soon after the first survivors were flown to the hospital.

The accident occurred at 11:12, under conditions of daylight. After the accident two other aircraft landed after which the airport was closed.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Other	Total
Fatal	4	79		83
Serious		13		13
Minor/None	1			1
Total	5	92		97

Table 1. Injuries to persons

Note: The FSE is included in this passengercount.

1.3 Damage to Aircraft

The aircraft was destroyed by impact forces and the ensuing fire.

1.4 Other Damage

At a location 414 meters from the end of runway 34 in the direction of the extended centerline, a barbed fence was cut and an area with crop of about 100 meters wide and 300 meters long was damaged as a result of the accident sequence and the subsequent rescue of victims and the recovery of the wreckage.

1.5 Personnel Information

1.5.1 General

Because both pilots held the rank of captain, distinction is made between the pilot-in-command (pilot A) being the AFT captain and the acting captain (pilot B) being the candidate Palair captain.

The pilot flying Palair flight 301 was sitting in the left seat and performed the captain's duties according to the AFT Standard Operating Procedures (SOP). He had completed his type training and both company and Macedonian licensing regulations required him to complete a minimum of 50 flight hours route training before he could be pilot-in-command on the AFT/Palair Fokker 100 operation. The Macedonian government had anticipated that as soon as the lease contract between AFT and Palair would end, the operation would be taken over by Palair. For that purpose the Macedonian government had taken over the AFT company requirement of 50 hours route-training, followed by a government examination, for the issue of a Macedonian licence.

The pilot-in-command of this flight was the route-instructor, in this case the Director of Flight Operations of AFT, and was the pilot not flying. He was sitting in the right seat and performed the first officer duties according to the AFT SOP. This flight was intended to be a progress checkflight for pilot B.

1.5.2 Flight Crew Information

Pilot A (Pilot-In-Command, Training Captain and Pilot Not Flying)

a. date of birth: 24-09-1943

b. nationality: Netherlands

c. profession: airline transport pilot employed by Fokker Aircraft B.V. and was contracted out to AFT in the function of Director Flight Operations.

d. last medical check: 12-10-1992
Result: qualified medical certificate for ATPL (B1)

e. licence: Netherlands ATPL (B1), no. 77-0020, first issue 20-10-1977 and valid until 01-10-1993. Date of last validation: 14-10-1992
The ratings on the licence were: Flight Instruction, Flight Radiotelephony, Cessna 500-series, Piper PA-31, Fokker F-27, Fokker 50, Fokker F-28, and Fokker 100.

f. total flying experience: 11,200 hours. On the Fokker 100: 1,180 hours, of which 54 hours in the last 3 preceding months.

g. additional information:
- holder was qualified for basic flight instruction since 13-05-1975 and was also allowed to give flight instruction on the Fokker 100.
- the last flight was on 04-03-1993 on the route Zürich - Skopje. After resting 24 hours he reported for duty on 05-03-1993.

Pilot B (Acting Captain and Pilot Flying)

a. date of birth: 24-09-1958

b. nationality: Macedonian

c. profession: airline transport pilot employed by Palair since 16-10-1992

d. last medical check: 18-01-1993
Result: qualified medical certificate for ATPL (B1)

e. licence:
- Netherlands ATPL (B1), no. 0070966, first issue 18-01-1993 and valid until 18-01-1994.
- Yugoslavian ATPL no. 681/6646, issued on 10-05-1989 and valid until 10-05-1993, with instrument rating for B737-300

f. total flying experience: 5,580 hours. On the Fokker 100: 65 hours total in the last preceding month.

g. additional information:
- during his previous career, holder was employed by JAT as a first officer on the DC-9 (10-11-1981), B727 (17-05-1985), and B737-300 (04-04-1990) and captain on the B737-300 since 12-09-1990
- the Netherlands ATPL was restricted to AFT operations. This restriction would be deleted from the licence after 200 flying hours had been completed in one year. According to Macedonian regulations he had to complete a minimum of 50 hours in route training and pass a Macedonian examination before he could act as a pilot-in-command on the Fokker 100.

- the last flight was on 04-03-1993 on the route Zürich - Skopje. After resting 24 hours he reported for duty on 05-03-1993.

1.5.3 Cabin Crew Information

All three cabin attendants held the appropriate licences issued by the Civil Aviation Authority of the Federal Republic of Yugoslavia. They also held the Palair company certificates for the AN-24, TU-154, F-100 and F-28. There were no Netherlands licences required for this operation, however the cabin crew attendants followed an RLD approved training course for the Fokker 100. Furthermore, a Fokker Aircraft Flight Safety instructor was assisting during the first weeks of the operation.

1.5.4 Ground Handling Crew Information

The Swissair Flying Station Engineer

a. date of birth: 03-12-1967

b. nationality: Swiss

c. profession: Line maintenance engineer with Swissair since 01-02-1988

d. licence: Swissair company licence, according FOCA licence no. 1

e. * experience as a line maintenance engineer:
    - on A310, MD80 and Fokker 100, on the Fokker 100 since 28-02-1988
  * experience as a FSE:
    - A310: 09-08-1992 - 18-10-1992
    - Fokker 100: from 01-03-1993 (4 days prior to the accident)

f. additional information:
  - holder followed the following courses:
    * 1988; Basic training for deicing (theoretical and exercise)
    * 1989; Refresher course including blue-ice phenomena
    * 1990; Refresher course
    * 1991; Training for deicing equipment operator and test 18-11-1991
    * 1992; Refresher course and examination 20-10-1992.

  - the last flight was on 05-03-1993 on the route Frankfurt - Skopje

- recorded working hours from 01-03-1993:
  01/03; 07:30 - 23:00 (LT)
  02/03; 06:30 - 21:30
  03/03; 07:30 - 22:30
  04/03; 07:30 - 23:40
  05/03; 07:10

Note: These working hours are not the actual working hours, since he was only working when the aircraft was on the ground between flights.

According to the Fokker 100 Technical Cooperation Agreement between Palair and Swissair, responsibility for maintenance on the Fokker 100 was contracted out to Swissair. This included line maintenance and heavy maintenance (after Swiss Federal Office for Civil Aviation (FOCA) and The Netherlands Civil Aviation Authority (RLD) approval), modifications, and technical support. Based on article 3 of this agreement a Swissair ground engineer (or Flying Station Engineer according to Swissair) was available. The FSE would perform routine maintenance checks according to Swissair checklists, perform trouble shooting and repairs in accordance with maintenance manuals and minimum requirements to ensure aircraft airworthiness and flight safety at all stations, except at Zürich and Geneva, and make the necessary entries in the aircraft technical log. He had to keep the captain and the station manager informed of any problems and repairs in progress.
According to the above mentioned Swissair procedures, the FSE was authorized to perform the inspection for ice-contamination.

The Palair Ground Handling Crew

Palair had a total of 9 ground handling crewmembers under training for the Fokker 100, to assist in the ground maintenance at Skopje Airport. Most of these crewmembers had been employed in the former Yugoslavian Airforce. Six crewmembers had attended an "Airframe, Powerplant and Electric course", preceded by a "Digital course" for the Fokker 100. The three other crewmembers had attended the "Avionics course" for the Fokker 100. Furthermore, on-the-job-training was performed in the Netherlands under the supervision of Fokker. More on-the-job-training was planned with Swissair in Zürich in the future.

1.6 Aircraft Information

1.6.1 General

a. nationality and registration: The Netherlands, PH-KXL

b. aircraft type: Fokker F28 mark 0100 (Fokker 100)

serial no.: 11393

year of construction: 1992

manufacturer: Fokker Aircraft B.V. Nederland

c. engines: 2 Rolls Royce Tay 650-15

position:	1	2
serial no.:	17458	17457

d. The aircraft was registered in The Netherlands aircraft register, no.: 4460, dated, January 26, 1993, under the name of Fokker Aircraft B.V., address: Hoogoorddreef 15, Amsterdam.

e. The Certificate of Airworthiness no. 4460 was issued at January 21, 1993 and valid until November 16, 1993.

f. At the time the aircraft departed Skopje Airport, the take off weight was 92.706 lbs (maximum allowable take off weight is 98,000 lbs), the centre of gravity for take off was calculated at 23.2 % percent mean aerodynamic chord, which was within the limits of the aircraft's flight envelope.

g. Additional information:

The aircraft accumulated 188 flight hours and 136 flight cycles. Both Rolls Royce Tay engines accumulated approximately the same number of hours and cycles. Examination of the service records, crew write-ups, action items, trend monitoring data, and flight recorder data of previous flights did not reveal any significant deviations, with the exception of the following maintenance complaints which were written up in the technical log:

1. On the night of 04-03-1993 during a scheduled flight from Skopje to Frankfurt, the aircraft had been delayed as a result of a flap position computer malfunction. This gave a no flap indication and a speed limit flag on the left hand PFD. There was a normal flap indication on the right hand PFD. The flaps functioned normally, there was no asymmetry or disagreement. The alternate FCC was selected on the left hand side, this removed the speed limit flag on the left hand PFD. The aircraft was dispatched according to the Dispatch Deficiency Guide (DDG) and the Aircraft Operating Manual (AOM) requirements. Neither in the technical log nor in the aircraft maintenance log reference was made to the applicable DDG or AOM requirements for dispatch.

2. During the initial climb on the scheduled flight to Frankfurt on 04-03-1993 and during the scheduled flight from Frankfurt to Skopje on 05-03-1993 a GPWS fault occurred during climb out. The system was reset on approach below 2,500 feet radio altimeter.

1.6.2 Fokker 100 Fuel Storage System

Each wing fuel tank consists of four separated compartments, as indicated in figure 1, page 15. The most inboard wing compartment is the collector tank (CT) from which the engines are fed through the boosterpump system. The next compartment numbered 1, is the main tank (MT1), which ranges from Wing Station (WS) 2635 to WS 4700. This compartment is enclosed by the wing front and rear spars and two closed ribs. Fuel can pass these ribs only in inboard direction through flapper check valves near the bottom of these ribs. Also at the bottom of rib WS 2635 is a jetpump system installed. The upper wall of MT1, consisting of the wing skin and hollow "top hat" stringers, provides a fuel transfer channel from the CT into the main tank compartment 2 (MT2). Of the set of top hat stringers that range from the CT into MT2 only the forward four are completely open at both ends. The others are plugged, but not completely so that fuel can penetrate into the stringer channels. MT2 ranges from the closed rib WS 4700 to the almost closed rib at WS 8200. The latter rib allows fuel migration only through relatively small stringer cut-outs. In this compartment a partially closed rib is positioned at WS 5280. Openings in this rib consist of stringer cut-outs and lightening holes. Fuel enters this compartment through the hollow stringers mentioned above and leaves through the inward flapper check valves.

Main tank compartment 3 (MT3) ranges from rib WS 8200 to the closed end rib at WS 11190. Fuel can enter and leave this compartment through the openings in rib WS 8200. In this compartment are several ribs with only small openings to restrict fuel migration.

1.6.3 Fuel Circulation

Operation of the boosterpumps, e.g. when the engines are running, does not only feed the engines but also drives the jetpump system. These jetpumps transfer fuel from MT1 into the CT. These jetpumps have excess capacity and excess fuel will leave the CT again through the hollow stringers into MT2. MT1 will be replenished from MT2. During operation of this system the CT will remain full and the MT1, MT2 and MT3 approximately level.

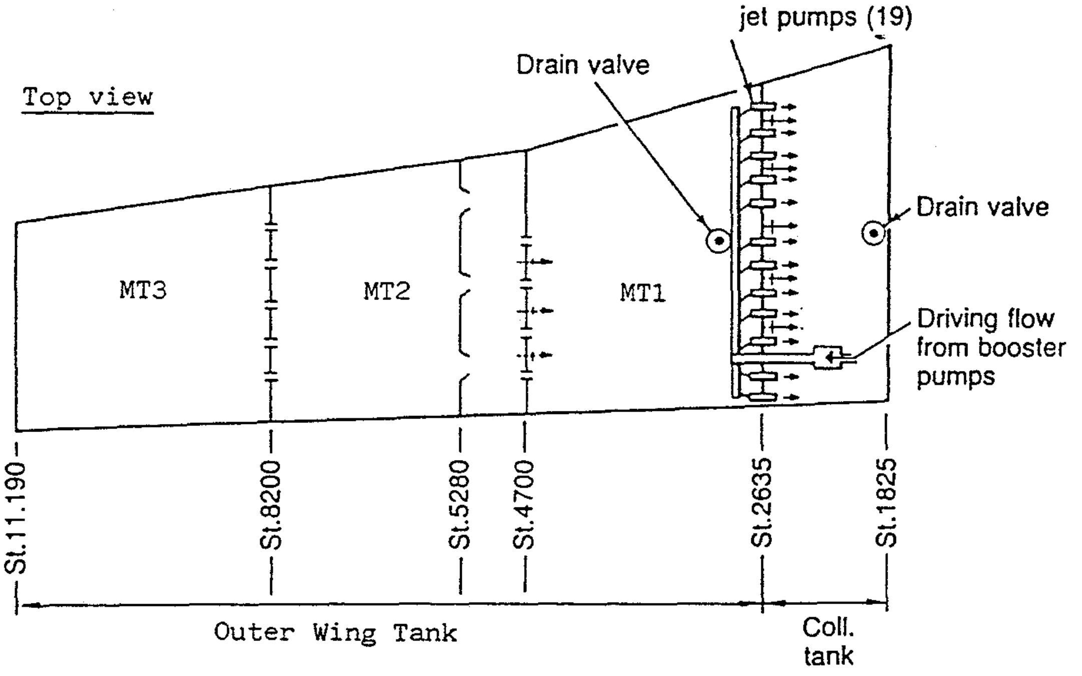
1.6.4 Refuelling

When refuelling through the Single Point pressure refuelling adaptor, the fuel will enter the tanks in the left and right CT's first. Overflow from the CT's enters into the MT2's through the hollow stringers. From the intermediate compartment between WS 4700 and WS 5280, the fuel is distributed over the main tank compartments. The various openings in the ribs separating these compartments, however, restrict mixing of residual and added fuel. If MT1 would contain a large amount of residual fuel, the added fuel would enter only slowly through the bottom flapper valves to equalize the levels of MT1 and MT2. Likewise, due to the restrictions posed by the partially closed rib at WS 5280 and the various ribs further outboard, residual fuel in MT2 (and MT3) could be "pushed" outward without substantial mixing, due to the added fuel entering MT2 at WS 4700.

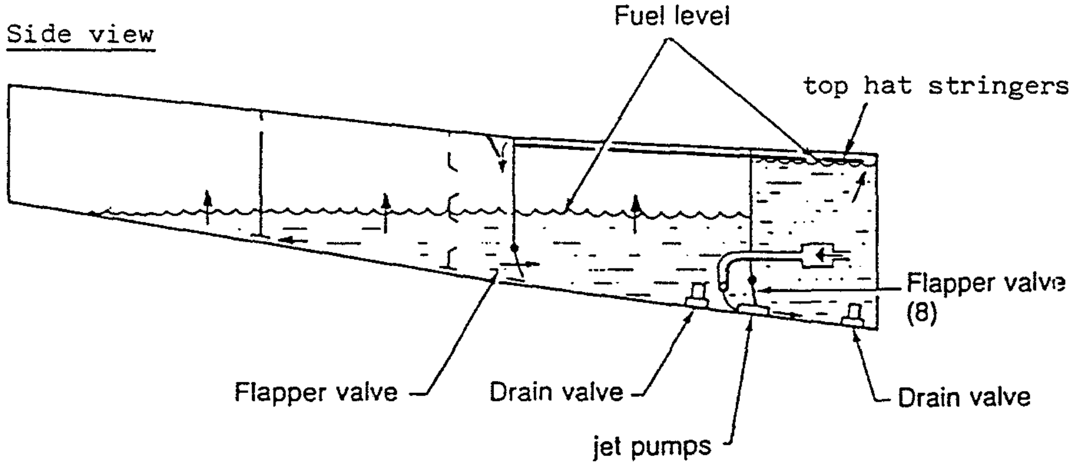
Figure 1.

Fuel Transfer to Collector Tanks

Top view



Side view



Source: Fokker Aircraft B.V.

Because the refuelling adaptor is positioned very close to the right CT, the connecting lines to the left CT are much longer. Due to some pressure drop in these lines the right CT and wing tanks may fill more rapidly than the left tanks. To prevent this a restrictor is included in the fuel line to the right CT but its effect depends on the refuelling pressure.

With the stated maximum fuel capacity a certain fuel expansion space is left, mainly in the highest, most outboard, tank compartment (MT3). Some part of the upper wing skin of MT3 will therefore not be in contact with fuel when the wing tanks are full and the aircraft is static. However, due to taxying on uneven ground or during turning that upper wing skin may become temporarily "wetted".

1.6.5 Take Off Flight Director Pitch Commands

During the take off roll the FD control law provides a fixed 10° nose up pitch command to the PFD, but during the rotation the pitch command is adjusted as necessary to capture and hold a speed of V_2+10 kt. The 10° pitch command floor in the speed control loop ensures that the aircraft will climb even if the V_2 speed is set much too high. Pitch limits are -5° and +18°, and underspeed is limited to 1.2 V_{stall}.

1.6.6 Roll control

Roll control on the Fokker 100 is normally effectuated by two hydraulically powered ailerons. The left aileron is powered by hydraulic system 1, the right aileron by hydraulic system 2. The aileron control systems are interconnected mechanically by an anti-upfloat cable. A servo tab at each aileron is locked during normal operation. If one aileron actuator becomes depressurized, the servo tab will unlock to assist in manual operation of the affected aileron. If hydraulic pressure is not available, both servo tabs are unlocked and are operated by the control wheel movement. The ailerons are then operated by the servo tabs. An aileron trim wheel is located at the pedestal, operating by biasing the spring feel unit. With both aileron hydraulic systems active, there is no aerodynamic control force feedback.

1.7 Meteorological Information

General Conditions

There was a cyclonic circulation in the atmosphere ground layer maintained by advection of cold air with the centre in the Ionic See, which was moving towards the East via Greece. The cyclonic activity conditioned the northern circulations of moderate intensity on higher altitudes.

Cloudy weather prevailed over the entire Republic of Macedonia;
- 5/8 - 8/8 Stratocumulus ceiling at 1,000 - 2,500 meters;
- 1/8 - 4/8 Stratus ceiling at 300 - 500 meters;

- possible isolated embedded Cumulonimbus, base at 800 meters with tops up to 7,000 meters, moderate icing and turbulence. The precipitation was of moderate intensity in the form of snow, sleet and rain.

At Skopje airport it was cloudy all day long with Stratus and Nimbostratus clouds and it snowed. Wind, direction North with 3 - 5 knots. Horizontal visibility from morning till afternoon varied between 1,000 - 5,000 meters. Air temperature around 0°, dewpoint -2° to -1° C. Air pressure QNH 1,008 hectopascals.

Conditions at the time of the accident

- wind: 350°/5 knots
- visibility: 1,000 meters
- precipitation: moderate snow
- clouds: 2/8 Stratus at 2,000 feet, 8/8 Nimbostratus at 5,000 feet
- temperature: 0° C
- dew point: -1° C
- QNH: 1,008 hectoPascals.

Applicable METARs

Time	Wind	Visibility	Precipitation	Clouds	Temp./Dewp.	QNH	Trend
UTC	°/knots	meters			° Celsius	hPa	
09:30	360/05	2,000	light continuous snow	3/8 St at 2,000 ft 8/8 As at 9,000 ft	0/-2	1,008	nosig
10:00	330/05	3,000	light continuous snow	3/8 St at 2,000 ft 8/8 As at 9,000 ft	0/-2	1,008	nosig
10:30	300/03	2,000	moderate continuous snow	8/8 Ns at 5,000 ft	0/-1	1,008	nosig
11:00	350/05	1,000	moderate continous snow	2/8 St at 2,000 ft 8/8 Ns at 5,000 ft	0/-1	1,008	nosig

Table 2. Applicable METARs

Applicable TAF

For the period 10:00 - 19:00 UTC
- wind: 020°/10 knots
- visibility: 3,000 meters
- precipitation: light continuous snow
- clouds: 3/8 Stratus at 2,000 feet, 6/8 Stratocumulusc at 4,000 feet, 8/8 Altostratus at 8,000 feet.

- trend: temporary from 10:00 - 16:00 UTC;
  - * visibility: 1,800 meters
  - * moderate continuous snow
  - * 8/8 Nimbostratus at 5,000 feet

Additional Information

Witness Statements

The airport handling agent stated it was snowing very hard prior to the departure of Palair flight 301. The tower controller stated the visibility was limited to 900 meters because of the snow. One of the Palair ground handling crewmembers stated, while standing in the main station building, he lost sight of the aircraft during take off because of the heavy snow. Another witness in the watch tower reported visibility to be about 1,000 meters with heavy snowfall. Taking all the abovementioned into consideration, it could be concluded that during take off of Palair flight 301 at least moderate snowfall existed.

DFDR Temperature Data

Total Air Temperature (TAT) and Static Air Temperature (SAT) are presented on the flight deck of the Fokker 100 on the no. 1 Multi Function Display Unit. TAT is also recorded on the DFDR, sampled once per 2 seconds. The recorded TAT data started at 11:05:32 and show -1° C most of the time, except that between 11:07:48 and 11:10:42 in 5 continuous periods spanning 90 seconds in total a temperature of -2° C is recorded. The TAT showed 0° C between 11:12:04 and 11:12:10 while the aircraft was airborne. The TAT recording system accuracy is stated as ± 0.9° C. The temperature sensor is located in the left side airconditioning unit air inlet.

1.8 Aids to Navigation

Navigational aids played no role during the accident sequence.

1.9 Communications

No equipment-related or other communication difficulties were reported between air traffic control facilities and the flightcrew involved in this accident.

1.10 Airport Information

1.10.1 General

The airport Skopje-Petrovec is located 16 kilometres in easterly direction from the town Skopje. The airport reference point is at 41°57'40" North latitude and 21°37'37" East longitude. The airport elevation is 238 meters. The difference between the elevation of the threshold of runway 34 (234.2 meters) and the threshold of runway 16 (238 meters) is 3.8 meters. Transition altitude of the airport zone is 3,350 meters.

The airport has one runway with taxiways and aprons. Runway 16/34 is 2,450 meters long and 45 meters wide. The clearway is 2,570 x 300 meters.

Fire fighting service, first aid service and snow cleaning equipment are provided at the airport. The annual serviceability of the airport is throughout the year with a warning that icing conditions during the winter period December - February exists and should be taken into account.

1.10.2 Applicable SNOWTAM

Information regarding the runway condition is published in a Notice to Airmen (NOTAM) or in case of snow conditions in a Snow NOTAM (SNOWTAM). The Skopje operations log indicated that at 11:00 the following SNOWTAM was issued: RWY 16, cleared runway length is 2,450 meters, width 45 meters. Deposits: wet or water patches. Measured or calculated coefficient 0.39 to 0.36, medium/good (Measuring device: Friction Tester).

1.10.3 Airport De-/Anti-icing Equipment

At the time of the accident Skopje airport was equipped with an FMC deicer/washer model LA-1000 with a capacity of 1,000 gallons. The unit was configured with pumps and nozzles for ARCTIC fluid. The ARCTIC fluid is equivalent to Type I fluid and has similar hold-over properties. The FMC-equipment has the ability to heat up the deicing fluid.

For de-/anti-icing procedures the following definitions apply:

Deicing:	Any procedure by which frost, ice and snow is being removed from an aircraft. It can be done by mechanical means, hot-air or by spraying the aircraft with (heated) deicing fluid.
Anti-icing:	A precautionary measure which prevents frost, ice and snow to form or accumulate on the protected surfaces of an aircraft during a certain time interval. This is usually done by spraying a deiced aircraft with a special anti-icing fluid.
Holdover time:	The estimated time during which the de-/anti-icing fluid will prevent frost, ice or snow to form or accumulate on the protected surface of an aircraft.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The airplane was equipped with a Fairchild CVR, part no. 93-A100-80, serial no. 59220, which was located in the aft baggage compartment. The CVR was removed from the aircraft and examined at the laboratory of the Bureau Enquêtes Accidents in Paris, France. The recording consisted of four channels of good quality audio information. One channel contained the cockpit area microphone audio information. Two other channels contained information from pilot and copilot radio channel (hot mikes). The last channel contained information from the aircraft's public address system. The CVR had a 30 minutes recording capability. Channel 1 contained an encoded time pulse every 4 seconds for the purpose of synchronization with the DFDR. The CVR-recording started at the moment of engine start-up (See appendix 2).

1.11.2 Digital Flight Data Recorder

A Fairchild digital flight data recorder (DFDR), part no. 980-4100-DXUN, serial no. 10197, which was located in the aft cabin in a compartment above the right side lavatory. The DFDR was removed from the aircraft and examined at the Centre d'essais en Vol of Brétigny, France.

The DFDR appeared to have suffered from heat more than the CVR. The outer casing was found to be severely burnt and its front had partly melted. The crash protected module also suffered from heat and presented a black and orange discolourisation. The tape and the kinematics were damaged by heat.

Two playbacks were performed. The first playback presented some losses of synchronisation at the end of the flight. The second playback, using a slightly different method to recover data on the tape, presented also losses of synchronisation, but allowed to recover some more data lost with the first playback. See appendix 3 for plotted graphs.

1.12 Wreckage and Impact Information

1.12.1 Airframe Damage

Appendix 1 contains some photographs of the wreckage. The wreckage was primarily distributed over an area with a length of 220 meters and a width of 40 meters. The fuselage was broken in three major parts, i.e. the cockpit and a part of the fuselage, a mid part ending before the wing, and the aft fuselage. Of the cockpit and mid-fuselage parts, the right side had disappeared. Of the aft fuselage, the cabin part was destroyed by fire.

The right wing was completely disintegrated until inboard of the wing root. The left outer wing part had separated near the position of the outer flap trackfairing and was also disintegrated. The remaining part of the left wing was in one piece, including a part of

the wing centre section.
Both engines had separated from the fuselage. The right engine had partly penetrated the cabin some three meters forward of its normal position. The horizontal stabilizer together with the upper part of the vertical stabilizer had separated.

The orientation of the main wreckage trail was approximately 005° M. The first impact mark was a furrow of 6 meters length, aligned with the left side of runway 34. This furrow started 382 meters beyond the departure end of the runway. The second mark, in line with the first, led into the slope of a service road and began about 10 meters from the end of the first mark. The direction of these impact marks was approximately 345° M. Parts found along these impact marks were from the right wing tip, the right aileron and from the outer end of the right wing fuel tank structure.

After traversing the service road the right wing cut the barbed wire of the airport fence, but the concrete poles at 3 meters apart were left intact. A deeper and wider furrow in the soil was found north of the service road. It started at 10 meters from the road, had a length of 30 meters and was deepest (0.8 meter) at approximately 28 meters. Close to each other, parts from different aircraft components were found here, such as fragments from the right inner wing leading edge and ribs and stringers, a broken cabin window frame, both right overwing exit hatches, and the horizontal stabilizer feedback link. To the right of this area there was a hole with a diameter of approximately 2.5 meters in which a puddle of fluid was found, identified as engine oil. Beyond these deep holes no clear impact marks in the ground were found, but fragments of the aircraft were scattered all over.

Twenty to thirty meters further down the trail the right aft cockpit window frame was found and several larger pieces of fuselage side skin, cabin window frames, and parts of the right engine bypass duct. Some 10 to 20 meters further down the trail parts of the left wing tip and leading edge, the outboard half of the right elevator and the right tip of the horizontal stabilizer were found. Again some 20 meters further the horizontal stabilizer with the upper half of the vertical stabilizer still attached, was found upside down.

The right outboard flap was found 20 meters to the right of the horizontal stabilizer, but the right inboard flap was laying 30 meters to the left of this and 40 meters further down the trail. Parts of the right engine cowling and inlet duct were some 10 meters beyond the horizontal stabilizer. From this point a track started towards the location of the right thrust reverser unit, some 80 meters away in the direction approximately 345° M.

At about 20 meters beyond the horizontal stabilizer, a 12 meters wide area up to the main wreckage started with all kinds of cabin interior parts, side panels, seats, food containers, etcetera. At 20 meters into this area was the right side of the wing center section, consisting of the right wing to fuselage joint and parts of the fuselage main frames, the right sidestay bracket and the lower parts of the overwing emergency exit apertures. Again 20 meters further there was the right engine accessory gearbox. And finally the main wreckage spread out between 15 and 50 meters further down, consisting of the aft fuselage, the engines, the left thrust reverser, the right main landing gear and its wing attachment bracket, a part of the left wing and center wing section including part of the fuselage side wall and the retracted left main landing gear, the remains of the mid fuselage and the left side front fuselage and cockpit. Between these main parts there were still some connections in the form of electrical wire bundles and control cables.

For a detailed description of the airframe damage, see appendix 4.

1.12.2 Engine Damage

Both engine fire bottles were found filled. Both hydraulic fire shut-off valves were found open. The RH fuel fire shut-off valve was open. The RH crossfeed fuel shut-off valve was closed. The LH fuel lever in the cockpit was found in the open position, whereas the RH fuel lever was found in a position between open and closed (old start detent).

The thrust reversers were found in the closed and locked position. The RH thrust reverser had a large scorch area on the bottom inner side. The DFDR showed that the thrust reversers remained stowed throughout the take off run and flight.

1.12.3 Systems Damage

The nose landing gear was found in the retracted position with the doors closed. The LH main landing gear (MLG) was found in the retracted position. The RH MLG was found in the extended position. Both MLG doors were found still attached to the crash beam in the main rear fuselage wreckage. The LH forward door actuator was found in the extended position with the piston rod bent. The aft door actuator was missing but later found with the piston rod extended and bent.

The landing gear selection lever in the cockpit was found in the gear down position with an indentation mark in the up position. One other Fokker 100 operator (Swissair) was asked to check whether similar indentation marks could be found on the landing gear selection levers in their aircraft. No such indentation marks were found during that inspection.

The CVR recorded the gear up command given by the PF 12 seconds before the end of the recording. The DFDR, which samples the landing gear parameters once every 4 seconds, shows the LH MLG in transit on the last recorded frame which comes 9 seconds after the gear up command and 3 seconds before the end of the CVR recording. The normal reaction time is 6 to 9 seconds.

The aft part of the tail cone with the speedbrakes and its control system was relatively undamaged. The speedbrakes were found in the closed position and could not be opened by hand, which indicates that the hydraulic part of the control system still provided a hydraulic lock, which was confirmed by DFDR data.

Both aileron actuators were found. The RH aileron actuator was found completely separated from both aileron and wing structure, while the LH aileron actuator and the LH tab lock-out actuator were still attached to the wing structure. The RH tab lock-out actuator was also found attached to the adjacent wing structure.

The LH tab lock-out actuator showed a 35 millimetres extension. This indicates that the tab lock-out actuator was extended, which corresponds to a depressurized aileron actuator. The LH and RH aileron actuator pistons showed an extension equivalent to 0.8° aileron deflection, aircraft right wing down. The aileron chains in the control columns were found intact.

The anti-upfloat cable lock on the rear spar, which locks the anti-upfloat cable with the flight control lock engaged, was found in the locked position. The flight control lock lever in the cockpit pedestal was found in the unlocked position.

Two RH wing liftdumper actuators were found, one attached to a part of the wing rear spar, the other separated from the rear spar but still attached to the push-pull rod mechanism. The middle actuator was found in the liftdumper retracted position. The outboard actuator was found in the liftdumper extended position. Two LH wing liftdumper actuators were found in the remains of the LH wing, both damaged by post impact fire and/or overheat, in the liftdumper retracted position. The DFDR data did not show liftdumper anomalies. There is no indication that the liftdumpers were not in during the take off and flight.

Both rudder actuators were found in their normal environment in the main rear fuselage wreckage. The rudder surface itself was broken. The part which remained connected to the actuators was found in a large LH deflection and could not be moved. Both actuators showed a piston extension of 36 millimetres. DFDR data revealed that large rudder deflections were recorded in the last part of the flight.

The complete elevator installation was found, but broken from the vertical stabilizer. There was no position difference between the LH and RH control surfaces. Both surfaces were still attached to the stabilizer and connected to the elevator booster and could be moved by hand together.

The LH and RH horizontal stabilizer actuators showed an extension of the piston equivalent to -5.5° horizontal stabilizer position, which corresponds with the DFDR data at the end of the recording.

The RH outboard flap drive spindle was found broken in two, its extension length could be determined equivalent to 8.4° flap deflection. The LH inboard spindle extension length was equivalent to 8.2° flap deflection. The LH middle spindle extension was equivalent to 8.0° and the LH outboard spindle extension length was equivalent to 8.4°. The flap selection lever in the cockpit was in the 8° position. The marking on the LH inboard flap also indicated an 8° position.

1.13 Medical and Pathological Information

After the accident the Institute of Forensic Medicine submitted a pathology report concerning the two pilots. The autopsy revealed that both pilots died as a result from blunt force trauma, mostly from the right side. Toxicological testing revealed a complete absence of alcohol, drugs or carbonmonoxide.

1.14 Fire

During the impact with the ground the aircraft disintegrated, followed by several explosions. The cockpit including the forward part of the cabin and the tail surfaces separated from the main fuselage. Several residual fires broke out on the wreckage debris and an intensive fire destroyed the aft fuselage.

Examination of the engines and parts of the structure that disintegrated during impact, did not show any sign of pre-impact fire. Also the witnesses did not report fire before impact.

1.15 Survival Aspects

1.15.1 Search and Rescue

A United Nations (UNPROFOR) Bell 212 helicopter pilot, while walking on the ramp to his office, heard an impact sound shortly after the take off of the Palair Fokker 100. Via telephone he immediately offered his services to the tower, which were accepted. Shortly after that the Bell 212 took off and found the wreckage site. It landed near the aircraft and notified the tower and his office, who in turn respectively called the emergency services and a nearby UNPROFOR army base. The Bell 212 took off from the wreckage site with 7 survivors for the hospital in Skopje, while another UNPROFOR helicopter at Skopje Airport, a Bell 206, was being prepared for assistance. The Bell 212 made a total of 4 trips to the hospital, with a total of 13 passengers. The Bell 206 made two trips with one passenger each time.

Shortly thereafter the fire brigade and the local police arrived at the accident site and fire fighting and rescue actions were started. Later on another helicopter of the Macedonian State Police arrived but all survivors were already transported to the hospital.

1.15.2 Survivability

Due to the impact on the right side and front fuselage, only the fuselage aft of the wing remained sufficiently intact to provide survival space for its occupants. During the final stage of the impact sequence this aft fuselage part was hit by the separated right engine. The hot and presumably burning engine core penetrated the aft fuselage and started a fire that eventually destroyed this fuselage part.

1.16 Tests and Research

1.16.1 Calculations on the Fuel Temperature

The aircraft arrived at Skopje airport with a large amount of fuel remaining, as a result of Palair's fuel tankering policy. Since the flight from Frankfurt was long enough to produce a significant cooling of this fuel mass, an estimation was made by Fokker of the (average) fuel temperature during the various stages of the stop at Skopje, to determine whether fuel temperature could have resulted in a wing surface temperature lower than the outside air temperature.

Fuel quantity and time data from the fuel slips were used and temperature data from the METAR reports (See appendix 5). Also fuel temperature data from some long flights with a Fokker 100 prototype aircraft were used to calibrate industry-standard equations for aircraft fuel temperature changes during flight. Details of these calculations for the actual recorded temperatures during the Palair flight 242 Frankfurt-Skopje are presented in appendix 6. The results, based on fuel quantities as stated, are as follows:

- Fuel remaining after previous flight: 11,500 lbs, temperature -14.7° C
- Fuel added during first refuelling: 3,500 lbs, temp. +2° C
- Fuel added during second refuelling: 2,000 lbs, temp. +1.7° C

- Est. average fuel temp. prior to first refuelling: -13.3° C
- Est. avg.temp. immediately after first refuelling: - 9.8° C
- Est. avg.temp. immediately after second refuelling: -6.9° C
- Estimated average fuel temp. at time of take off : -5.9° C

These calculations are based on immediate and perfect ("ideal") mixing of cold and warm fuel. An estimated error margin of ±15% has been applied to the calculated temperature at the end of the flight from Frankfurt to Skopje, which results in a temperature range between -3.4° C and -8.0° C for the end result of -5.9° C.

1.16.2 Fuel and Fuel Temperature Distribution

The calculation result presented in the previous section assumed ideal mixing of the added fuel with the fuel in the tanks. This may not be accurate, however, because jet fuel has a low heat conductivity. The mixing will further depend on certain details of the aircraft fuel storage and transfer system. The fuel system of the Fokker 100 was described in section 1.6.2 through 1.6.4.

In a situation in which the CT and MT1 and MT2 would be filled with a large amount of residual, cold fuel and a relatively small amount of much warmer fuel would be added through the pressure refuelling system, that warmer fuel is unlikely to be distributed (and mixed) evenly over the tank compartments. Since the fuel is entering into the CT first, some mixing is likely to occur there, but not necessarily completely. The partly mixed fuel will then pass through the hollow stringer channels and increase the temperature of the upper wing skin locally. From the compartment between WS 4700 and WS 5280 the warmer fuel could then distribute over MT2 and MT3 and into MT1. Given the relatively large volume of MT1, the fuel temperature in this compartment itself will most likely be the least affected.

After starting the boosterpumps, cold fuel from MT1 will be drawn into the CT and mix there, MT1 being replenished from MT2. The mixed fuel from the CT will again pass through the hollow stringer channels into MT2. Operation of the boosterpumps over a longer period of time would produce a mixing process in which most of the wing tank fuel contents would be involved, possibly except the fuel in MT3.

1.16.3 Fuel Temperature Test

In order to gain a more quantitative insight into the temperature effects of mixing colder and warmer fuel due to refuelling and subsequent booster-pump operation, an introductory test was conducted by Fokker. In this test a Fokker 100 prototype aircraft with 2,670 kg of fuel in each wing tank was exposed overnight to outside air temperature. Early in the morning, to reduce effects of outside air temperature variation and solar radiation, the aircraft was slowly refuelled to wing tank capacity and the wing skin temperature change was measured in 12 positions on both the left and right wing tanks. For the location of the temperature probes and the measured temperatures see table 3. The average outside air temperature during the test was +5° C and the measured temperature of the fuel truck ("bowser") was +15.5° C. A total amount of 2,430 kg of fuel was uplifted, i.e. approximately 1,215 kg added to each wing tank. Refuelling was done at a relatively slow rate of 200 kg/minute. The resulting "ideally" mixed fuel temperature after refuelling would be approximately 8° C.

This test did not represent the conditions during the stop of PH-KXL at Skopje and was not intended to do so.

The results of this test are shown in figure 2 and 3 (page 27) for the right wing and the left wing respectively. The numbered traces show the wing skin temperature change during and after refuelling for each of the probe positions shown in figure 4 (page 27). The Fokker 100 fuel temperature test report has been inserted in appendix 7.

It appears that immediately after start of refuelling, the locally measured wing skin temperatures of the CT and MT1 increase rapidly. Not only the skin attached to the hollow stringers - through which fuel is passing - shows a temperature increase, but also the skin attached to the "leaky" plugged stringer channels. The probes on MT2 respond also, but slower and to a lower temperature. Of the probes on MT3 only the probe next to rib WS 8200 shows some response. This indicates that the warming effect of the added fuel does not extend significantly into MT3. The probes on the CT and MT1 reach a maximum temperature during the refuelling and these temperatures remain fairly stable for quite some time. The maximum recorded skin temperatures remain below the "bowser" temperature in this test.

This test showed a difference between the right and left wing in that the left temperatures increased slower and to a lesser level than at the right side. This was probably due to a lower refuelling flow rate into the left tank which would be due to the low refuelling rate used in this test.

A significant effect can be seen to occur after switching the boosterpumps on. Due to the mixing of the fuel in the CT with that from MT1, the upper skin temperatures drop again rapidly to approximately the ideally mixed temperature level. There is again little effect on the skin temperatures of MT3. Another significant detail is that temperatures recorded at the drain valves indicate that there can be significant temperature difference between a tank top and bottom.

Source: Fokker Aircraft B.V.

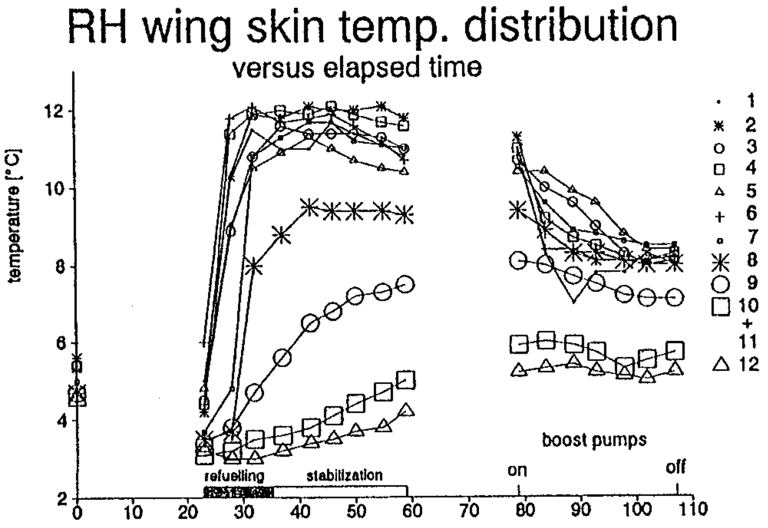


Fig. 2

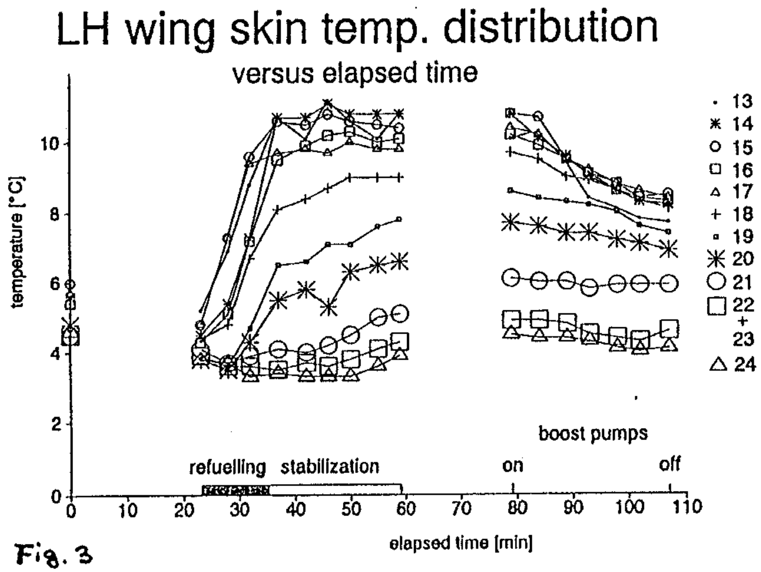


Fig. 3

Table 3. Temperature measurement location number

Wing Station number	RH wing Stringer number				LH wing Stringer number			
	Str. 2.33	Str. 2.34	Str. 2.36	Str. 2.38	Str. 2.33	Str. 2.34	Str. 2.36	Str.2.38
2490		1				13		
2890	2			3	14			15
3350	4			5	16			17
4370		6				18		
5630		7				19		
7250		8				20		
8650		9				21		
9600	10		11		22		23	
11090		12				24		

Above table outlines the measurement location number for the LH - and RH wing at each wing station and stringer number (Str. -).

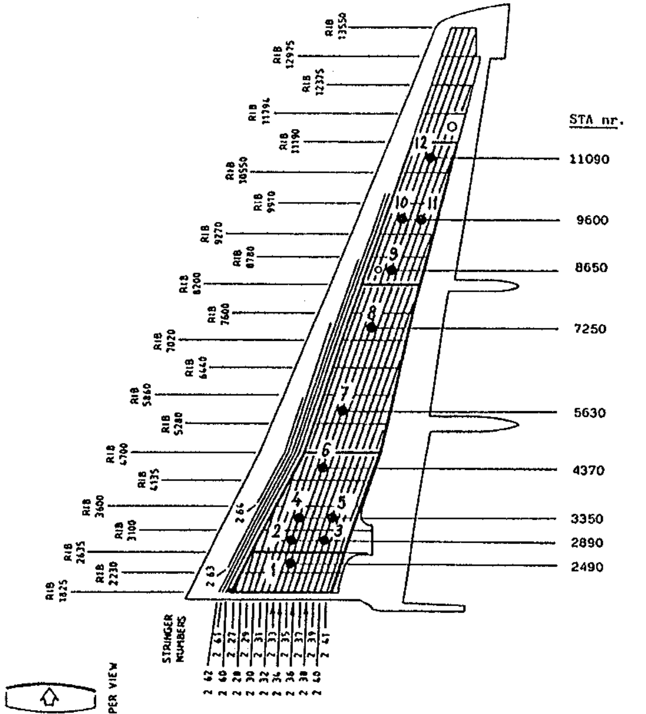


Figure 4. Location of temperature measurement point on RH wing upper surface.

1.16.4 Aerodynamic Studies and Simulation

Over the years a vast amount of research data has been generated on how aircraft flying characteristics are affected by frozen contamination on the airfoils. Fokker has also contributed to this with windtunnel model and full scale aircraft flight tests. The Fokker studies concentrated on the effects of relatively small amounts of frozen contamination, typically ice particles of 1-2 millimetres height distributed over the entire wing, 1 such particle per square centimetre on average. This "typical" contamination could represent a thin coating of frozen rain drops or snow flakes, or frost ("roughness"). It appeared that even such a relatively thin contamination layer can reduce the maximum obtainable wing lift by up to 35% and reduce the AOA for maximum lift by 5 or 6°. The largest effects occur when such distributed contamination is positioned near the wing leading edge, or more generally, on about the forward 30% of the wing section. Also, the effects are likely to be more severe with contamination of the outer wing because the ice particle size relative to the wing chord increases with the decreasing wing chords towards the wing tip.

Present wing design includes controlled progression of airflow separation when approaching the stalled condition. The wing is designed such that normally (i.e. not contaminated) airflow separation with increasing AOA occurs first on the middle and inboard parts of the wing. This ensures that the most outboard part of the wing where the ailerons are located will be affected last, thus ensuring roll control into the stall. The main effect of distributed ice contamination (particularly contamination on the forward part of the wing) apart from reducing the maximum lift is that the designed-in good stall characteristics are destroyed and that the important outer wing part is likely to stall first rather than last.

In response to certain facts appearing from this accident investigation, Fokker conducted further windtunnel tests using a development windtunnel model of the Fokker 100. In these tests the effects of frozen contamination on the wing fuel tank area were investigated and also the effects of frozen slush in the gap between the wing and the right inboard trailing edge flap.

From these tests it appeared that variation of simulated ice roughness height on the fuel tank area had only a marginal effect on the lifting and pitching characteristics of the contaminated wing and a moderate effect on drag. More significant effects, up to 14% loss of maximum lift and 2° reduction in AOA for maximum lift, were found with a roughness distribution that also included the wing area between the leading edge and the fuel tank. This test represented full scale ice particles of 0.9 mm distributed over the wing upper surface and 12 mm on the fuel tank area. The effect of the asymmetrically closed flap gap were also marginal and mainly a rolling moment increasing with AOA, which would be easily counteracted if roll control would not be affected otherwise.

Using the "typical" distributed contamination test data related to aircraft behaviour during take off described above, Fokker had earlier expanded the aerodynamic model of the Fokker 100 to include contamination effects on lift, drag and pitching moment. This simulation model was used to study the effects of wing contamination on take off characteristics, including variations in rotation technique, basically in symmetric flight.

The Fokker 100 aerodynamic model (including the effects of contamination) is implemented on the engineering simulator which is used by Fokker primarily for studies related to the man-machine interface and comprises state of the art simulation technology. The simulator is equipped with a vision system, but is fixed base so that motion cues including e.g. buffet can not be presented. With the implemented aerodynamic model it was not possible to vary the spanwise lift-distribution as it would result from various forms of wing contamination and also this aerodynamic model could not accurately describe the rolling motions that occurred to Palair 301 after lift off. Therefore the simulation model had again to be expanded to include roll characteristics such as modified aileron effectiveness and reduced roll damping.

After establishing that the DFDR data on roll angles and aileron input were reliable, the DFDR data were analyzed to determine data on aileron effectiveness and roll damping that could be applied to the engineering simulation model. Due to restrictions of this model, the effects had to be modelled in such a way that variation of the location and distribution of the contamination on the wing could not be taken into account. The resulting model was implemented on the fixed base Engineering Flight Simulator and flown by several pilots including one member of the State Accident Investigation Commission. These simulator sessions showed aircraft behaviour very similar to the accident flight.

The aerodynamic effects represented in the simulation test on the Engineering Flight Simulator are summarized below (See also figure 5 below):

- Reduced C_{Lmax} relative to the clean wing.
- Reduced α at the moment of maximum lift relative to the clean wing.
- Significant decrease of C_L with increasing α, just prior to reaching C_{Lmax}.
- Significant increase in drag at an α higher then the α for C_{Lmax}.
- Change in the aircraft aerodynamic moments (pitch, roll and yaw).
- Effects on the elevator hingemoments and elevator effectiveness (Related to contamination on the horizontal stabilizer).

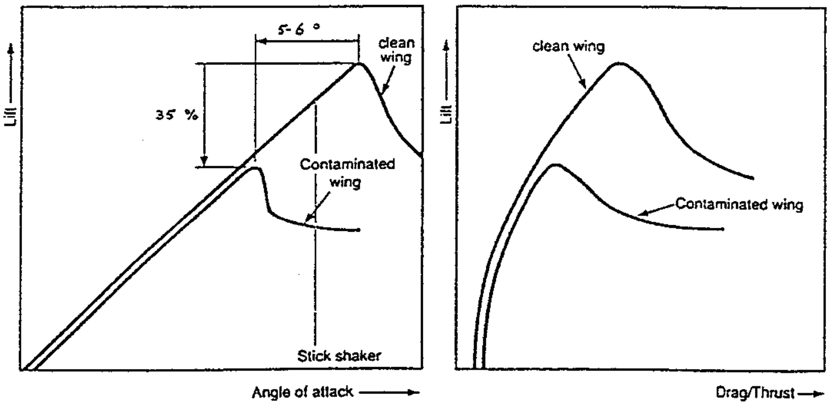


Fig. 5 Typical effect of wing contamination on aircraft lift and drag

1.17 Additional Information

1.17.1 Applicable Manuals and Procedures

The following manuals and procedures were valid or applicable at the date of the accident.

A. Airplane Flight Manual

No specific reference was made in the Fokker 100 AFM with regard to the exterior inspection of the aircraft, or to deicing and anti-icing procedures, nor was there a legal requirement to include such information.

B. AFT Fokker 100 Aircraft Operating Manual

With regard to the preflight check of the aircraft, the following is stated in the exterior inspection section, page 1, version 1, issue 4:

> "The exterior inspection may be omitted if qualified maintenance personnel have carried out this inspection." And further on:
> "Prior to each flight, the flight crew or maintenance crew shall verify that the aircraft condition is acceptable for flight. Check that all flight controls are unobstructed, and that all surfaces are clear of ice, snow and frost."

With regard to cold weather operations of the aircraft the adverse weather section of the AFT Fokker 100 AOM (see appendix 8) included the following guidance on page 1, in part:

> "General
> Small ice and snow deposits on the aerodynamic surfaces which accumulate during a ground stop might appear insignificant but can seriously affect the maximum lift of the wing, and the controllability and performance of the aircraft. Thin layers of ice resulting from frost or freezing fog may cause a certain sandpaper roughness on the wing and tail upper surfaces. This roughness may cause airflow separation resulting in control problems, wing drop, or even a complete stall shortly after rotation."

Furthermore it is stated on page 1:

> "EXTERIOR INSPECTION
> Pay special attention during the exterior inspection to those areas where snow or ice could affect system operation.
> - Remove all protective covers.
> - Check that all wings and control surfaces are free of ice and snow.
> - Check gear and gear doors for impacted snow or ice.
> - Check that the following areas are free of snow or ice:

> * Flight controls and surrounding areas
> * Air conditioning inlets and exhausts
> * Fuel tank vents
> * Angle of attack vanes, pitot heads and static ports
> * Engine and APU intakes."

Furthermore it is stated on page 2:

> "When taxying or holding in icing conditions at temperatures below +1° C, accelerate the engines to 85% N1 for one minute prior to take off and at intervals of not more than 60 minutes during prolonged holding on the ground."

This instruction originated from the engine manufacturer Rolls Royce and has been amended through the Fokker 100 AOM Bulletin no. 46 dated December 07/92, as follows:

> "In icing conditions in combination with temperatures of less than +1° C/34° F, the take off roll must be preceded by a static engine run up to take off EPR. Engine operation without abnormal vibration must be observed prior to brake release.
> During prolonged ground operation at idle, accelerate the engines to 60% N1 for one minute at intervals of not more than 30 minutes and within 5 minutes prior to take off."

The Fokker 100 AOM Bulletin 46 states further:

> "These precautionary measures are necessary to shed possible fan ice and to ensure that the EPR probes in the fan are free of ice prior to take off.
> Note that on the ground engine icing conditions can occur when visible moisture is present such as cloud or fog with low visibility, rain, snow, sleet or ice crystals or with standing water, ice or snow present and OAT is below +5° C/41° F."

A copy of the Fokker 100 AOM, section Adverse weather operation is attached in appendix 8.

C. AFT Basic Operating Manual

The following is stated at the section function description of the captain:

> "The captain maintains overall responsibility for the execution of the flight."

And with regard to the section flight execution the following is stated:

> "Ensure that checklist and standard operating procedures are adhered to and carried out thoroughly."

D. AFT Standard Operating Procedures

With regard to cockpit seating and the preflight check of the aircraft the AFT SOP no. 1, dated 18-02-1993, states:

Item 2. "The pilot-in-command shall be in the left hand seat."

Item 5. "A. The captain performs a walk around, the first officer starts APU, loads FMS and obtains airport data.
B. The captain communicates with ground engineer, cabin crew and company, the first officer does ATC and weather."

E. Swissair Maintenance Preflight Checklist

The FSE would perform routine maintenance checks according to Swissair checklists, perform trouble shooting and repairs in accordance with maintenance manuals and minimum requirements to ensure flight safety. The routine maintenance checks consist of the Maintenance Preflight Check (MPC). The MPC as mentioned in the Fokker 100 Maintenance Requirement consists of the "Vorflug controlle" (V-check) of which two types exist. One for line stations other than homebase Zürich (This one would be applicable during the stop at Skopje). And one for the homebase Zürich only (See appendix 9). The V-check has to be performed after the transit check, just before engine start prior to every flight. The V-check applicable for Skopje (H1E-04 issue 1) contains the following additional checks in winter (Items 11 and 12):

[quote]

> ADDITIONAL CHECK IN WINTER
>
> For Snow & Ice
>
> Engine inlet LH & RH .... SPC
> With ladder
>
> Wing Upper & Lower Surfaces, Landing Gear .... SPC
>
> Note: There could be INVISIBLE ICE on the wing
> upper surface & wing roots area.
> Take a ladder and check carefully.

[unquote]

The V-check for Zürich (H1-113 issue 4) contains a check (Item 12) to be performed before every flight with temperatures below 15° C and an additional check during winter operation (Items 13 and 14). [Translated version]

[quote]

> BEFORE EACH DEPARTURE
>
> Execute Clear Ice check, if temperature is below 15° C.
> The area around the ice indicators must, with the help of a ladder, be touched with the hand and be checked for ice.
> The Ice indicators can also be checked with a bar for free movement
> **If ice is present it must be removed**
>
> **Upper surface of wings around ice indicators** ..... CHECKED

ADDITIONAL CHECK IN WINTER	
For Snow & Ice	
Engine Inlets LH & RH With ladder	CHECKED
Landing Gear	CHECKED

[unquote]

Furthermore it is stated in the Swissair Handling Manual, section 2.5.2, Responsibilities with regard to deicing/anti-icing:

"The authority to decide whether deicing/anti-icing is necessary, lies with the pilot-in-command."

F. <u>Briefing to Fokker Pilots With Regard to Contaminated Wings</u>

During the second half of 1992 all Fokker pilots received a personal briefing on the results of simulation studies of take off with contaminated wings. These simulation studies were performed by Fokker as part of the United States National Transportation Safety Board's investigation of the F28 accident at LaGuardia airport on March 22, 1992.
In addition all Fokker pilots received a copy of the December 1992 Flight Safety Digest, issued by the Flight Safety Foundation. This publication is almost entirely devoted to the subject of aircraft ground operations in icing conditions.

1.17.2 AFT Adverse or Cold Weather Operations

Ground deicing and anti-icing procedures were not (yet) included in the AFT BOM. As AFT operation started with only one Fokker 100, the applicable procedures contained in the AFT Fokker 100 AOM were seen as a supplement to the BOM. (See also section 1.17.1) Because the AFT operation was still in a preliminary phase, it was not yet decided if the deicing and anti-icing procedures would be incorporated into the BOM or published as separate procedures in one form or another.

1.17.3 Post-accident Publications from Fokker and the RLD with regard to Wing Ice Contamination

On March 18, 1993, Fokker issued an All Operators Message no. AOMF100-013 (and MF28.003) which revealed that wing contamination due to ice could not be excluded as a possible cause of the accident. In AOMF100-013 Fokker considered it very important to remind both F28 and Fokker 100 operators of the precautions to be taken in cold weather operation as detailed in the Fokker 100 AOM, chapter 7.13.01. The precautions mentioned in AOMF100-013 are to positively ensure that any aircraft is clean when taking off.

In March 1994 Fokker informed its F28 and Fokker 100 operators of the preliminary investigation results, based on the press release issued by the Macedonian State Accident Investigation Commission. The subject of ground icing has further been addressed by Fokker in a special (re-issue) of its Wingtips magazine and in contributions to several ground icing and de-/anti-icing related conferences.

On December 17, 1993, the RLD issued Airworthiness Directive (AD) no. 93-167(A) with regard to operating limitations and take off procedures in icing conditions for all Fokker 100 aircraft, which had to be accomplished within 10 days after issuance. The sections limitations and normal procedures of the Airplane Flight Manual (AFM) had to be revised in accordance with AD 93-167(A). In this AD the existing procedures concerning inspection for ice and snow contamination were reiterated and more emphasis was made concerning danger of contamination related to cold soaked wings in combination with visible moisture and high humidity conditions was presented. In addition an optional alternate take off rotation technique to increase stall margin during take off was presented.

This AD was revised and reissued in 1994 to mandate either a physical hands-on check that the wing leading edge and wing upper surfaces are free of ice or other contaminations before take off or that the alternate take off technique is adhered to. See also appendix 10. This AD was issued under the assumption that the airplane is operated under an approved de-/anti-icing program to clear the airplane surfaces from ice, frost, snow accumulation etcetera, such as contained in the US FAR 91.527, FAR 121.629 and its corresponding AC 120-60 or an equivalent program.

1.17.4 Training of Palair Flight Crew

The initial training program for the Fokker 100 started with 6 Palair flight crews. They attended two weeks Fokker 100 groundschool training at Fokker Aircraft, a Flight Management System instruction and five Fixed Base Simulator training sessions, which were closed with an RLD-approved examination. All flight crewmembers, except one who discontinued the training due to personal reasons, passed.

The training was continued with Full Flight Simulator training on a Fokker 100 simulator. After this, the training would be continued by line oriented flight training, after which Palair, under the supervision of the Macedonian authorities, would perform an examination. In this way the flight crewmembers would obtain a Macedonian type rating in their current Macedonian licences.

During the training of the first three flight crewmembers on the Full Flight Simulator, it became evident that Palair and the Macedonian authorities at that time could not perform the examinations on the Fokker 100. Therefore, the training program was altered and the future Palair flight crews were to be trained to obtain a Netherlands B1 (ATPL) with a type rating for the Fokker 100. After they passed the RLD-approved examination (on simulator and visual flight on the aircraft type) a Netherlands ATPL licence was issued, restricted to AFT operations only. This training was completed in December 1992.

During the initial Fokker 100 operation of Palair at Skopje, there were 8 Palair flight crewmembers with Netherlands ATPL licences who had passed examinations on the AFT Fokker 100. Route training started, to obtain 50 flying hours per Palair flight crewmember, under the supervision of AFT captains/route-instructors. Prior to the route training, the Palair flight crewmembers attended briefings with regard to the use of the AFT BOM, the Work and Rest times Regulations, the Jeppesen Navigation documentation, Flight Safety training, and the use of the aircraft flight documentation. Four AFT captains/route-instructors were involved in this operation. During the flight and route-training attention was given to the subject of take off in icing conditions including rotation techniques and the need for preflight wing inspection.

2 ANALYSIS

2.1 General

At the time of the accident the aircraft had a valid Certificate of Airworthiness. The maintenance transit check was properly carried out at Skopje Airport. The two maintenance complaints with which the aircraft arrived at Skopje played no part in the accident sequence of events.

The AFTAS and candidate Palair captain were certified and qualified for their respective tasks in accordance with company standards and RLD regulations. The CVR evidence and witness' statements indicate that the candidate Palair captain (pilot B) was controlling the airplane and performed the captain's duties and the AFTAS captain (pilot A) was performing the non flying pilot duties.

Examination of the wreckage and maintenance records revealed no evidence of preimpact failure or malfunction of the aircraft structure or systems.

From the wreckage information it could be concluded that the MLGs were in transit to the up position when the main impact took place. The nose landing gear (NLG) apparently reached the fully retracted position with the doors closed, while the MLG's most probably came very close to or even reached the fully retracted position. The down position of the landing gear selection lever may be explained by displacement as a result of the cable system fractures associated with the destruction of the fuselage during impact.

The extension of the LH tab lock-out actuator of the aileron control system may have been caused by the loss of hydraulic power supply to the aileron actuator during the impact sequence, since the lock-out actuator extends under spring force in case of loss of hydraulic power. DFDR data did not reveal any aileron control input problems. The Board also considered that the anti-upfloat cable lock may have got locked during the impact sequence as a result of the forces induced on the flight control lock cable, and that the flight control lock was not engaged during the flight.

The available evidence of the wreckage and the DFDR data revealed that the aileron, rudder, elevator, and horizontal stabilizer control systems functioned normally during the take off and the flight up to the impact.

Study of the DFDR and the CVR recordings, witnesses statements, and postaccident examination of the engines indicate that both engines functioned normally during take off and until impact. The Board determined that there were no signs of pre-impact engine damage or fire.

The SNOWTAM which was made at 11:00 stated that the runway surface condition was: Wet or water patches. The braking action was determined to be medium to good. The DFDR and the CVR evidence confirmed that the aircraft accelerated normally until lift off and that the take off run was not affected by runway contamination.

Consequently, the analysis of this accident focused on the following: The weather affecting the flight; details of the flight; wing inspection; crew performance; AFT/Palair procedures and guidance.

2.2 Prevailing Weather Conditions

The Meteorological Aviation Routine weather reports (METARs) and the Terminal Aerodrome Forecast (TAF) for Skopje Airport were prepared by the Aeronautical Meteorological Service at Skopje Airport. The temperature recorded at the airport during the time of the accident was 0° Celsius, and light snow was falling increasing to moderate snow from the beginning of the day up to the time of the accident. Several witnesses stated that the snow melted upon touching the ground. There was no visible snow on the apron, taxiway and runway prior to the accident.

The Total Air Temperature values of -1° C and -2° C recorded by the DFDR are, given the stated system accuracy of ± 0.9° C, not necessarily in disagreement with the weather reports. The -2° C values recorded while the aircraft was taxying, could demonstrate an effect of evaporative cooling, given the reported dewpoint of -1° C. That means that the entire aircraft could have been exposed to subfreezing temperatures due to this evaporative cooling effect.

The Board believes that due to the mixed precipitation (i.e. wet snow) and below-freezing dewpoint, flight 301 was exposed to conditions that were conducive to airframe icing and that the AOM cold weather procedures should have been applied.

2.3 The Flight of Palair 301 and the Loss of Lateral Control

2.3.1 Reconstruction of the Flight

This reconstruction is based on a composition of the DFDR and CVR data (See also figure 6 on page 39). Synchronization of these data was obtained by decoding the time pulses on channel 1 of the CVR tape.

The take off ground roll and acceleration were established to be normal.
"V1 Rotation" was called during second 49 (11:11:49 UTC). Rotation started during second 50 ,as indicated by the change of the nose wheel sound on the CVR, at a speed of 136 kt. Lift off occurred during second 54, at a speed of about 150 kt and at a pitch angle of 9° and an AOA of 7.5°.

Vertical acceleration (further referred to as normal acceleration) during the rotation remained initially steady at a level of 1.09g. However, from second 56 on the normal acceleration trace became "noisy". During seconds 56 and 57 the normal acceleration varied between 1.11 and 1.0g. During second 58 the normal acceleration dropped below 1.0g, to 0.95g, and at this time the aircraft started rolling to the right approximately 11°, counteracted by almost full right wing-up aileron input. During the time interval seconds 55-57 between 8 and 10° ANU elevator was maintained and pitch angle and AOA increased steadily. The pitch angle increased from 12 to 15° and the AOA increased from 9.5 to 11°. A climb rate of approximately 900 feet/minute developed and the PNF called "Positive". The second half of that word was spoken somewhat hesitant, coincident with the aircraft rolling 11° to the right (wing drop).

During second 00 (11:12:00) the aircraft returned slowly to wings level and aileron input was reduced to neutral. Elevator input which had been reduced during the previous seconds, was increased again to approximately 10° ANU. When the aircraft was level the PF called "Gear up". As a result of the reduced elevator angle during the previous second, the pitch angle and AOA had reduced slightly, to 12° and 10° respectively, but now also increased again. Airspeed was nearly constant and the aircraft kept climbing, but the normal acceleration increased also and peaked at 1.22g at second 01.

However, as the aircraft returned to wings level, the roll rate was apparently not arrested and during the next 3 seconds the aircraft rolled 50° to the left, with full left wing-up aileron input and full right rudder input to counteract. At second 04, when the aircraft was in a 50° left bank, the PNF made an exclamation to which the PF responded "What is it?". The PNF then called "Oh..Deselect!" at second 06 with considerable emphasis and the Autopilot disconnect was operated two seconds later when the aircraft started recovering from the extreme right bank angle. From the DFDR it could be established that the Autopilot had not been engaged during the flight.

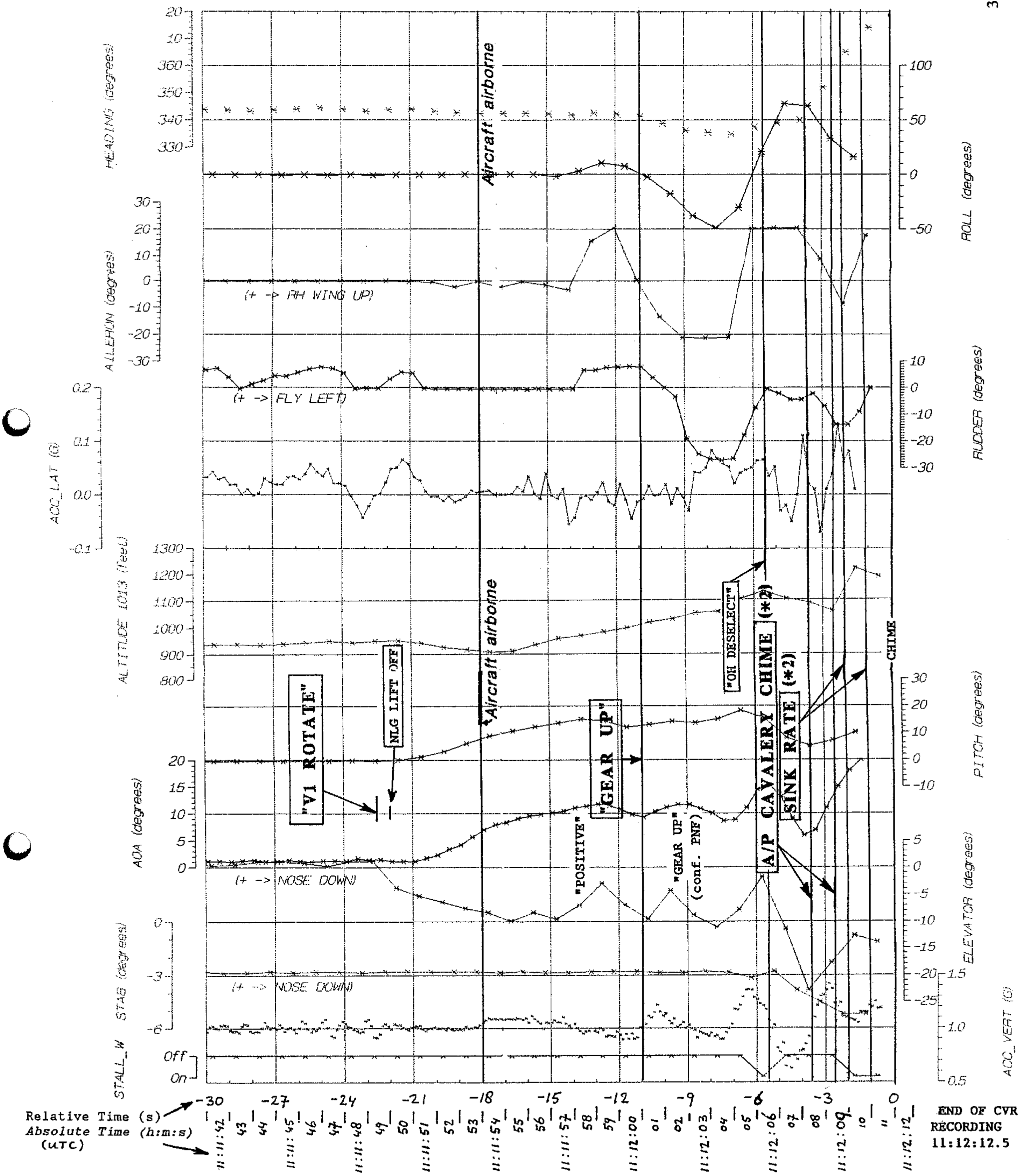
As the aircraft then started to return to wings level during second 05, rudder input was gradually reduced to nearly zero, but aileron input was reversed to full right wing-up within one second, apparently due to the developing high roll rate. The aircraft rolled extremely fast to the right through the wings level position with full right wing-up aileron input and still about 8° right rudder at the start of second 06. The maximum roll rate exceeded 50°/second and the maximum recorded roll angle to the right was 63°. During the previous roll to the left, the pitch angle had increased to 18° as a result of increased elevator input. Reducing elevator angle during second 05 when the aircraft started rolling to the right again, did not prevent a peak normal acceleration of 1.36g being generated which, however, collapsed to 0.63g only 2 seconds later when the aircraft was in a right bank of more than 60°. From second 07 until 10 the aircraft recovered to approximately 15° right bank.

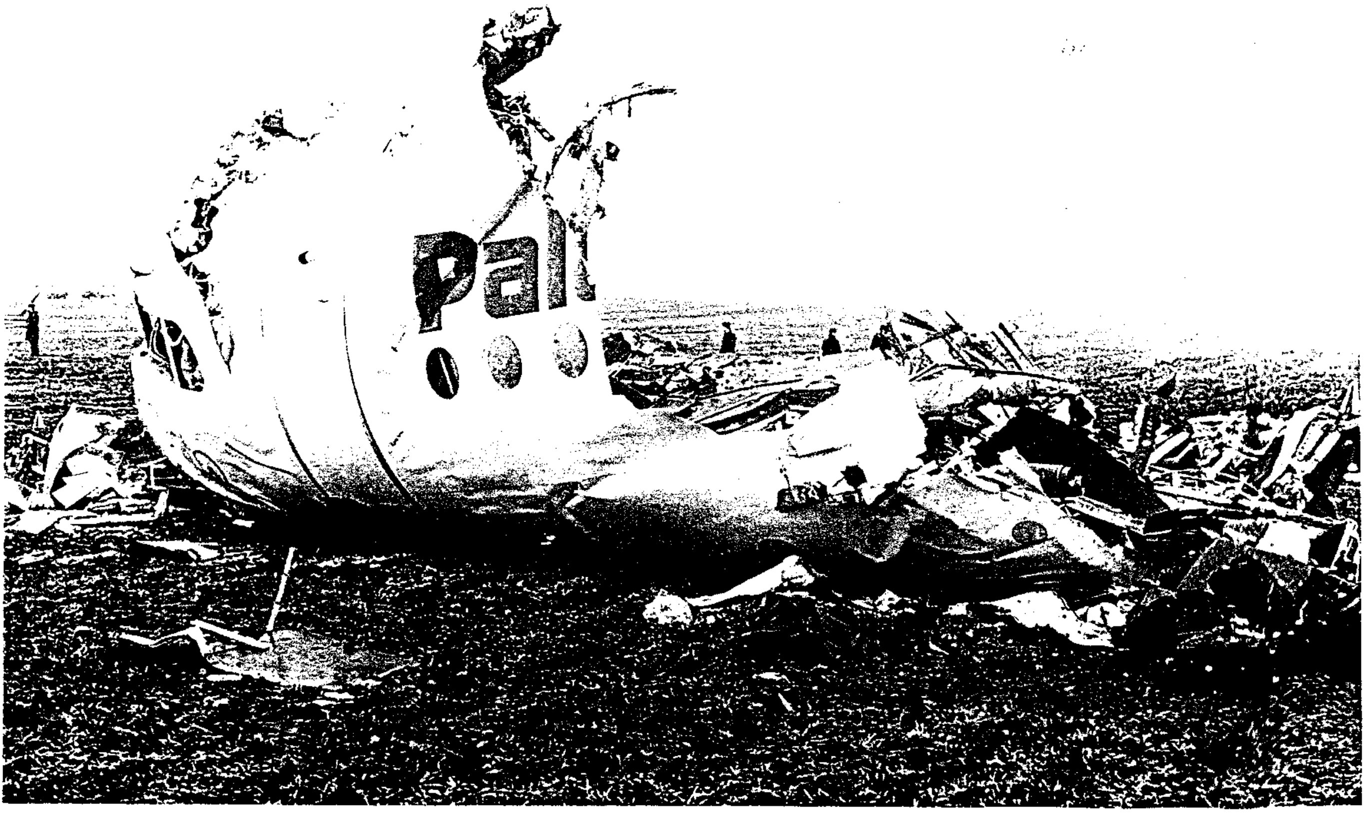
During the extreme right bank the FSE on the jumpseat called "Nose up", the elevator angle was increased to almost full ANU and the stabilizer trim setting was increased from 3 to 5.2° ANU. During the extremely fast roll to the right the stall warning system had operated briefly, but stopped since both the pitch angle and AOA reduced considerably during this manoeuvre. In response to the elevator and stabilizer trim inputs, the AOA increased again and the aircraft briefly generated a normal acceleration of approximately 1.4g and the stall warning operated again. Notwithstanding these control inputs a sink rate of approximately 2,000 feet/minute developed, according to the radio altimeter, and a GPWS Mode 3 "Sink Rate" warning sounded twice.

The final DFDR data at second 10 indicate a right bank of approximately 15°. Prior to impact however, the aircraft had rolled further to the right again, because the wreckage indicated a right bank angle at impact of approximately 90°.

Accident of SKOPJE

occurred on March 5, 1993 *F100 registered PH-KXL*





Cockpit and forward cabin section

Tail and aft cabin section

During the final phase the recorded airspeed and pressure altitude were somewhat erratic and also the engine parameters varied mildly. There is an approximate 2 seconds gap between the end of extracted DFDR data and the end of the CVR recording.

From this reconstruction it appears that the take off rotation was done at a correct speed and pitch rate. It also appears that upon lift-off slightly increased elevator input was needed to maintain pitch rate and that there was no pitch up tendency when the roll disturbances started. The correctness of the recorded aileron and roll angles was verified by analyzing appropriate fragments of the previous flight.

2.3.2 Impaired Lifting Capability

An interesting pattern is revealed when comparing the AOA and normal acceleration traces from the DFDR in figure 6, page 39.
During the rotation, at second 56, the normal acceleration becomes somewhat noisy as the AOA approaches 10°, most probably as a result of stall buffet. The normal acceleration remains above 1g until the AOA exceeds approximately 11° and the initial roll to the right develops. At second 01 the AOA has reduced to below 10° and the aircraft is briefly capable of generating a normal acceleration of more than 1g, up to 1.22g, until the AOA exceeds approximately 11° again. Another "g-break" then occurs and the aircraft rolls to the left. During second 04 the AOA is again below 10° and the normal acceleration can increase, this time to 1.36g, until the AOA exceeds approximately 11° again and another "g-break" occurs. This is repeated once more during seconds 08 and 09 which show another increase of AOA from below 10°, and increasing normal acceleration until the AOA exceeds approximately 11°. It is also apparent that each "g-break" (possibly except the last one) seems to coincide with the application of large, up to maximum, aileron deflection. But in this respect it should be noted that the sample rate of once per second of both roll angle and aileron angle could be too low to describe the relations sufficiently accurate.

This sequence demonstrates that the lifting capability of the aircraft wing was impaired above 10° AOA and limited to approximately 11° AOA whereas it would normally not stall at AOA's below 16.5° for flaps 8°. It is also clear that whereas roll control through aileron input is normally maintained into the stall, in this case this control was lost. Aileron input could even have had an adverse effect because the aircraft seems to have rolled towards the side of the downward deflected aileron, i.e. opposite to the normal direction. There is no preference for rolling in either direction in this sequence. The stall warning system (stick shaker) operated as per design when the AOA exceeded 13°. The maximum roll rate that can normally (i.e. with normal roll damping characteristics) be generated through control wheel input is approximately 20°/second on this aircraft type in this speed range.

The fact that the aircraft wing was briefly capable of generating a normal acceleration in excess of 1.0g each time the AOA had reduced to below 10°, points to a possibility of recovery if the AOA had remained below 10°. However, each time the aircraft attitude was near wings level, elevator input and pitch angle were increased possibly to follow the

Flight Director pitch-up command (since the speed was above V_2+10 kt = 148 kt in this case). Apparently the reduction of the AOA to below 10° allowed re-attachment of the airflow and lift build-up until airflow separation recurred at higher AOA. Interruption of the aircraft vibration during this phase was reported by the surviving cabin attendant.

A mechanical reason for the evidently impaired lifting capability of the aircraft can be excluded. Many people had seen the aircraft and its wing from a close distance before the take off and no damage was observed. The condition of the wing remains after the accident did not provide any indication of pre-existing damage. The recorded flight data do not support a malfunction of the flight control systems. But the weather conditions and the recorded and observed aircraft behaviour, however, support the possibility of the aircraft wing carrying ice contamination at the time of take off.

2.3.3 Further Aerodynamic Analysis

After lift off the aircraft started climbing and accelerated. The climb gradient was calculated to be less than half of what the aircraft would normally be capable of under the given conditions. Speed increased to approximately 160 kt and the height reached was approximately 150 feet. Higher numbers from the DFDR for radio and barometric altitude were presumably due to effects of bank angle and sideslip.

Further analysis of the DFDR data showed that drag increase was relatively small until an AOA of approximately 8°, but was very substantial at higher AOA's than 10°.

The apparent development of large area airflow separation above 8° AOA and particularly above 10° AOA indicates more severe effects than found in the additional windtunnel testing representing ice-accumulation on the wing tanks and relatively light contamination on the wing leading edges. This would mean that airflow separation occurred relatively forward, close to the leading edge, due to more "rough", thicker contamination than represented in that test. The coincidence of massive drag increase and loss of roll control and roll damping at AOA's above 10° indicates that airflow separation due to contamination occurred at least on the outer wingparts, but it does not exclude airflow separation also on the inner wingparts.

This analysis did not allow determination of the location and distribution of the contamination in more detail.

2.3.4 Results of the Simulation

Several pilots, including airline pilots and pilots from government agencies were, after familiarization with the fixed base Engineering Flight Simulator, confronted with flying characteristics of the Fokker 100 as affected by wing contamination. The aerodynamic model implemented in the simulator contained modified lift, drag, pitching moment, aileron effectiveness, and roll damping at larger AOA. The model could produce divergent roll oscillation upon exceeding a certain AOA, depending on the pilot's input.

When unexpectedly confronted with this modified flying behaviour, most pilots responded more or less instinctively with large aileron and rudder inputs, not unlike those recorded on the accident DFDR, to keep the aircraft wings level. Resulting flight paths were also reasonably similar to the accident flight. Large aileron and rudder inputs were not avoided because the pilots did not expect stall phenomena in this phase of the take off and at speeds well in excess of the stall speed and even in excess of the stick shaker onset speed.

Wing drop (stall buffet could not be simulated because of the fixed base) could be prevented by initially rotating to a lower pitch angle than indicated by the FD. Divergent roll oscillation could be prevented if the pitch angle was immediately reduced after a wing drop. Only a small pitch reduction would be needed to achieve this result.

The Board noted that an aerodynamic simulation model based on data from the DFDR can be expected to produce similar flight results. If such similarity is found, that does by itself not prove that the accident aircraft wings were contaminated. But the fact that modelling of expected and tested aerodynamic consequences of contaminated wings can be shown through a simulation with variable pilot input to produce flight behaviour very similar to the accident flight, is strong support for the correctness of the assumption as regards the effects of wings contamination.

A striking result is that in the accident flight only a small reduction of elevator input would have been needed to restore and maintain roll control at the initial stage of the roll oscillation. This would, however, be against the normal take off rotation technique (including following the FD) and not likely be applied, unless the pilot would be aware of what the reason for the disturbance could be. Therefore, the Board will recommend that during (recurrent) training pilots should be demonstrated the effects of wing contamination on aircraft handling and controllability. It should not be the intention to train recovery techniques, but to increase awareness of how the aircraft could behave with wing contamination and the results of control inputs.

2.4 Contamination of the Wing

2.4.1 External Inspection of the Wing

Witness statements suggest that the wing check for ice contamination was concentrated on the right inner wing. The FSE looked from the front of the wing and from behind. The check may have included a look in spanwise direction, but there are no explicit reports on this, nor of the results of such a check. Neither is there a confirmation that the left wing was checked to the same extent as the right wing. The statements of the ground handling crew indicate that the icy contamination of the flap and the wing lower surface of the left wing was not significantly different from the right wing.

Several persons have touched the wing leading edge to check for ice. However, due to the height above the ground, only tall persons would be able to touch the leading edge near the wingtip but not the wing upper surface right behind the leading edge. The FSE used a baggage cart to stand on for a check of the wing upper surface, in front of the inner wing some 2 meters outboard of the wing root. From that position the FSE could not have had a clear view of the outer wing upper surface.

In the statements of the ground handling crew, the time of the wing check was related as some 15 minutes after the second refuelling and also some 15 minutes prior to engine start. According to the fuel slip, the second refuelling was done between 10:35 and 10:45, but the refuelling itself would be completed within 2 minutes, because of the stated fuelling rate of 1,200 litres/minute. Number 2 engine start occurred at 11:05:32 according to the CVR. This does not define the time of the wing check accurately, because of the uncertainty of the refuelling time. The Board believes, however, that a time frame between 10:50 and 10:55 is a reasonable estimate. This would mean that the wing check occurred some 15 to 20 minutes prior to the take off, and approximately 1 hour 15 minutes after arrival.

At the time of the ground check the aircraft had been exposed to light precipitation, increasing to moderate, for about 1 hour 15 minutes. Without recorded data on precipitation rate and accumulation, it is difficult to assess the thickness of the precipitation layer that would have accumulated on the wing surface of the aircraft during this period. Meteorological data for visibility limited by snowfall suggest that a visibility of 1 km would relate to a water equivalent snowfall rate of approximately 1 mm/hour. There is no direct relation between actual snow layer thickness and its water equivalent if the snow has an unknown water content, i.e. is called wet.

The aircraft arrived with a relatively large amount of very cold fuel in its wing tanks, which could cause the wet snow falling on the wing surface to freeze, or produce frost. The latter is demonstrated by the frost seen at the wing lower surfaces, under the fuel tanks.

The Board believes that, under the prevailing weather conditions, it could be expected that the wing upper surface would have been covered by a thin snow layer, possibly frozen to the skin. The estimated layer thickness of 5 mm on the flaps stated by the ground handling crew is considered excessive. An important question is then, how the FSE and the accompanying ground handling crew could find that the inner wing upper surfaces were clean, i.e. "only wet of melted snow"?

It is the opinion of the Board that the results of the fuel temperature test after refuelling, conducted by Fokker Aircraft some time after the accident, point to a possible explanation for this. Although the test results described in 1.16.3 were not obtained at conditions similar to those at Skopje airport during the refuelling of Palair 301, they may provide some important trends.

The wing upper surface temperature of the collector tank and main tank compartment 1 responded rapidly to the warmer fuel being added. In the test the maximum skin temperature remained below the temperature of the fuel in the fuel truck. But on Skopje airport the temperatures of the outside air, the aircraft and the fuel in the truck were not so far apart, only the residual fuel in the aircraft tanks was much colder. It is, therefore, conceivable that during and after refuelling of Palair 301 the upper skin temperatures of the collector tank and main tank compartment 1 could have approached the fuel truck temperature closer than in the test.

This warming effect due to the added fuel being well above 0° C could, according to the test result, remain during the time between the first and second refuelling and again after the second refuelling. For an observer this could create the impression that the snow was melting on the wing just like on the ground because of the nature of the snow and the (air) temperature and not because of some other effect. This would be an illusion, however, because the outer half of the wing tank could not benefit from this warming effect and would thus collect snow. The warming effect causing the snow to melt on the inboard wing part would anyhow soon disappear after the boosterpumps were switched on prior to engine start.

It follows from the above that the condition of the inner wing upper surface, part of which can be seen from a standing point, is not necessarily representative of the contamination condition of the wing. Therefore, a check of the wings for contamination must include the outer wing parts. In this respect the Swissair V-check instructions described in 1.17.1 E are too limiting in their descriptions of what part of the wing should be checked and they should be amended.

The Board is aware that the characteristics of aircraft fuel storage and transfer systems may differ from aircraft type to type in this respect, with consequences for the way in which the contaminated condition of the upper surfaces may be affected by differences in fuel temperature. But this is in itself not consequential, as long as the wing contamination check instructions take these differences into account.

The German version of the Swissair V-check instructions (H1-113 issue 4) to be used at Zürich, directed particular attention to Clear Ice on the inner wing upper surfaces only (ice indicators area). The English version (H1E-04 issue 1) to be used at outstations, "Additional Check in Winter For Snow & Ice", referred to "Wing Upper & Lower Surfaces, Landing Gear SPC" without being specific. The note at this item, however, directed particular attention to the possibility of "...INVISIBLE ICE on the wing upper surface & wing roots area". The contents of these V-checks are also otherwise very similar, and no evidence has been presented that would explain why the instructions for a wing contamination check at outstations would have to be different from those at the home base. Therefore the Board believes that if a difference in meaning as regards the extent of the surface to be checked had been intended, this may not have been apparent to the FSE. It is also noted that according to Swissair records, the FSE had experience as a line maintenance engineer on the A310, MD80 and Fokker 100 aircraft, on the latter type since 28-02-1988. As a FSE on the Fokker 100, the assignment with Palair was his first experience and was only in its first week. In view of the FSE's extensive experience at home base Zürich, most probably including the V-check for the Fokker 100, the Board believes that this background may have caused the FSE to look only for (clear) ice on the inner wing upper surface, the area where ice-indicators were installed on the Swissair Fokker 100 fleet.
Neither of the V-checks drew explicit attention to the importance of "Small ice and snow deposits on the aerodynamic surfaces..." mentioned in the AFT Fokker 100 AOM (See section 1.17.1 B), which would call for a contamination check of the entire wing upper surface.

The "ice indicators" mentioned in the German V-check for Zürich were tufts and coloured decals similar to those applied to the McDonnell Douglas MD80 series aircraft. On the latter aircraft type, (clear) ice released from the inner wing upper surfaces during rotation and lift off has caused a string of engine ice-ingestion damage occurrences, including the loss of the SAS MD80 after take off from Stockholm/Arlanda in December 1992. Swissair had installed these features on its Fokker 100 fleet on its own initiative. The accident aircraft was not equipped with these features. According to the manufacturer, the Fokker 100 fleet in total has sofar not produced any report of engine, fan, inlet or nacelle damage attributable to ice released from the inner wing upper surface, although the presence of (clear) ice on the inner wing upper surface was occasionally reported.

When confronted with the snow/slush collected from the flaps, the FSE gave his opinion to the ground handling crew that the aircraft needed not be de-iced, that he considered the wing clean and that deposits would blow off. There is no reason to believe that his report to the flight crew as regards the need for deicing would have been different.

The Board notes that the recorded working hours of the FSE are considered excessive, even taking into account that he occasionally rested during the flights. Witness statements indicate that on the morning of the accident flight the FSE was relaxed and in a positive mood. There are no indications that his preflight activities were affected by his previous working hours.

2.4.2 Wing Contamination prior to Take Off

About 15-20 minutes elapsed between the wing-check and take off of Palair 301. During this period the wing upper surfaces in all probability became further contaminated with ice and/or snow due to the combination of:

- Continuous snowfall, increasing from light to moderate;
- The wing upper surface temperature decreasing to the estimated average fuel temperature of -5.9° C. (See section 1.16.1);
- The OAT of 0° C;
- Evaporating cooling effects of the aircraft resulting in a TAT of -2° C according to DFDR data.

2.5 Crew Performance

2.5.1 Crew Responsibilities

Based on the instructions A - F in section 1.17.1, the Board believes that the following requirements were applicable to this operation. In case of possibly conflicting requirements in the various publications, the Fokker 100 AFM requirements should prevail.

1. The captain (pilot-in-command) has the overall responsibility for the safety of the flight.

2. The pilot-in-command shall be in the left seat. In this case however, the pilot-in-command (pilot A) was giving route-instruction and therefore he was seated in the right seat. Pilot B, who was the captain-under-training and acting captain, was sitting in the left seat. (This was confirmed by witness statements and the CVR readout)

3. According to the AFT SOP the captain performs the walk around, while according to the Swissair maintenance procedures the FSE would perform the walk around. In general it is accepted that the captain, depending on training and company procedures, may delegate tasks to other qualified personnel. However, the results of the decision whether to perform deicing and/or anti-icing or not, or at least the condition of the wing surfaces, must be reported to the captain. There is no written procedure in the Swissair procedures of such a feed-back to the captain.
   According to the statement of the training captain of the incoming flight from Frankfurt (Palair flight 242), the preflight inspection at Frankfurt was carried out by the FSE and was reported to him.
   The decision whether to perform deicing and/or anti-icing must be seen as an advice to the captain, who has to make the final decision.

4. The Swissair FSE was authorized and qualified to perform the preflight inspection of the Fokker 100.

5. These regulations require an inspection for the presence of ice or snow on the wings in order to decide whether deicing or anti-icing is necessary.

2.5.2 Flight Crew Actions

Due to work and rest time limitations the crew of the previous flight was relieved by the flight crew of the accident aircraft. As the decision for relief was taken at a late stage, the flight crew arrived at the aircraft only 20 minutes prior to scheduled departure. They went immediately on board of the aircraft for flightplanning and to prepare for departure. Witness reports stated that the flight crew appeared relaxed and in no hurry.
The Board believes that the flight crew was well rested and fit for duty. Furthermore the investigation has not produced any indication of physical or psychological problems that could directly have affected their performance.

The flight crew was briefed about the weather enroute and at destination Zürich by the AFT dispatch officer. The flight crew decided to uplift an additional 2,000 pounds of fuel on top of the company standard amount of 15,000 pounds to a total of 17,000 pounds.

After preparation of the loadsheet by Palair ground handling it was checked by the PF (pilot B). Due to a calculation error a correction of +10,000 pounds was made to the TOW. Corrections for an additional person (FSE) in the cockpit were not made however.

Company standard operating procedures stipulated that the pilot-in-command (captain) has to perform the outside preflight inspection of the aircraft, however this was not done and it can be assumed that this was delegated to the FSE who was qualified for this task.

From witness statements it was established that during the ground stop de-/anti-icing of the aircraft was discussed between the FSE and the three Palair ground handling crewmembers. At that time a handful of slush was removed from the right hand and left hand inner flap surface. Since the CVR recording begins at engine start-up, only part of the preflight preparations was recorded by the CVR, and consequently there is no recorded confirmation nor any related witness statement that de-/anti-icing of the aircraft was discussed between the FSE and the flight crew, or how it was discussed. However, a statement of the previous flight crew gave an idea how such a reporting by the Swissair FSE's was done. Furthermore the Swiss FSE's skills were highly regarded as was the reputation of the Swissair company. The accident flight crew for that matter may therefore have been inclined to accept the opinion of the FSE without criticism. Anyway, no initiative or action was taken to de-/anti-ice the aircraft.

It is the opinion of the Board that based on the available aircraft condition information in relation to the actual weather condition at de-/anti-icing procedures should have been applied.

The Board established that at Skopje airport de-/anti-icing equipment was available, including heating facilities of type I fluid.

From the CVR readout it appeared that, during the pre-take off check while the aircraft was taxying, upon arming the AFCAS PROF mode after NAV mode selection, a level 1 alert was generated. This was because of a speed limit flag (SPD LIM) on the left PFD caused by a faulty flap position computer. This malfunction had also occurred on the previous flight and was written down in the aircraft technical log. Apparently the malfunction could not be corrected and was referred to base (Zürich). In the technical flightlog there was no reference made to MEL procedures for dispatch.

Pilot A identified the AFCAS mode fault as being associated with the speed limit flag which had occurred on the previous flight, and on his suggestion the PF selected the left FCC to alternate source. After this selection the FD commands and various status informations on the left PFD are supplied by the no. 2 FCC rather than the no. 1 FCC. This means that the left and right FD signals are then from the same source. The attitude indications were not affected, because these were provided by separate Inertial Reference Systems (IRS).

The Board noted that at the end of the ensuing brief discussion a wrong conclusion was drawn by pilot A that both Flight Directors (FD's) would be supplied from different sources. However, the "alternate source" selection was acceptable under the AFT DDG (MEL) provisions.

The Board notes that prior to engine start normal procedures for a new flight crew are to take a look in the technical log and read - if any have been written down - the complaints and remarks, discuss these and take the necessary actions in order to dispatch the aircraft in an airworthy condition.
From the CVR readout it can be deduced that the problem of the faulty flap position computer was known and had been discussed before. With the level 1 alert (AFCAS mode) immediate reference was made by the PNF to the associated speed limit flag on the

left PFD. A confirmation on the correct identification of the problem can also be heard from the FSE on the jump seat.
The Board could not establish why the left FCC was not selected to alternate from the beginning of the flight preparations in accordance with the AFT DDG procedures but this may have been related to the FSE working on the malfunction during the ground stop.

In view of the common source of the FD information, the Board also gave consideration to whether the accident could have resulted from the PF following incorrect FD commands from a possibly malfunctioning common no. 2 FCC. Due to the fact that the attitude presentations are unaffected as explained above, a malfunctioning FD would be obvious on both PFD's and would probably be noticed immediately by the flight crew. There were no immediate turns anticipated after take off and usually FD-pitch and roll commands are regarded as advisory at this stage of the flight. Recorded roll rates from the DFDR far exceeded the control capability of the aircraft and therefore the recorded roll excursions could not result from flight crew input.

The Board concluded that the problem of the flap position computer and the switching of the left FCC to alternate source, although causing some distraction and a minor delay, was not a contributing factor to the accident, and established that the aircraft was dispatched in an airworthy condition from a technical point of view.

According to published procedures the take off had to be preceded by a static engine run-up to take off EPR (Fokker 100 AOM and Bulletin 46). From the CVR readout it could be established that after engine start and during taxi-out nothing was mentioned with regard to this special procedure nor did any of the persons on the flight deck make any remark with regard to the weather conditions outside the aircraft at that time. From the CVR and DFDR data it could be established that a static engine run-up was not performed. The Board believes that the flight crew failed to properly assess the weather conditions as being cold weather according to the Fokker 100 AOM, section adverse weather operation and thus apply the cold weather procedures mentioned in section 1.17.1. However, the Board also determined that not performing a static engine run-up did not contribute to the accident.

Netherlands aviation regulations require the CVR to be switched on prior to the reading of the first checklist. In addition to automatic start of the CVR, when an engine fuel lever is selected to open, a DFDR/CVR ground control push button is installed, to be operated during the flight deck preparation as mentioned in the Fokker 100 AOM section 6.02.01. Since the CVR recording started at the time of engine start-up, the crew conversation and the followed checklist procedures and possible conversation with the FSE prior to that moment were not recorded. Recording of cockpit conversation prior to engine start, to include the cockpit preparation procedures, could have been of great assistance to this investigation. The fact that the decision making as regards the need for de-/anti-icing was not recorded nor covered in witness statements, precludes a determination of why the aircraft was not de-/anti-iced.

The Board considered that the weather conditions being a cold spell after several days of relatively high temperatures may have presented itself in a deceiving way. When the flight crew travelled from Skopje town to the airport it did not snow. Light snow was only encountered when they were near to the airport and the snowflakes reportedly melted on contact with the car windshield. The flight crew went immediately to the aircraft, exposed themselves to the weather minimally and concentrated their attention inside the cockpit. Somehow the pilots' mind-set may have become that the weather was not threatening the safety of the operation. A report from the FSE that the aircraft needed not be de-iced may have fitted very well in a "weather picture" that the snow melted upon contact with the ground and apparently also upon contact with the wing.

The recorded 7 minutes on the CVR prior to the accident did not contain any reference to the outside conditions including the (increasing) snowfall. And finally the exchange: [aircraft rolling to the left:] PNF: "Ahh shit", PF: "What is it?", [aircraft rolling extremely fast to the right:] PNF: "Oh deselect!" indicates clearly that neither pilot realized what the reason for the aircraft behaviour was.

The Board noted that 32 minutes elapsed between the flight crew boarding the aircraft and requesting engine start-up clearance to ATC. Whilst this time interval is considered relatively short, this cannot by itself be taken as an indication that the preflight preparations were flawed. Turn-around time for a scheduled flight can be reduced by delegating tasks to qualified personnel. Witness statements and the part of the flight preparations recorded on the CVR indicate that the flight crew worked concentrated on the preflight checklist items and was relatively relaxed in performing their tasks. The flight crew did not noticeably restrict itself in taking time to do the things they considered needed to be done, as demonstrated by the additional refuelling, the loadsheet correction and the additional "time on the runway" to complete the checks following the discussion of the effects of the flap position computer malfunction. They did not waste time and expressed satisfaction that the departure delay had been limited to "not too bad, 17 minutes delay", but no evidence has appeared that could support a position that the flight crew omitted certain actions or applied shortcuts to prevent or reduce a departure delay. The Board believes that the omission of cold weather-related actions was brought about by circumstances other than time constraints which, in the absence of a more precise identification, are described as lack of situational awareness of the flight crew and FSE as regards the icing potential of the weather conditions and the possible effects thereof.

More exposure of the flight crewmembers to the actual weather conditions, for instance by doing the walk-around check themselves, would most likely have helped to create or reinforce their weather awareness, apart from enabling their direct confrontation with the wing contamination. But in most airline operations this aspect taken by itself would not be enough reason to require the flight crew to do the walk-around check themselves. Flight operations management could and should ensure that other persons to whom such tasks are delegated are properly instructed as regards acceptability of certain conditions and related procedures.

In the opinion of the Board the circumstances of this accident indicate that the flight crew and FSE may have held different perceptions of the meaning of "clean wing" and of the acceptability of certain amounts of contamination. The nature of the organization, the relatively short time the key persons were working together and the apparent lack of consistent instructions and procedures may have prevented such a difference in perception from becoming manifest earlier.

The interaction of the pilots recorded on the CVR suggested that although both pilots were experienced captains, the PNF as training captain was in fact leading and coaching the PF rather than merely observing his conduct as a captain-under-training. Whilst this impression could be influenced somewhat by the PNF calling checklist items and the PF responding, the authority of the PNF was apparent but not such that opinions of the PF would be suppressed. Taking into account their different cultural backgrounds and both being restricted in speaking a foreign language, their communication would appear natural and respectful to each other.

It was also apparent from the CVR, that during flight preparation and taxying, including ATC communication, the attention of the pilots was very much focussed inside the cockpit. No indications were found that the weather conditions outside the aircraft had registered in the minds of either the PF or the PNF. The light to moderate snow should at least have been noticed by the PF while taxying the aircraft and by both pilots doing the flight controls check (aileron-up). The Board considers it conceivable that the actual weather circumstances and the very limitid exposure of the pilots to the actual weather conditions may have combined to an incorrect mindset about the weather. This mindset was not challenged by the FSE's report to the flight crew. The possibilities of the effects of cold soaked fuel were apparently not taken into consideration in their mindset.

The CVR leaves no room for an interpretation that there could have been mixed feelings among the pilots and FSE over a decision not to apply de- or anti-icing. Whatever the response of the PF to the FSE's report on the wing condition may have been, a decision not to apply de- or anti-icing must have had the consent of the PNF, the pilot-in-command. The general impression remains that all three persons in the cockpit believed in the correctness of what they were doing.

2.6 AFT/Palair Procedures/Guidance

2.6.1 AFT Deicing Procedures

There were no deicing or anti-icing procedures published in the Fokker 100 AOM, section adverse weather operation. Reference however, was made to anti-icing hold-over times to be published by the operator. Neither the AFT SOP nor the AFT BOM included any deicing or anti-icing procedures applicable to AFT ground operation in cold weather. However, de-/anti-icing procedures and hold-over time data were included in the Fokker 100 aircraft Maintenance Manual. Inclusion of de-/anti-icing procedures in the AFT BOM or SOP was an open action item for the operations review by the RLD. The accident occurred before this action item could be completed.

The section Adverse Weather Operation of the Fokker 100 AOM gave a general description of the effects of cold weather operation on the aircraft handling and performance, i.e. information on the effects of airframe icing, exterior inspection procedures and special engine run-up procedures prior to take off. However, at the time of the accident there were no clear instructions as to when to apply anti-icing if deicing was considered not necessary.

The Board believes that operators should submit specific guidelines and procedures to the regulating authority with regard to cold weather operation to be included or referred to in the BOM and/or SOP prior to the start of cold weather operation.

In relation to the question if publication of AFT deicing and anti-icing procedures would have prevented this accident, the Board notes that cold weather procedures that were stated in the Fokker 100 AOM (e.g. the engine run-up) were not adhered to. It is uncertain whether additional procedures would have been adhered to, but its existence might have increased the probability that someone had interrupted the misjudgment sequence leading to this accident. For prevention of this particular accident something more than written procedures was needed: Awareness of the icing potential of the weather conditions.

2.6.2 Palair Operating Environment

At the time of the accident, about one month since the start of the Fokker 100 operation with Palair, the operation was still evolving, with only one aircraft and several crews under training. Operating procedures had to be developed for the situation in the Republic of Macedonia and organizational infrastructure was complicated if existent. Schedule disturbances and last minute changes were frequent, availability of equipment irregular and communications difficult. These circumstances put a heavy burden on a relatively small number of capable and dedicated people. However, there is no indication that these circumstances were of direct influence in this accident.

This operation consisting of Palair management and crew, AFT operations and crew, and Swissair maintenance brought people together from widely different cultural, educational, and company backgrounds. Various organizational safeguards in terms of procedures and otherwise common knowledge had yet to be developed, in the absence of which the success of the operation seemed to depend on only a few individuals. There appeared to be no safeguards against errors made by these individuals.

The Board notes that lease operations in which various airline company functions are contracted from different sources, are increasing in number. The potential procedural inconsistencies and communication problems of these conglomerates require serious attention from the regulating authorities.

2.7 Further Preventive Measures Considered

2.7.1 General

Apart from the operational/procedural aspects the Board considered whether aircraft means or modification could be employed to prevent recurrence of this type of accident.

2.7.2 Use of Wing Leading Edge Heating on the Ground

The Board considered a United States Federal Aviation Administration AD no. 93-11-01, prescribing a modification on McDonnell-Douglas DC-9-10 aircraft. Like the Fokker 100 the wings of the DC-9-10 are not equipped with leading edge slats. This AD required a modification of the bleed air anti-ice system so that a hot airflow would be provided for prevention of ice formation on the wing leading edges prior to the take off. The Board decided not to recommend similar measures at this time for the Fokker 100 aircraft for the following reasons:

- Following ice-related accidents in North America more emphasis has been put on deicing and anti-icing procedures, including pre-take off (tactile) checks for wing contamination;
- this accident investigation showed that in case of cold soaked fuel, after landing (frozen) contamination may be collected on the entire wing upper surface which would not be prevented with the heating of the leading edge only;
- the mentioned modification might mislead the crew to believe that the system enabled deicing of the entire wing surfaces without spraying with deicing fluid and not solely of the wing leading edge;
- application of such a system would require engineering specific for the aircraft type to prevent overheat damage to the wing leading edge structure.

Nevertheless the Board considered that enabling of wing leading edge heating on the ground could be beneficial to further increase the effectiveness of prescribed de- and anti-icing procedures.

2.7.3 Ice Detectors

The Board notes that there is a worldwide activity in developing ice-detector technology for application to aircraft. These developments are promising but the Board considers that the systems being offered, including the associated warning systems, are not sufficiently matured at this stage to require their application. Further development should be encouraged and closely monitored.

2.8 Epilogue

In summary, it is the opinion of the Board that this accident could have been prevented if the aircraft had been de-/anti-iced. This would have been the result if:

- The flight crew had realized that under the given circumstances the aircraft needed at least an anti-ice treatment/protection, either as a consequence of their own appreciation of the weather conditions or as a consequence of the report from the FSE following his wing inspection;
- the FSE had checked the entire wing upper surface, including the outer wing parts and identified contamination requiring removal;

- reliable means had been available to detect and signal to the flight crew prior to take off that the wing surfaces were ice-contaminated.

The accident could also have been prevented if the flight crew had immediately recognized that given the weather conditions, the disturbance of the aircraft's flight path after take off could be due to wing contamination and had responded by reducing the aircraft pitch angle.

3 CONCLUSIONS

3.1 Findings

1. The crew was properly trained and certificated for the flight.

2. The aircraft was certificated, equipped and maintained in accordance with existing regulations and approved procedures.

3. There was no evidence of preexisting aircraft structural, systems, or engine faults that contributed to the accident.

4. At the time of the accident the outside air temperature at Skopje Airport was 0° C and the dew point was -1° C, and it was snowing.

5. The weather conditions during the groundstop were conducive to airframe icing and were to be considered cold weather according to the Fokker 100 AOM.

6. The aircraft arrived at Skopje Airport with a large amount of very cold fuel on board.

7. The aircraft was refuelled in two steps with an interval of approximately 45 minutes.

8. The temperature of the fuel added was above 0° C.

9. During and after refuelling warming up of the inner wing upper surfaces occurred, tending to cause any frozen deposits to melt.

10. The wing contamination check was performed approximately 15-20 minutes prior to take off.

11. At the time of the wing contamination check the wing lower surfaces and the trailing edge flaps were contaminated, and most probably also the outer wing upper surfaces.

12. The FSE performed a close visual and tactile check of the right inner wing upper surface.

13. There are no indications that the outer wing surfaces were similarly checked by the FSE.

14. The Swissair V-check instructions directed particular attention to clear ice on the inner wing upper surfaces and did not explicitly call for a check for contamination of the outer wing surfaces.

15. The flight crew did not perform, or participate in, the walk-around check.

16. As a result of boosterpump operation related to engine start, the inner wing upper surface temperature would drop below freezing level due to cold soaked fuel being mixed with the added warmer fuel.

17. Between the time of the wing contamination check and the take off further wing contamination accumulated due to the continuous snowfall and the lowered wing surface temperature.

18. Prior to take off the aircraft was not sprayed with deicing or anti-icing fluid.

19. The aircraft acceleration and lift off were normal.

20. The take off rotation was performed at a correct speed and pitch rate.

21. The aircraft behaviour and performance after take off were typical for wings contaminated with ice.

22. The wing lifting capability was limited to an AOA of approximately 11°.

23. The flight crew and the FSE underestimated the potential dangers of the weather conditions in combination with cold soaked fuel.

24. The flight crew did not comply with the prescribed cold weather operation procedures as regards engine run-up.

25. There are no indications that the flight crew considered the actual weather conditions as a cold weather operation according to the Fokker 100 AOM.

26. This multi-sources operation had insufficient procedural consistency.

27. Essential information with regard to crew conversation and checklist procedures was not recorded prior to engine start-up.

3.2 Cause

The Board determined that impact with the ground in a steep right bank shortly after lift off was caused by loss of roll controllability due to contamination of the wings with ice. This situation resulted from an omission to carry out spraying of the aircraft with deicing or anti-icing fluid in meteorological conditions conducive to icing, due to a lack of ice-awareness of the flight crew and the Flying Station Engineer. Contributing factors were a lack of common background and procedures in a difficult multi-sources operational environment.

4 RECOMMENDATIONS

Since the circumstances leading to this accident are not limited to the Republic of Macedonia, the Netherlands Aviation Safety Board provides the following recommendations to airworthiness authorities, airlines, aircraft manufacturers, flight training institutes, and equipment manufacturers.

4.1 Review airline operating instructions and training materials to ensure that these include criteria for flight and ground crews for the application of anti-icing as well as deicing. Ensure that these highlight the pitfalls in judging the contamination condition of the wings at temperatures around the freezing level when the fuel tanks contain cold soaked fuel, taking also into account the operation of the aircraft fuel system where applicable.

4.2 Develop flight simulation facilities that can represent aircraft handling characteristics in take off as affected by wing contamination, and include a simulator demonstration with such affected handling characteristics in initial and/or recurrent pilot training to increase pilot awareness of how the aircraft could behave with wing contamination and the results of control input.

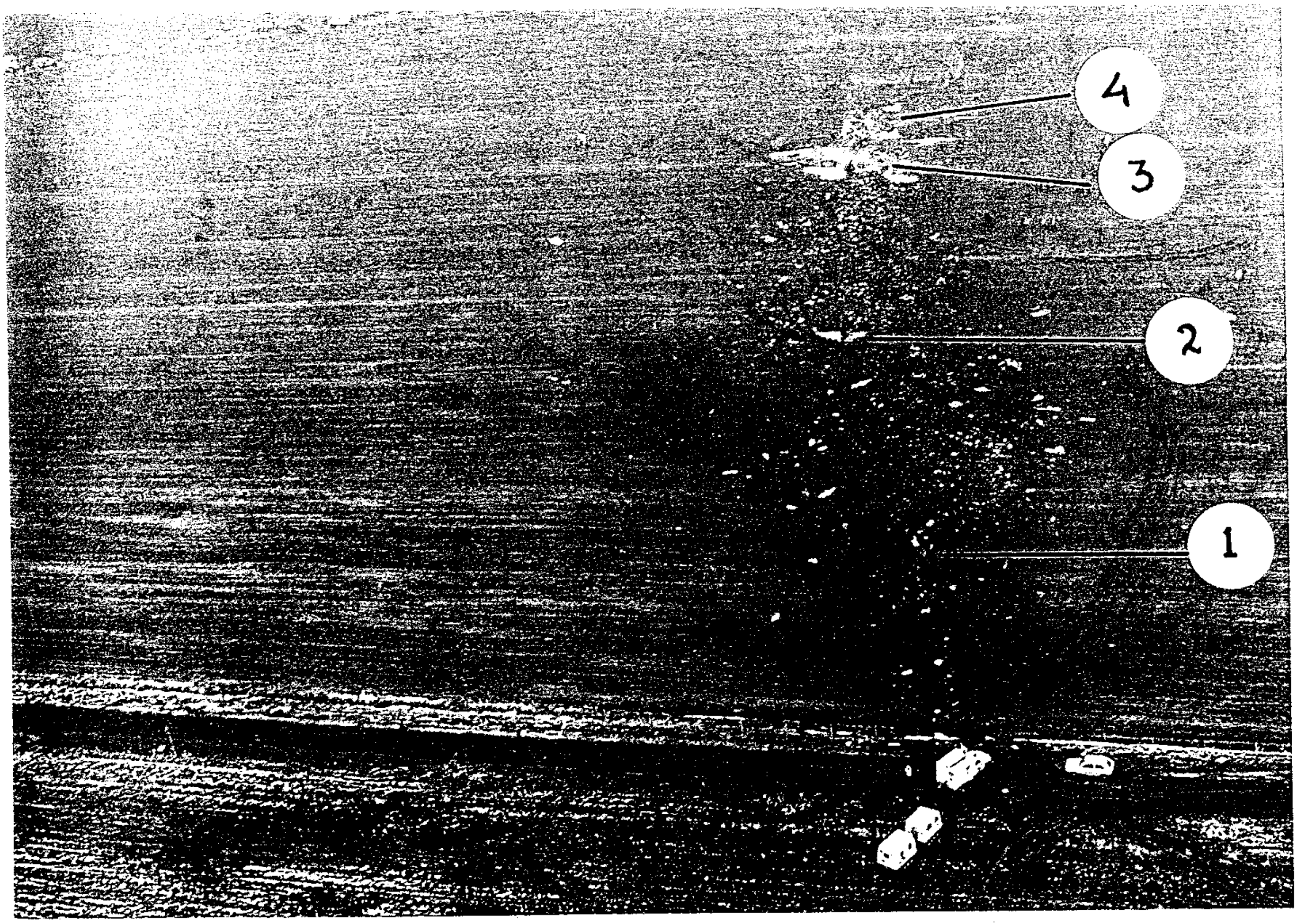
4.3 Stimulate the development of means to assist the flight crews in detecting frozen contamination on critical aircraft surfaces prior to take off.

4.4 Review operational regulations and airline operating procedures to ensure that CVR operation is started automatically or by crew action at the beginning of the flight preparation procedures. Ensure sufficient CVR-recording capability to retain the entire flight preparation at least until take off.

4.5 The regulating authority should require submission of specific guidelines and procedures for cold weather flight operation from airline operators prior to the start of such operations.

4.6 Approval of (lease) operations that involve aircraft, crews, operations and/or maintenance support, or other airline functions contracted from different sources, should be subjected to thorough review of procedural consistency.

PHOTOGRAPHS



1. Main impact area
2. Stabilizer and top of fin
3. Tail and aft cabin section
4. Cockpit and forward cabin section

APPENDIX 2

TRANSCRIPT CVR

PF : Pilot Flying (Pilot B)
PNF : Pilot Not Flying (Pilot A)
FSE : Flying Station Engineer
PA : Public Address

Elapsed Time [min:sec]	Originator	
00:01	PNF	It's not only twenty also wait for N1 indication
00:04		[Chime]
00:10	Ground Engineer	You can start number one
	PF	Number one
00:20	PF	Oil pressure, N2
00:27	PF	Yes, fuel
	PNF	Go ahead
00:46	PF	Everything OK, thank you, Good Bye. After take off check
	PNF	After take off checklist
	PF	Sorry after start check
00:52	PF	22 yes
00:56	PF	OK, after starting checklist
00:57	PNF	Anti-icing
		[Beep from Ground Engineer plugging out]
	PF	I put anti-ice on and set this to auto
01:04	PNF	Engine panel
	PF	Checked
01:05	PNF	Flaps
	PF	Set for take off 8
01:10	PNF	Fuel levers
	PF	Checked open
01:14	PNF	Trims
	PF	22 You set
01:16		[Stabilizer trim "Whooler" 2x]
01:20	PNF	And door selecters I do it. Cabin crew door selectors man, automatic please
01:28	PNF	Checklist completed
01:29	PF	Request taxi

03:52	PF	Yes it disappeared
	PNF	Yes it disappeared ok
03:55	PF	Ok, continue with checklist
03:56	PNF	Only what we have to realise, we have now the same source hé ?
	PF	Ja, I have from you
	PNF	Ja, it should, no it's the FCC from number 3 that's not the common source....
04:10		That's acceptable, if you have two, than you have common source. Ok continue with the checklist
	TOWER call	Palair 301 reclearance climb to 120 flight level. Sir, now you back for take off.
	PNF	Flight level 120, and we need a minute on the runway
	TOWER	That's OK
04:30	PNF	OK, No hurry
04:33	PNF	Before take off, flight instruments are checked
	PF	Left side checked
	PNF	Flight mode panel is set, brake temperatures in the green
04:40	PNF	Take off data and briefing
	PF	Normal standard, speeds 134, 1, 146
04:47	PNF	Ja
	PF	Briefing is standard
	PNF	OK
04:52	PNF	The flight controls are checked, radar and transponder are set, I switch on my radar
04:58	PF	Maybe, we should switch the radar on and put the tilt about 5 to 6 up
	PNF	5 or 6, yes
	PF	Yes, there may be some kind of CB
05:05	PNF	The liftdumpers are armed, below the line
05:07	PF	Below the line
05:09	PNF	APU is OFF, take off configuration, normal checklist completed
	PF	OK
05:17	PNF	We wait for the clearance
05:20	PNF	Palair 301 is ready
05:23	TOWER	Call you back shortly Sir
05:24	PNF	Roger
05:34	TOWER	301 cleared for take off wind is from 010 degrees 3 knots
05:35	PNF	301 cleared for take off
05:42	PNF	The lights.... [Ding Dong]. Yes...... and you can take your hand here...... ja
05:53	PF	Take off
05:56	PNF	Checked
06:06	PNF	Thrust checked
	PF	Roger
06:23	PNF	V-one Rotate
06:33	PNF	Positive

01:30	PNF	Palair 301 request taxi
	CABIN	Door selectors automatic
01:32	PNF	Thank you
01:36	TOWER	PMK 301 Taxi to holding point for Runway 34
01:38	PNF	Taxi holding point 34
01:40	PF	Right side
	PNF	The clock to run...two
01:49	PNF	Ah, not too bad 17 minutes delay, we were not supposed to fly, because it was a work and rest time limitation of the other crew, but we did not anticipate on that, so a bit late. [Response from FSE on the jumpseat]
01:30 till 01:50	PA	Oxygen mask etc.
02:10	CABIN	[Reports ready]
02:20	PNF	Thank you
	PF	Vala
02:25	PF	Unlock flight controls
02:26	PNF	Unlocked the flight controls
02:27	PF	And before take off checklist
	PNF	Before take off checklist
02:29	PNF	Left
	PF	Checked
02:32	PNF	OK, right up here
02:38	PNF	Ja
02:40	PNF	And the liftdumpers, auto throttle, NAV and PROF [Chime]
02:46	PNF	AFCAS mode
02:51	TOWER	Are you ready to copy Palair 301 ?
02:53	PNF	Go ahead
02:57	TOWER	Cleared to destination flight level 280 is approved. After departure follow Ribno One Delta squawk 6001
03:05	PNF	Roger, cleared to destination flight level 280 Ribno One Delta departure squawk 6001
03:13	TOWER	Copied correctly, continue line up, call you back for departure due separation Sir
03:20	PNF	Eh, Roger, line up and hold
03:22	PNF	Ok, we check the, it's probably by the cause of the speed limit you have
03:23	PF	Ja
03:38	PNF	I think that's a consequential failure
	PF	Yes I have on my side (*) speed limit flag, yes because of the flaps
(*)	FSE	Ja [on background]
	PNF	Yes that's why he went to alternate, if you go alternate
	PF	I will try

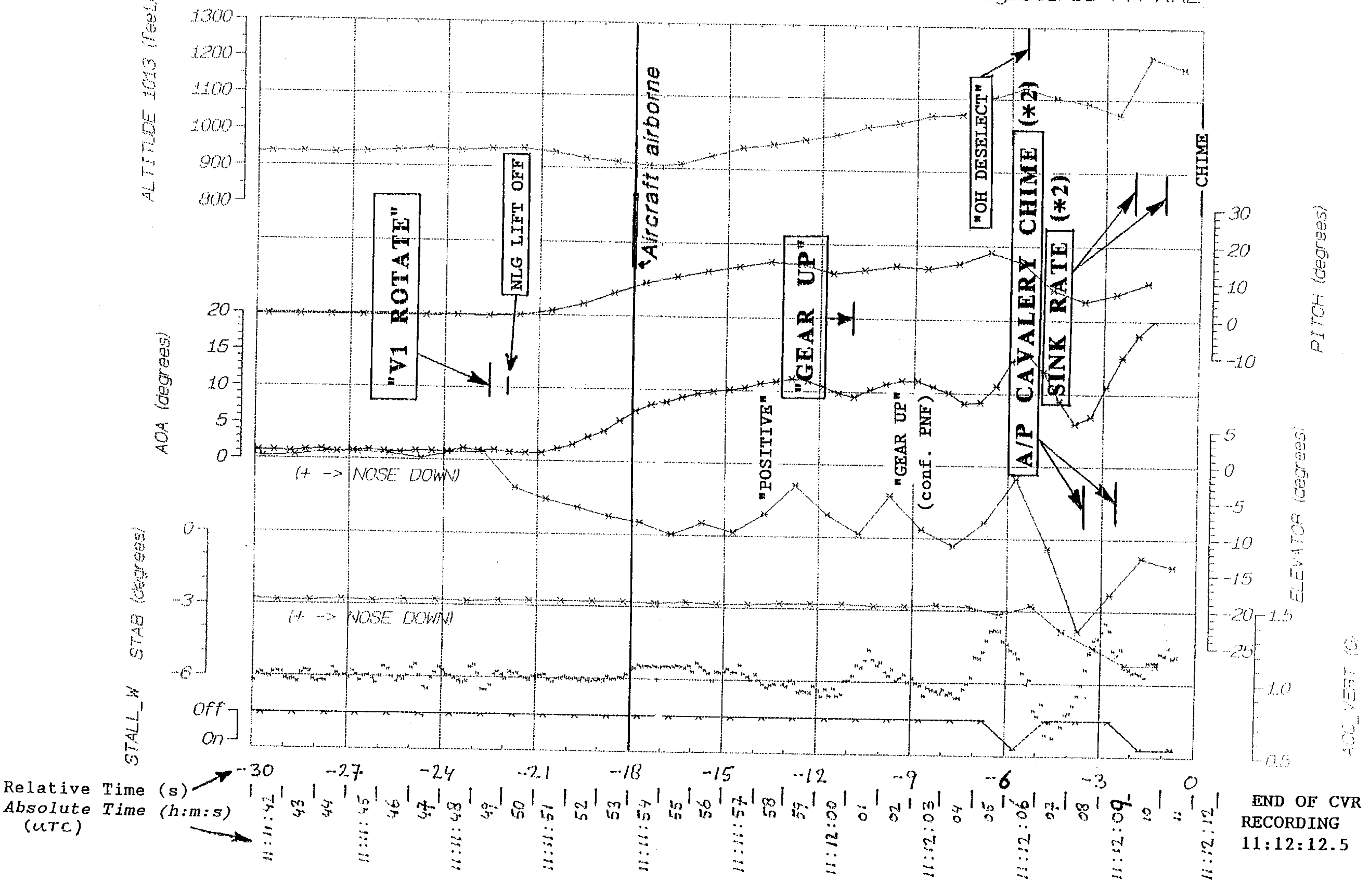
06:36	PF	Gear up
06:38	PNF	Gear up
06:39	PNF	Ahh shit
06:40	PF	What is it ?
	PNF	Oh deselect !
	FSE	Nose up
06:43		[AP Cavalry chime 2x]
06:45		[Sink rate 2x]
06:48		Oh .....

[end of recording]

Accident of SKOPJE

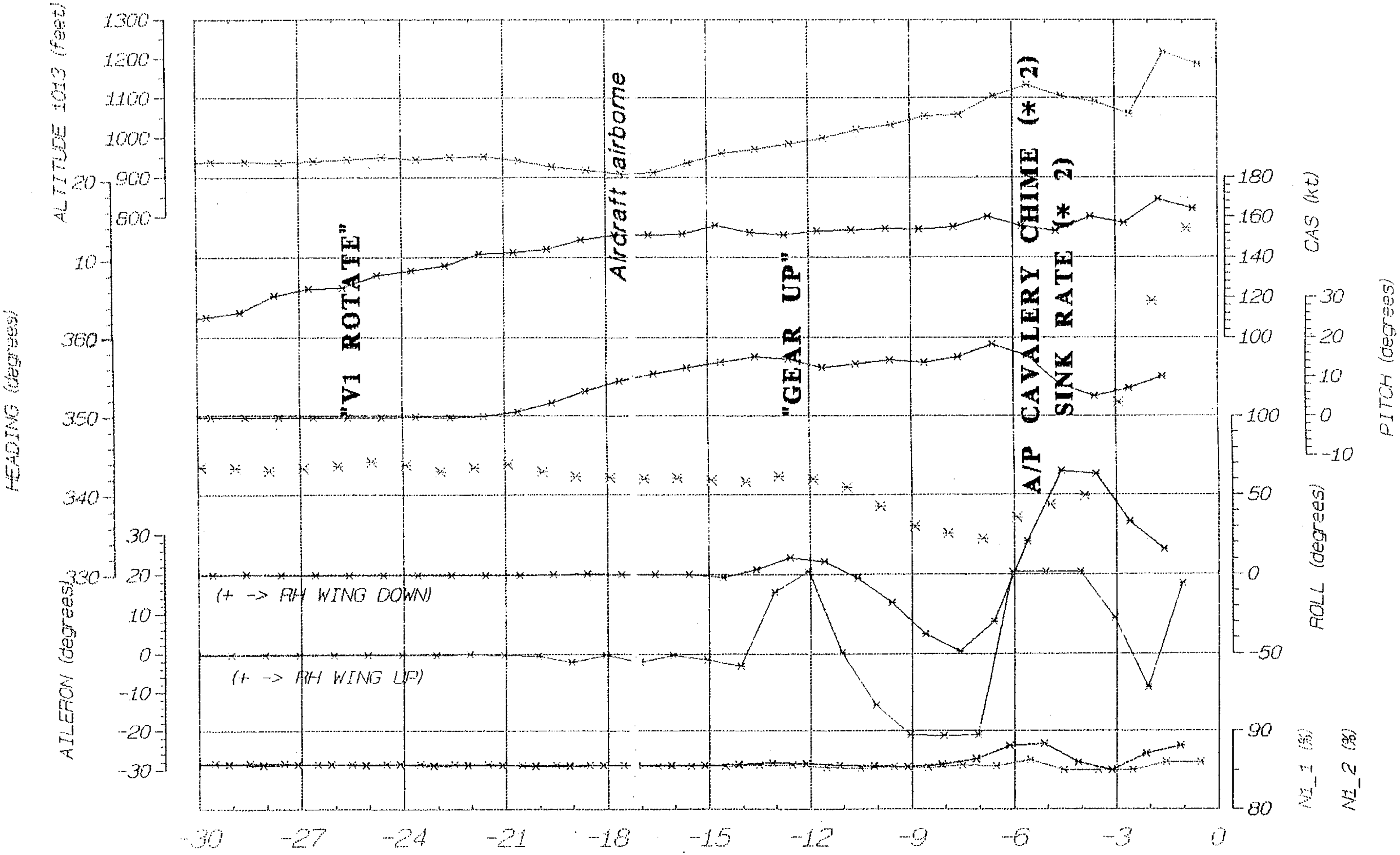
occurred on March 5, 1993

F100 registered PH-KXL



Accident of SKOPJE

occurred on March 5, 1993 *F100 registered PH-KXL*



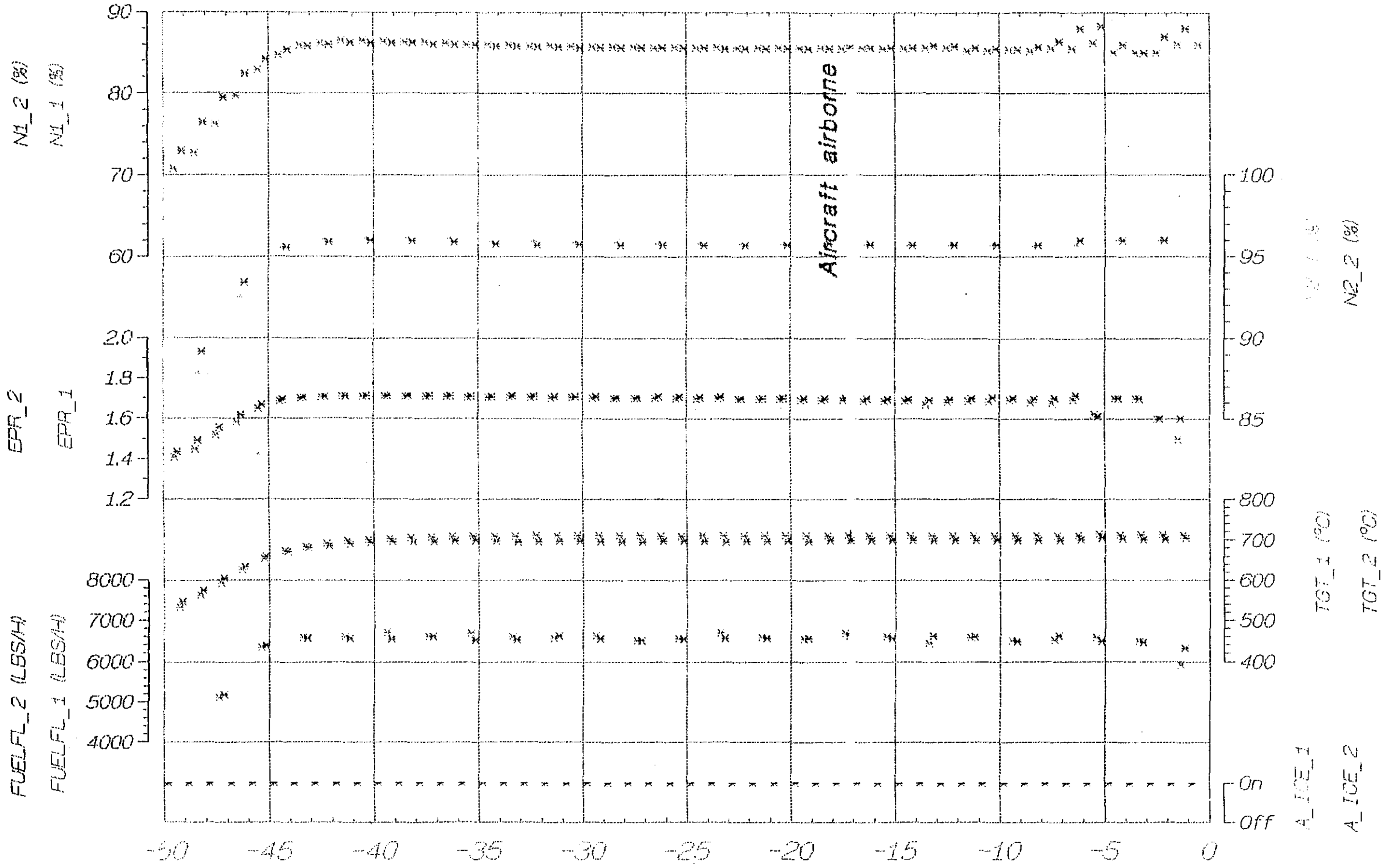
Airline PAL AIR

Laboratoire B.E.A.

Plotted: March 25, 1993

Accident of SKOPJE

occurred on March 5, 1993 F100 registered PH-KXL



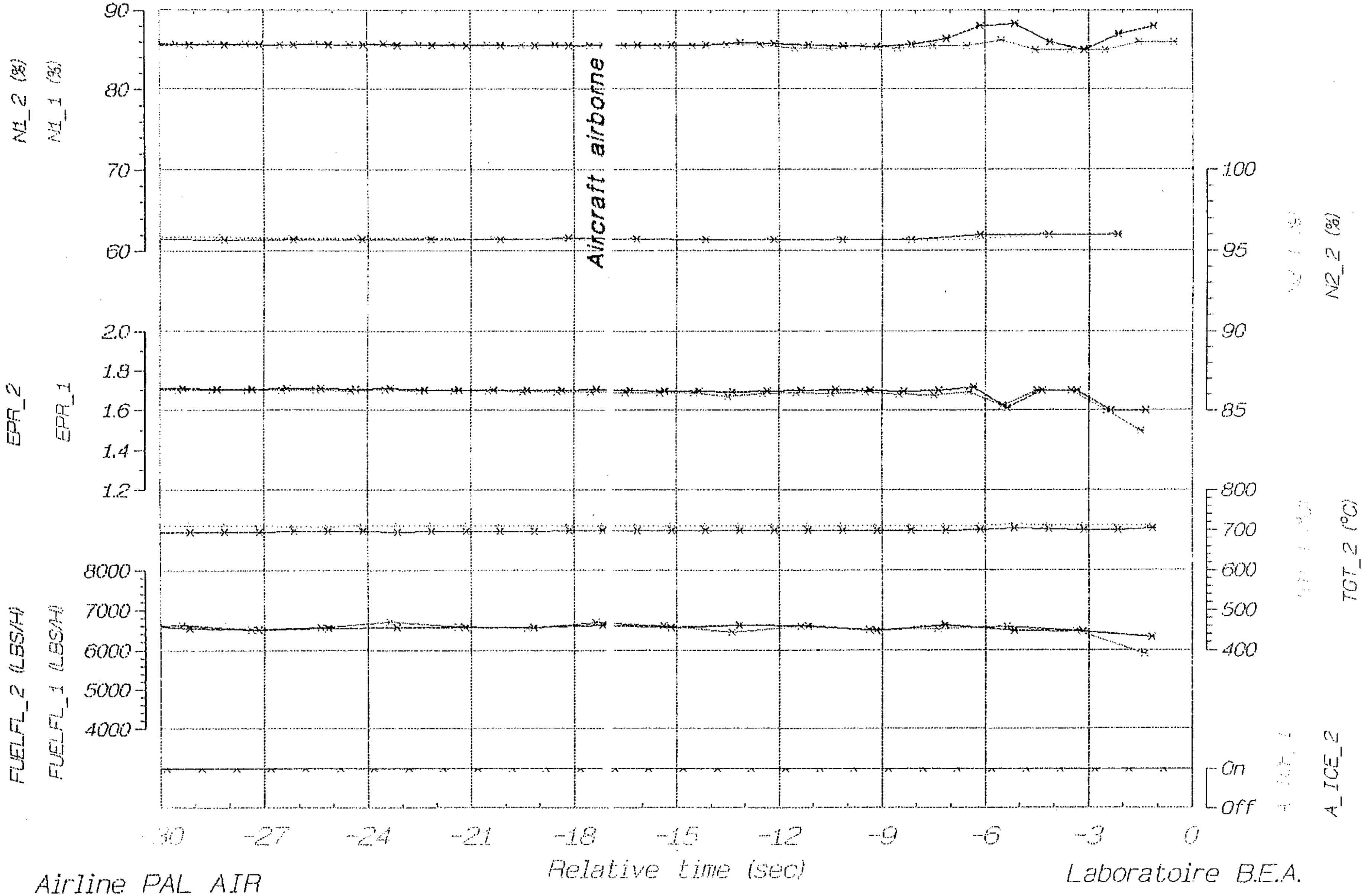
Airline PAL AIR

Laboratoire B.E.A.

Plotted: March 24, 1993

Accident of SKOPJE

occurred on March 5, 1993 F100 registered PH-KXL



Airline PAL AIR

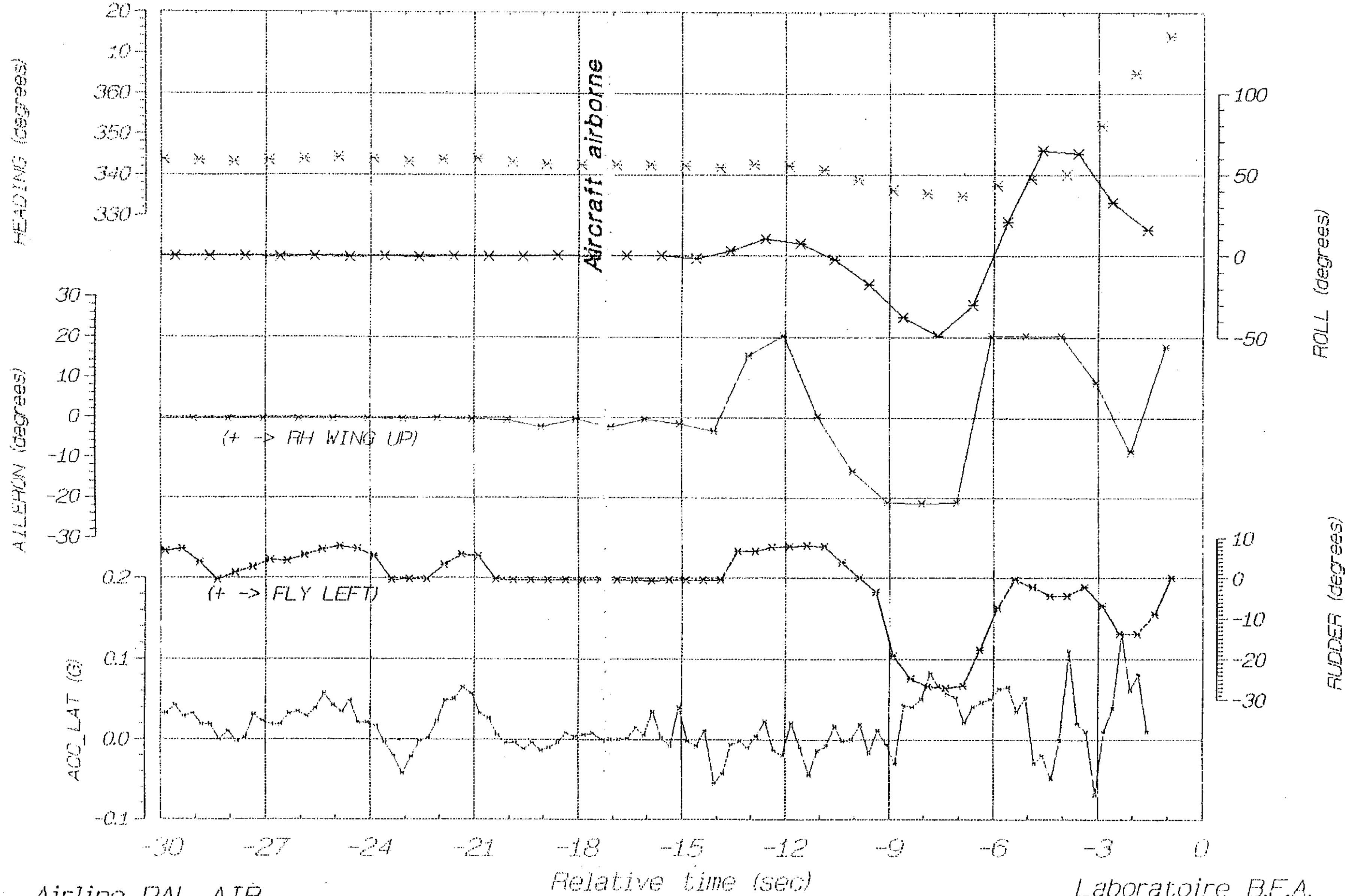
Laboratoire B.E.A.

Plotted: March 24, 1993

Accident of SKOPJE

occurred on March 5, 1993

F100 registered PH-KXL



Airline PAL AIR

Laboratoire B.E.A.

Plotted March 24 1993

APPENDIX 4

AIRFRAME DAMAGE

Front Fuselage and Cockpit

The cockpit section was heavily damaged at the right hand side, actually the entire right hand side was torn off. The left hand side was distorted but still in shape up- to the third cabin window. The wrinkling and cracking of this part indicated fuselage bending to the left (relative to the normal aircraft's attitude). The passenger door and its surroundings were relatively undeformed. The flightdeck was crushed and destroyed.

For the presentation of the flight information in the cockpit, the Fokker 100 is equipped with an Electronic Flight Instrument System (EFIS). Therefore it was not possible to establish instrument indications at the moment of impact, except for the following indications:

- Throttle levers: take off thrust position (fully forward) (*)
- Landing gear lever: gear down (*)
- Flap lever: 8° flaps down
- Engine ignition: continuous
- Engine anti-ice: on
- Left FCC switched to alternate.

(*) Note: Lever positions unreliable due to impact forces.

The windshields and the left hand aft cockpit window were still in place but damaged (the latter most probably by the rescue team), both sliding windows were found along the wreckage path and the right hand aft cockpit window frame was found early in the wreckage trail.

The missing parts of the right side indicated an impact plane oriented as 90° right bank and 15° - 20° nose down pitch. From the galley only very small parts were found back along the wreckage path. The forward cabin attendant seat, facing backwards next to the main entrance door, was damaged but still in position.

The cabin area was completely destroyed, all seats, seat tracks, luggage bins and lining were torn off and found along the wreckage path, only some of the floor beams and supporting structure remain attached to this section of the aircraft. The lower part of this aircraft section, the cargo compartment, avionics bay and nose wheel bay were relatively intact, except for the right hand side that was destroyed and dispersed. The nose gear was found in the retracted position and the nose gear doors closed. On this fuselage section no evidence of fire could be traced.

Center Fuselage Section

From the fuselage section, between the cockpit section and the wing, only the left hand and bottom side of the skin, including 10 cabin windows, and crushed parts of the floorbeam structure were found. No signs of fire could be traced.

Rear Fuselage and Empennage

The rear fuselage and empennage from was found as one piece at the location of the main wreckage. The cabin section up to the rear pressure bulkhead was severely attacked by post impact fire, the whole upper part until just below floor level was completely destroyed by fire.

The empennage aft of the rear pressure bulkhead received minor damage compared with the rest but was completely covered by sooting. Just behind the right hand stubwing there was a hole in the skin of roughly 75 by 50 centimeters, of which the skin edges were bent inwards. Further there were some small holes in this section caused by impact of loose fragments.

The vertical stabilizer and rudder were broken at the vertical stabilizer, rib 3.4, and showed some small penetration holes. The leading edge of this part of the vertical stabilizer showed two impact strikes, the dorsal fin one.

Both engines were separated and the stubwings were heavily damaged. The right hand forward engine hanger was attached to the engine together with the attachment fitting and a part of the partial bulkhead. The aft engine hanger was still attached to the rear fuselage part and was bent rearwards over the shackles. The left hand forward engine hanger was also still attached to the engine including the attachment fitting. The outboard end of the left hand aft engine hanger, which remained attached to the rear fuselage, was slightly twisted in forward and upward direction.

The cabin section in front of the rear pressure bulkhead was completely destroyed by fire and the whole underfloor compartment was filled with remains of melted and burned materials. The aft cargo door was still intact and in closed position. At the front of this section some completely crushed parts of the hydraulic tunnel and wheelwell structure were present. These parts showed hardly any fire damage.

The Right Wing

The right hand wing was completely disintegrated and the parts were found from the very beginning up to the end of the wreckage trail. Both flaps including the flap vanes were separated as complete units and incurred only minor damage as far as visible from the outside.

The right hand wing to fuselage connection was found on its own, the outer wing as well as the centre wing were torn away just outside the heavy connection ribs. Only the front and rear spar end fittings and the coupling fitting in the middle as well as the side stay bracket remained attached to this section. Between the middle and rear spar end fitting, the aft lower part of the rear overwing emergency exit aperture was still present. Post impact fire was visible on all above mentioned parts.

The right hand main landing gear was found in one piece, still attached to the main landing gear bracket. The latter was torn out of the wing structure. Broken parts of the side stay supporting beam, side stay member and the main gear actuator remained attached to the gear and main landing gear bracket. The gear was found in an extended position in relation to the main landing gear bracket, but due to damaged and missing parts it could not be determined whether this gear was extended or retracted during impact.

The Left Wing

The recovered part of the left hand wing was found with the main wreckage. Both flaps and the flaptrack beams were still attached to the wing. The front spar and lower skin (with Z stringers) of the centre wing section were still attached to the left hand wing. A part of the fuselage side panel structure, containing the aperture of the aft rear overwing emergency exit and 3½ cabin windows thereafter, remained attached to the upper side of the wing to fuselage connection.

The upper skin of the wing near the wing to fuselage connection in outboard direction along with the inner structure, wing ribs, front and rear spar were heavily damaged by fire. On the inboard part of this wing the fire damage was less and here the upper skin, and the two most inboard lift dumper panels were intact .

The outer wingpart, which separated in one piece, and the lower parts of both flap track fairings including the flap track fairing doors were found along the wreckage trail.

The left hand main landing gear remained attached to the wing in retracted position and suffered severe fire damage. It did not show signs of forced retraction.

Stabilizer

The horizontal stabilizer was found upside down along the wreckage trail. The vertical fin and rudder were broken roughly along a line at rib 3.4 and the edges of the honeycomb skin panels were slightly bent to the left. The outboard part of the right hand horizontal stabilizer and elevator were both separated from the aircraft and were found at different locations along the wreckage trail.

The left hand horizontal stabilizer was still intact except for the tip and leading edges which sustained severe damage. The leading edge of the vertical stabilizer and the front and upper part of the tail cone were missing. The bullet fairing was found in a reasonable shape. All parts showed fire damage or sooting.

APPENDIX 5

COLLECTED DATA FOR FUEL CALCULATIONS

Collected data from incoming flight Palair flight PMK242 (Frankfurt - Skopje):

- The PH-KXL made a night stop at Frankfurt from 4 - 5 March.
- Flight PMK242 refuelled at Frankfurt between 07:10 - 07:30 LT. The total amount of fuel in the tanks was 22,000 lbs. (Fuel policy; fuel at Frankfurt is cheaper than in Skopje) Fuel temperature was 4° C. Wheather at Frankfurt: "Fine and dry".
- Departure Frankfurt at 07:27 LT, total airtime: 02:09 hours, cruising level FL330 with -46° C SAT, arrival Skopje at 10:36 LT.
- Fuel used: 10,500 lbs, remaining fuel at Skopje: 11,640 lbs.

Collected data with regard to departure flight PMK301 (Skopje - Zürich):

- On March 4, the fuel truck at Skopje Airport was filled with 23,600 liters fuel at 21:00 LT. Total capacity fuel truck is 25,000 liters. Fuel flow during refuelling of aircraft is approx. 1,200 liters/minute.
- On March 5, at 08:00 LT, the fuel temperature in the fuel truck was 4° C.
- Between 08:15 - 08:25 LT a Tupolev was refuelled with 3,500 liters of fuel.
- Between approx. 10:55 - 11:00 LT, the PH-KXL was refuelled with 2,000 liters of fuel, (refuelled up to the standard total amount of approx. 15,000 lbs in the aircraft).
  After arrival of the new crew, the aircraft was refuelled with an additional 1,080 liters of fuel between 11:35 - 11:45 LT. (Total amount of fuel being refuelled in the PH-KXL was 3,080 liters, this is approx. 5,430 lbs). Total fuel on board: 17,070 lbs, this is equal to full wing tanks.
- The Meteorological Office at Skopje Airport measured the following Outside Air Temperatures on March 5: [LT/degrees C]
  01:00/3, 02:00/0, 03:00/-4, 04:00/-8, 05:00/-12, 06:00/-10, 07:00/-8, 08:00/0, 09:00/-2, 10:00/0, 11:00/0, 12:00/4, 13:00/4.
- On March 10, fuel samples were taken from the sealed fuel truck. The report on the fuel samples was in Macedonian language. The information that the fuel did not show any perculiarities was passed orally.

APPENDIX 6

FOKKER 100 FUEL TANK TEMPERATURE CALCULATIONS

Een onderneming van
Deutsche Aerospace

REPORT
Fokker Aircraft B.V.
Amsterdam
The Netherlands

	issue date: September 19,1994 issue 1
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L.J. Noordermeer	MPTJ
B.V.O.	via EQFA

title:

Fuel tank temperature calculations related to the F28 Mk0100 take off accident at Skopje, March 5, 1993

Summary

This report provides an estimation of the average temperature of the fuel in the aircraft's wing tanks during the period on the apron at Skopje and at the time of the crash.

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department / prepared EQFA H.C. Visser	department / checked EDBS W. Overmars	original issue date September 19, 1994
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report no.
FR-100-04

1. Introduction

On March 5, 1993, the F28Mk0100 aircraft PH-KXL, s/n 11393, experienced a roll control problem immediately after lift--off from Skopje airport and collided with the ground just beyond the runway. This roll control problem was probably related to ice contamination on the aircraft's wings. This report provides an estimation of the average temperature of the fuel in the aircraft's wing tanks during the period on the apron at Skopje and at the time of the crash.

Throughout the report it is assumed that the fuel in the aircraft's wing tanks is perfectly mixed at any time covered by the calculations. The results of the calculations discussed below are presented in figure 3.

2. Basic and pertinent data, relations and assumptions

All times are UTC, unless indicated otherwise.

2.1. During the night prior to the flight from Frankfurt to Skopje the aircraft sat on the apron at Frankfurt with 3650 kg (m_1) of fuel on board. The center wing tank was empty. The outside air temperature (OAT) during flight preparation was 0 °C which is also assumed to represent (and, given the time of the day, fairly accurate) the temperature of the main wing tank structure and its fuel contents (T_1).

From about 6:10 to 6:30, 6420 kg of fuel was added, leading to a total fuel quantity on board of 10070 kg which is close to the maximum of 10256 kg (thus: main wing tanks completely full with 7744 kg, center wing tank almost full with 2326 kg of fuel - maximum is 2512 kg).

Temperature of the added fuel was reportedly 4 °C (T_2). Since the center wing tank was only filled with fresh fuel, the temperature of its contents directly after fuelling is also 4 °C. Because of the close proximity of the center wing tank to the relative warm passenger cabin and the outflow valves which dump the cabin air underneath the center wing tank, it is assumed that the center wing tank contents do not decrease in temperature with lower OAT either on the ground or in flight.

If completely mixed the temperature (T) of the resulting amount of fuel in the main wing tanks, following the addi-

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tion of m2 = 7744 - 3650 = 4094 kg, is given by:

$$T = \frac{T_1 m_1 + T_2 m_2}{m_1 + m_2}$$

For the calculation of the temperature decrease of the fuel in the main wing tanks between fuelling and take-off the following equation has been applied (time t and time constant 3.5 expressed in hours):

$$T(t) = OAT + (T(0) - OAT)\, e^{-\frac{t}{3.5}}$$

Refer to the following sections and especially section 2.3.2 for the origin of this equation. The calculation has been done for the period from 6:20 (fuelling halfway) and 7:27 (take-off).

2.2. During flight (from 7:27 to 9:36) the temperature of the fuel in the main wing tanks will decrease due to the low (total) air temperature at altitude. A Rolls Royce study (ref. Rolls Royce Component Research Report IHR.10025) suggests the following empirical equation for the fuel temperature T at time t (in hours) in a flight at a specified total air temperature (TAT):

$$T(t) = TAT + (T(0) - TAT)\, e^{-\frac{t}{2}}$$

Since this equation was derived from flight test results of the Comet, VC10 and Super VC10, two flights of the Fokker 100 Q1 prototype (with about the same initial amount of fuel on board as in the flight from Frankfurt to Skopje) have been used to verify its validity for the Fokker 100. (The Fokker 100 has a feature which may be of significance in this respect, viz. the continuous circulation of part of the fuel contents via upper skin stringers on the inboard wing inner surface. In principle it may be expected that this feature leads to a quicker heat exchange between the fuel and the air than on aircraft without such a circulation system.)

In figure 1 the measured TAT and LH and RH collector tank

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fuel temperature (TFCT1 and TFCT2) are plotted against time for these two flights. When the above presented equation is used to calculate the fuel temperature, it can be seen that the calculated temperature decreases less than recorded during actual flight. This is especially true for flight 270 which is the more significant of the two because of the large reduction in TAT and the long duration of the flight. It can also be seen that with an adjustment of the time constant from 2 to 1.4 hours the equation fairly well approximates the actual fuel temperature decrease. Therefore, this value of the time constant has been used to estimate the fuel temperature reduction during the flight from Frankfurt to Skopje.

Two further refinements have been done after a comparison between measured fuel temperature data on a very long B747 flight and the results of the above equation (with time constant 1.4 hours) applied to that flight (ref. figure 4, taken from NASA Contractor Report 135198). The refinement suggested by figure 4 is that TAT is not the governing parameter, but TAT*, representing a 90% effective recovery term added up to static air temperature (SAT):

$$TAT^{*} = SAT\left(1 + 0.9M^{2}\frac{\gamma-1}{2}\right)$$

For the Fokker 100 this refinement has been combined with a correction for the influence of the temperature of the center wing tank contents during the first phases of the flight when transfer of fuel from the centerwing tank to the main wing tanks is active. This correction has been done by first establishing the moment of depletion of the center wing tank (total flight duration times initial center wing tank contents divided by total amount of fuel consumed during the flight), then followed by application of the mixing equation as given in section 2.1 (each time mixing a time-proportional part of center wing tank fuel with full main wing tanks minus the amount of added center wing tank fuel) after each step calculation for the temperature reduction in the main wing tanks. Thus the assumption is that center wing tank fuel first is transferred to the main wing tanks and that only mixed fuel goes to the engines.

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It turns out that both refinements (using TAT* in lieu of TAT and correction for the influence of the higher temperature in the center wing tank) tend to more or less cancel each other for flights up to about 2 hours, see figure 1 where these refinements have been applied to flight 270 of the Fokker 100 Q1 prototype. For longer flights the TAT* effect will, of course, dominate.

One uncertain point is whether the measured TFCT1 and TFCT2 accurately represent the average temperature of the total amount of fuel. It might be argued that due to the higher ratio of wetted surface and volume at the outer wing fuel temperature there would decrease faster than more inboard. However, there are two factors which work the other way: first, after the center wing tank has been depleted, the fuel in the outer wing tank will soon loose contact with the upper wing skin and thus heat exchange via the upper wing skin will decrease; second, the forced circulation via top skin stringers produces increased heat exchange at the inboard wing. Moreover, a slight temperature difference between inboard and outboard fuel at the end of the flight would only have a limited effect on the average fuel temperature since the bulk of the fuel is at that time concentrated inboard. However, to allow for this and other uncertainties in the calculation method as described above the result of the calculation for the fuel temperature decrease in flight is presented in figure 3 with a ±15% error margin. The calculation has been executed in steps covering periods varying from 2 to 10 minutes with constant TAT*.

2.3. Once on the ground in Skopje with 5280 kg of fuel remaining, the temperature increased due to fuelling (in two stages: reportedly 1523 kg from 9:55 to 10:00 and 907 kg from 10:35 to 10:45) and due to the ambient temperature.

2.3.1. The temperature of the fuel in the fuel truck had been measured at 7:00 and was reportedly 4 °C. The OAT between that time and the time of the accident according to Skopje Airport meteo continuously was around 0 °C. To estimate the temperature of the fuel in the fuel truck the same equation as applied to the temperature decrease in flight has been utilized, however with a different time constant and with TAT = OAT:

$$T(t) = OAT + (T(0) - OAT)\, e^{-\frac{t}{5}}$$

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The time constant of 5 hours has been derived from measurements at Dryden, Ontario, Canada on April 5 and 6, 1989 providing OAT and fuel truck temperatures over a 24 hour period (ref. National Research Council Canada Technical Report IME-CRE-TR-003, NRC No. 32124). These measurements are presented in figure 2, together with two lines which follow from the numerical evaluation of the above equation with time constant of 3, respectively 5 hours. Since with the time constant of 5 hours the gradient of the calculated line is very close to the gradient of the measured line in the areas where the OAT does not show gradient reversion, it is considered that with this value sufficient accuracy has been obtained to calculate the temperature of the fuel in the fuel truck.

The calculation has been executed in one step because of the constant OAT. No error margin has been applied since its influence on the temperature of the total amount of fuel would be negligible compared with the influence of the error margin applied to the temperature decrease in flight.

The determination of the temperature of the (assumed) completely mixed fuel after the two fuelling periods has been done utilizing the same equation as given in section 2.1:

$$T = \frac{T_1 m_1 + T_2 m_2}{m_1 + m_2}$$

This equation has been applied at the times 9:56 and 10:40 (in figure 3, however, the temperature increase has been spread over the length of the two fuelling periods).

2.3.2. During its stay of 96 minutes (from 9:36 to 11:12) at Skopje the temperature of the fuel in the aircraft also increased due to the higher ambient temperature. For the calculation the total period has been split into three phases as follows (for OAT see section 2.3.1):

20 minutes (9:36 - 9:56) at 0 °C - prior to first fuel addition
44 minutes (9:56 - 10:40) at 0 °C - between both fuel additions
32 minutes (10:40 - 11:12) at 0 °C - following second fuel addition

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The same equation as applied to the fuel temperature decrease in flight and in the fuel truck has been utilized, however with three different values of the time constant c (2, 3.5 and 5 hours):

$$T(t) = OAT + (T(0) - OAT)\, e^{-\frac{t}{c}}$$

This has been done since no reliable data could be found regarding the rate of fuel temperature increase/decrease with an aircraft static on the ground. It was therefore considered that the time constants of 2 hours (from the Rolls Royce study on temperature variation in flight) and 5 hours (derived from the NRC study for fuel truck temperature variation) represent the extremes between which, to an adequate accuracy, the time constant for fuel temperature variation with the aircraft static on the ground would be found. The value of 2 hours (fast variation) has been applied to the highest estimated temperature at the end of the flight from Frankfurt to Skopje (-15% error, see section 2.2), while the value of 5 hours (slow variation) has been applied to the lowest estimated temperature at the end of that flight (+15% error, see section 2.2). This leads to a maximum difference between the upper and lower average fuel temperature estimation at the time of the crash, and thus increases the level of confidence that the actual fuel temperature must have been in this range. The value of 3.5 hours has been applied to the middle value of the estimated temperature at the end of the flight from Frankfurt to Skopje.

3. Results

The result of all calculations is presented in figure 3. It can be seen that the estimated average fuel temperature just prior to the crash is -5.9 °C with an assumed error margin of +2.5 °C and -2.1 °C.

It is repeated here that this result assumes perfectly mixed main wing tank fuel at any time during and after refuelling.

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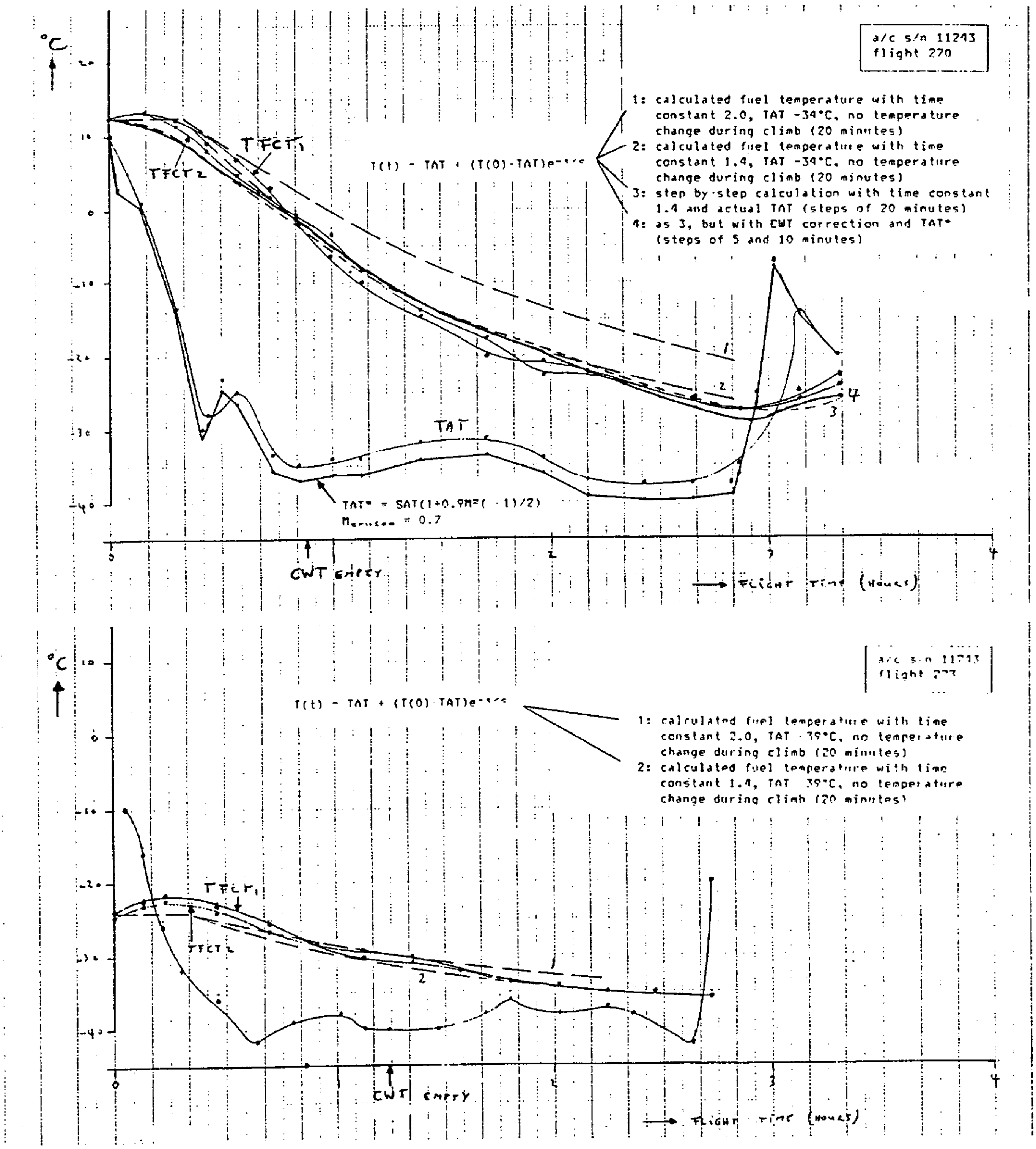

Figure 1 - Verification of empirical equation with Fokker 100 test data

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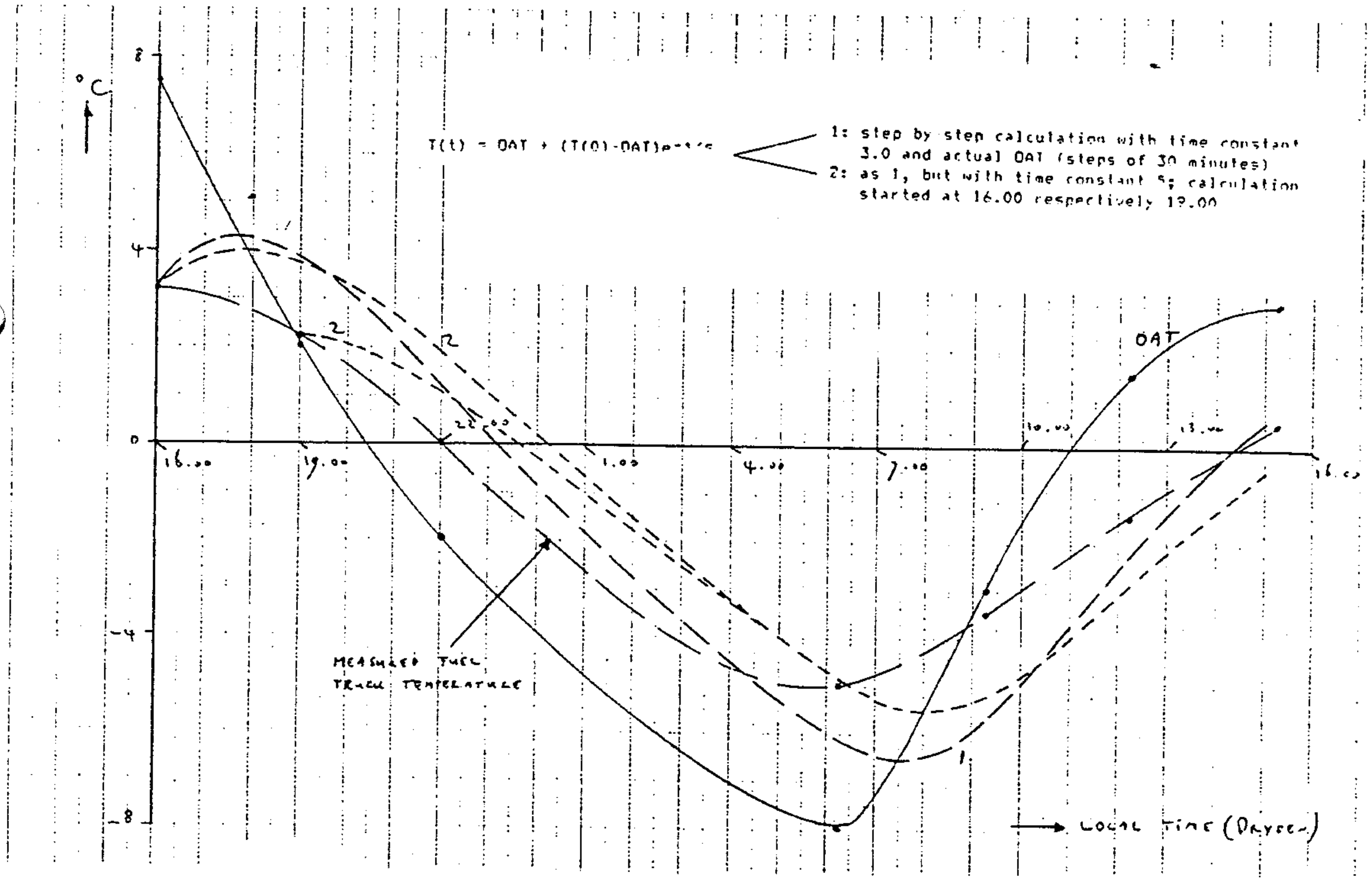

Figure 2 - Verification of empirical equation with Dryden fuel truck test data

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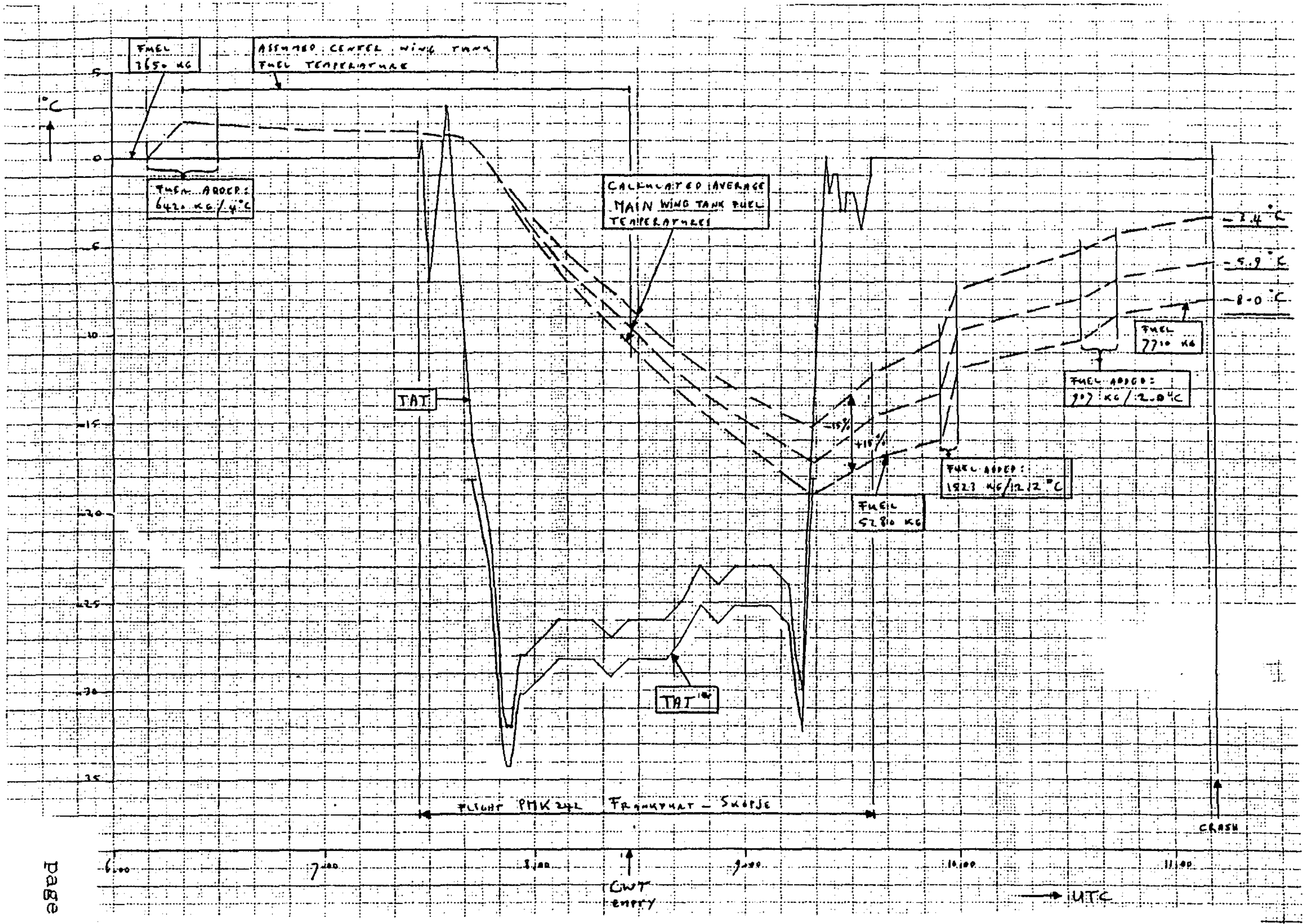

Figure 3 - Calculated fuel temperature changes in the hours prior to the crash

1 $T(t) = TAT + (T(0)-TAT)e^{-t/1.4}$

2 $T(t) = TAT^{*} + (T(0)-TAT^{*})e^{-t/1.4}$

$TAT^{*} = SAT(1+0.9M^{2}(\ -1)/2)$

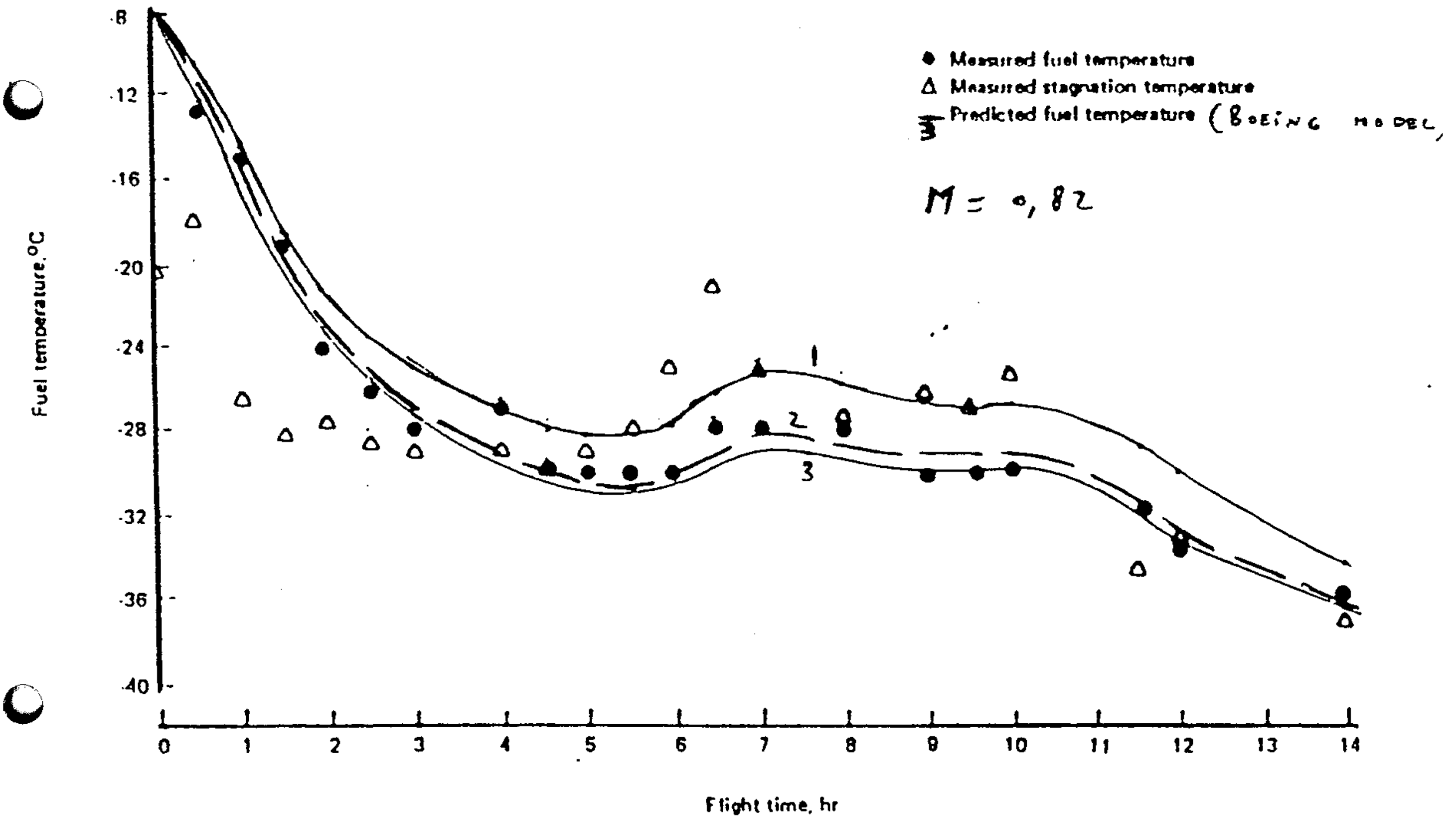

Figure 4-Correlation Between Predicted and Measured Fuel Temperatures (B747)

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APPENDIX 7

FOKKER 100 FUEL TANK TEMPERATURE TEST

REPORT

Fokker Aircraft B.V. Amsterdam
The Netherlands

issue date: Feb. 1994 issue no.: 1

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summary

The phenomenon of ice accretion on static wings associated with cold soaked fuel forms the background of these wing surface temperature measurements.
The characteristic behaviour of wing tank fuel system has been investigated through skin temperature measurements on the wing upper surface.
By loading of relatively high temperature fuel it should be possible to determine whether the initial cold fuel content is driven to the subsequent outer wing tank compartments.
On the Fokker 100, Q1 prototype aircraft the upper surface temperatures have been measured during fuelling and the subsequent temperature stabilization and during boost pump operation.
Skin temperature measurements between STA 2490 and STA 11000 of the LH - and RH wing upper surface were conducted. Ref. request for test AVB 7200.

It is concluded that the measured skin temperatures of the collector tank and the outer wing tank upto STA 5630 quickly approach the temperature of the loaded fuel, whereas the location at STA 11090 remains nearly unchanged.
This temperature difference remains for considerable time but reduces when boost pumps are switched "on".

The results of an almost similar test conducted on the collector tank of a production type Fokker 100 have been reported in UB-28-109.

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Contents

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1. Introduction

The phenomenon of wing ice accretion on the upper surface of the Fokker 100 Jet aircraft wing associated with cold soaked fuel forms again the background of these wing upper surface temperature measurements.
The purpose of the test was to investigate whether the initial cold fuel content of the wing tanks, in advance of fuelling is driven to the outer wing tank compartments during fuelling. Also the effect of the boost pump operation upon the mixing of fuel has been investigated.
The above effects have been measured by means of skin temperature measurements at specified locations along the wing between STA 2230 and STA 11190 on the upper surface of the LH - and RH wing.
Also, the different modes of fuel transfer in the main tanks during the turnaround time and until next "Take off" has been simulated, i.e. aircraft servicing including fuelling (boost pumps "off"), and engines running/taxi (boost pumps "on").
The tests were performed on the prototype Fokker 100 aircraft, Q1.
The tests were performed on the basic configuration with a full collector tank.
The request for test was registered under AVB 7200.

2. Description of the fuel system in the wing tank

The main fuel tank comprises two main compartments i.e. the Collector tank (CT), STA 1825 thru 2635, and the Outer Wing Tank(OWT).
The OWT is divided into three compartments by baffles;
- MT1 compartment; STA 2635 thru 4700,
- MT2 compartment; STA 4700 thru 8200,
- MT3 compartment; STA 8200 thru 11190.

A lay-out of the main fuel tank compartments is shown in figure 1 and 2.

Fuelling takes place via the pressure fill adaptor at the bottom of the RH CT from where the RH - and LH CT's (via the fuelling line) are filled simultaneously.
During pressure fuelling with boost pumps "off", the fuel flows through four top hat stringers from the CT into the MT2 compartment from where the fuel flows through the flapper valves and holes close to the lower wing surface at STA 4700, into the MT1 compartment and into the MT3 compartment, through the stringer holes close to the lower surface of the wing at STA 8200.
After fuelling the fuel level in the OWT is equal.

During boost pump operation the CT's are kept continuously replenished from the outer wing tanks through an array of 18 jet pumps. The jet pumps are driven by pressurized fuel bleed-off from the boost pumps. When the collector tank is full, the fuel flows back into the OWT (compartment MT2) through the four top hat stringers.
From the MT2 compartment the fuel flows back into MT1 compartment via the flapper check valves and holes close to the lower wing surface at STA 4700. Thus the boost pump operation causes a continuous recirculation of fuel between the outer wing tank and the collector tank.

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The maximum fuel level in the OWT is determined by the Level Control Pilot Valve which is located at STA 8780. This valve is adjusted such that after pressure fuelling a space (filled with vent air) is left to allow for fuel expansion. The air volume for expansion, the ullage, occupies the top of MT3 compartment and therefore a large part of the upper surface is not in contact with the fuel.

3. Test program and procedure

Preparation:

A matrix of measurement locations for the contact temperature sensors had to be pasted on the LH - and RH wing upper surface as indicated in figure 3. The appropriate numbers are indicated in table 1. In order to get the lowest possible initial fuel temperature the aircraft has to be parked outside the hangar longer than 12 hours (overnight) with a total fuel content of approx. 5340 kg in the main tanks.
The temperature of the fuel in the bowser must be as high as possible, therefore the bowser has to be parked in the hangar where the air temperature is controlled at 18 °C.

Test program:

Test shall start in the morning at about 7.00 hours in order to eliminate the effect of solar heating.

From the start of the test the collector tank fuel temperature TFCT1/TFCT2 shall be measured and recorded every minute. These sensors are located near the bottom of the tank close to the aft pump.

At the start of the test the collector tanks shall be full.
Possible leakage of fuel into the MT1 compartment causes a lower fuel level in the collector tank. Therefore,10 min. before fuelling the boost pumps shall be switched "on" in order to fill the collector tanks. Immediately afterwards the initial temperatures have to be measured,i.e. the temperature of the fuel in the bowser and the main tanks via the drain valves and skin temperatures of the upper surface of the wing.

LH - and RH main tanks shall be fuelled simultaneously via the pressure fill adapter with a flow of approx. 200 kg/min. This low figure has been specified to create sufficient time for manual recording of the skin temperature measurements during fuelling.
During fuelling the skin temperatures shall be measured at intervals of approx. 5 min.
After fuelling the temperature measurements shall be repeated for a period of an half hour.
Also the fuel temperature shall be measured via the drain valves and the Magnetic Fuel Level Indicators shall be read.

Above temperature measurements shall be continued during boost pump operation after completion of fuelling for a period of thirty minutes.
Finally the fuel temperature shall be measured via the drain valves at the collector tank and MT1 compartment.

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4. Instrumentation

Two "Fluke" digital contact temperature instruments were used to measure the wing surface temperatures.

Specified accuracy; - sensor: ± 2 °C.,
- reading: ± .75 °C.

Instrument identification; - serial nr. 4053/151750 used for the LH wing,
- serial nr. 4004/145267 used for the RH wing.

MRVS instrumentation for the outside air temperature (TAT) and fuel temperature in the collector tanks;
- LH collector tank, TFCT1
- RH collector tank, TFCT2

The TFCT sensor is located at STA 2400 close to the rear spar and approx. 5 cm. above the lower surface of the wing.
An assembly of a mini-bulb type of sensor and a stainless steel stem has been fixed inside the conduit of the defuel solenoid wiring. The length of the stem is 10 cm.

Glass tube thermometer, accuracy ± 0.5°C.

5. Test results and Discussion

(ref. FTS FLT nr: 5234)
In advance of the test the aircraft was parked outside the hangar for a period of approx. 58 hours. The average OAT was approx. 5°C.
The bowser was in the hangar ("hal 13") for a period of approx. 56 hours with a fuel contents of 19610 litre.

The MRVS recording started at 07:02:25 hours and the initial recorded temperatures were as follows;

TAT (=OAT) = 5.0 °C,
TFCT1 = 5.1 °C,
TFCT2 = 5.0 °C.

Above temperatures have been corrected for the calibration error.
The calibration errors are; TAT: 0.3 °C, TFCT1/2: 2.0 °C.
Corrections are established by subtracting the above errors from the measured values.

Meteo conditions during the test; dry, cloudless, OAT approx. 5°C.

After 10 min. boost pump operation the following temperatures were measured at the drain valves;

LH collector tank drain = 6.0 °C.
LH outer wing tank drain = 6.5 °C.
RH collector tank drain = 6.5 °C.
RH outer wing tank drain = 6.5 °C.

The aircraft fuelling to full started at approx. 7.35 hrs. and finished at 7.49 hrs.
At the start there was about 2670 kg fuel in both LH - and RH main fuel tank. Total 5340 kg.
The total amount of fuel loaded was 2430 kg.

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The temperature of the loaded fuel (from the bowser) was 15.5°C.
The surface temperature at the specified locations (see figure 3 and table 1) were measured once before fuelling and during fuelling and stabilization approximately every five minutes from the start of fuelling.

Before the boost pumps "on" condition the following temperatures were measured at the drain valves;
LH collector tank drain = 7.0 °C,
LH outer wing tank drain = 6.5 °C,
RH collector tank drain = 6.0 °C,
RH outer wing tank drain = 5.5 °C.

The magnetic Fuel Level Indicator values were:
1 LH outer - max,
2 LH middle - max,
3 LH inner - max,
4 RH inner - max,
5 RH middle - max,
6 RH outer - max.

Attitude monitor reading: 3C/D, which means almost level, within 1/2 degree.

The boost pumps "on" condition started at 8.33 hours and was finished at 9.04 hours.

After the boost pumps "on" condition the following temperatures were measured at the drain valves;
LH collector tank drain = 8.0 °C,
LH outer wing tank drain = 8.0 °C,
RH collector tank drain = 7.0 °C,
RH outer wing tank drain = 7.5 °C.

At the end of the test at 9:10:44 hours the final MRVS temperature recordings were as follows;
TAT (=OAT) = 4.5 °C,
TFCT1 = 7.5 °C,
TFCT2 = 7.4 °C.

During the test the following min./max. temperatures were recorded;

	minimum	maximum
TAT [°C]	4.	5.4
TFCT1 [°C]	5.1	12.1
TFCT2 [°C]	5.	13.5

Above temperatures have been corrected for the calibration error.

The measured skin temperatures are recorded in the tables of appendix A.

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The figures of the surface temperature distribution are presented versus elapsed time on page 14 thru 19.
The complete skin temperature distribution of the RH - and LH wing upper surface is shown on page 14 and 15. The maximum number of plotted lines is eleven therefore the measurement points 10 and 11 of the RH wing and 22 and 23 of the LH wing respectively have been combined. The average error in the presentation of these data is 0.1 °C.
Comparing these figures it appears that the temperature response of the RH wing upper surface is slightly faster than the LH wing. Also the maximum temperature reached at the end of fuelling is one degree higher. A reason for this could be the residence time of the fuel in the fuelling line to the LH collector tank and therefore the heat transfer from the fuel to the cold environment.
The RH tank supply line is equipped with a restrictor in order to equalize the fuel flow rate into both wing tanks. This restrictor has been sized for the maximum fuelling flow rate.
However, the flow ratio is not linear with the fuel flow rate therefore the applied low supply pressure of the bowser and therefore low fuel flow rate of 200 kg/min. causes an incorrect distribution of the fuel flow rate into the LH collector tank and RH collector tank.

After fuelling and the subsequent stabilization time the difference of the skin temperature along the wing is for the LH wing approx. 7°C and for the RH wing approx. 6.6°C.
At the end of the boost pump operation the difference has been reduced to 4.5 and 3.5 °C respectively.

For clearness sake the skin temperature distribution of the wing tank compartments is presented separately on page 16 thru 19, i.e. the Collector tank and MT1 compartment, and MT2 and MT3 compartments.

Collector tank and MT1 compartment temperature figure:

This figure also includes the measured TFCT temperature.
After mixing the added fuel with the initial fuel the bulk temperature of mixed fuel should be approx. 8°C.
The drain valve fuel temperatures measured after fuelling and the subsequent stabilization and TFCT are below this temperature. The measured skin temperatures are approx. 2°C higher so that a temperature gradient exist over the tank height at the collector tank and the OWT, MT1 compartment.
At the LH collector tank the measured TFCT1 temperature drop is less than the RH collector tank TFCT2. This might be an effect of the lower speed of fuel flow into the collector tank and therefore better mixing process due to a wider spread of relatively warm fuel. Better mixing also is supposed through the difference of the maximum temperature gradient which is 5.5°C at the RH - and 3°C at the LH tank.
At the end of the active mixing of the fuel by the boost pump operation the measured skin temperatures and TFCT's and the measured fuel temperature at the drain valves approach the predicted bulk or mixed fuel temperature of 8°C. The above maximum temperature gradient then has been reduced to approx. 1°C.

MT2 - and MT3 compartment temperature figure:

It is evident that the OWT, MT3 compartment skin temperatures (10 thru 12 and 22 thru 24) remain at about the same temperature during the subsequent fuelling, stabilization, and boost pump operation.

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After a time lag the MT2 and MT3 compartment skin temperatures (7,8,9 and 19,20,21) start to increase probably as soon as the fuel is overflowing the baffle at STA 8200.
The temperature rise prior to the booster pump operation, at the MT3 compartment upper surface at the measurement points 9 thru 12 of the RH wing and 21 thru 24 of the LH wing is considered to be an effect of the longitudinal conduction of heat through the upper surface skin and stringers
Also limited penetration of the added or mixture fuel and a gravity effect may have contributed to the temperature rise of the skin temperature.
After the boost pump operation the MT2 and MT3 tank compartment upper surface skin temperatures remain below the predicted mixed fuel temperature of 8.4°C.
An equilibrium temperature has been adjusted between the outside air temperature and the air temperature within the vent or expansion space.

6. Conclusions and Recommendation

The results of the skin temperature measurement show clear difference between LH - and RH wing tank fuelling, i.e. temperature gradient, and stabilization, probably caused by unequal flow rates.

During fuelling the upper surface skin temperature at the CT and MT1 compartment increases significantly faster than the OWT compartments MT2 and MT3. The temperature difference reduces only slowly as long as boost pumps remain "off".

During boost pump operation a significant difference of the skin temperature along the upper surface of the wing remains.
The skin temperature at the OWT, MT3 compartment doesn't change significantly, but nearly remains at the initial temperature within a range of 1°C during the subsequent fuelling, stabilization, and boost pump operation.

It appears through this skin temperature measurement of the upper surface of the wing that the initial cold fuel contents of the wing tank is driven (transferred by "piston flow") to the subsequent OWT compartments.

It is understood that mixing of fuel does not occur at the OWT, MT3 compartment. However the fuel was not in direct contact with the upper surface therefore, the influence of the cold fuel upon the measured skin temperature could not be well determined.
It is therefore recommended to repeat the test at low outside air temperature and reverse soaking temperature conditions:

- Aircraft parked inside the hangar, warm fuel in tanks, and
- Bowser parked outside, cold fuel in bowser.

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Figure 1.

Fuel Transfer to Collector Tanks

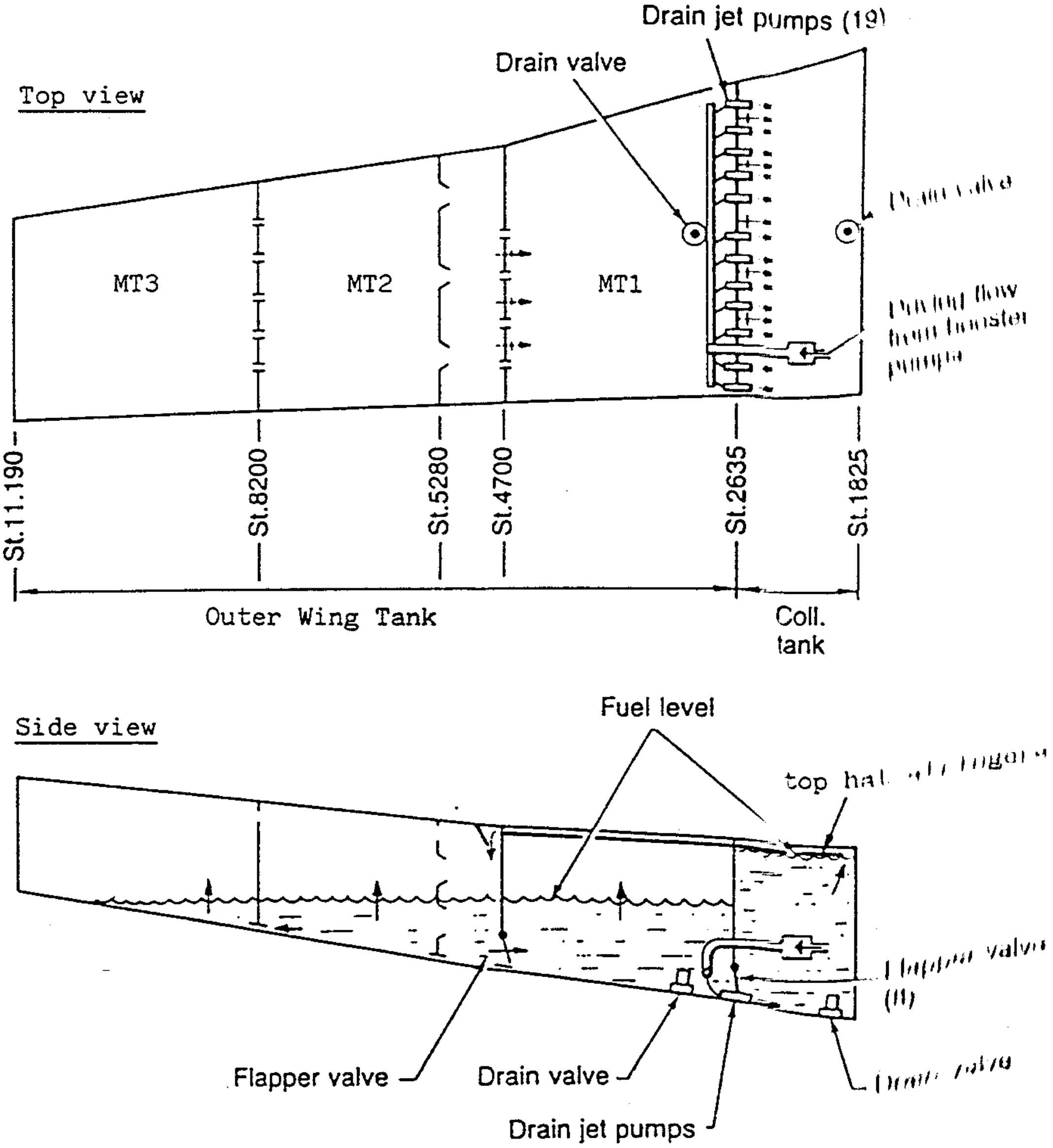

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Figure 2. Inside view of outer wing torsion box.

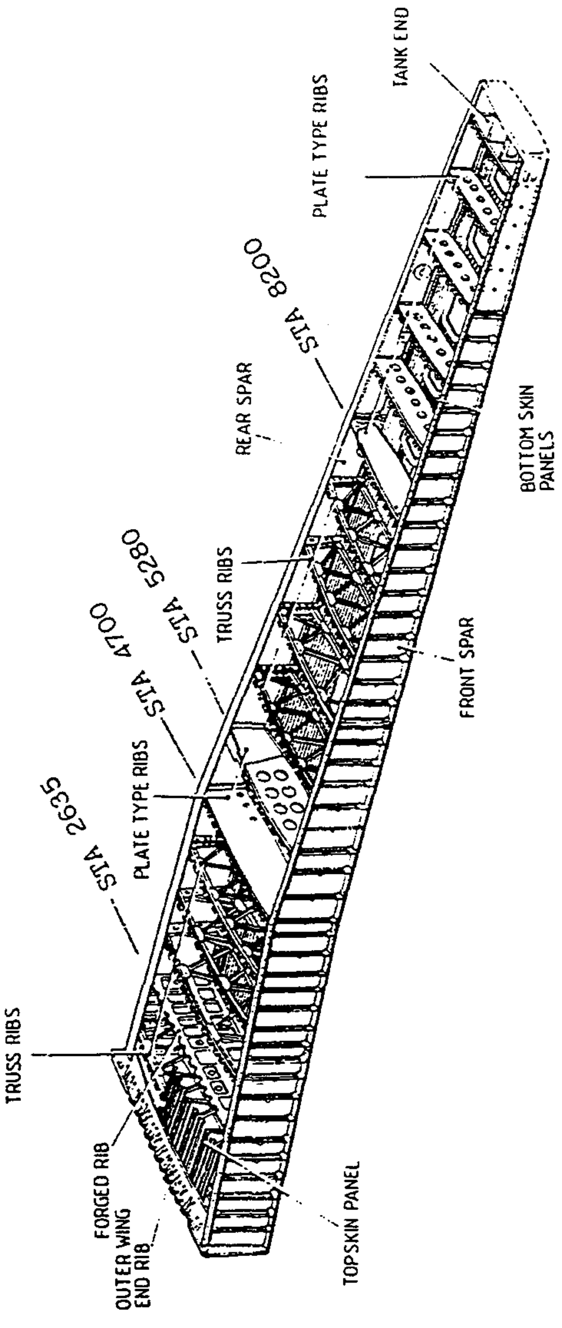

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Figure 3. Location of temperature measurement point on RH wing upper surface.

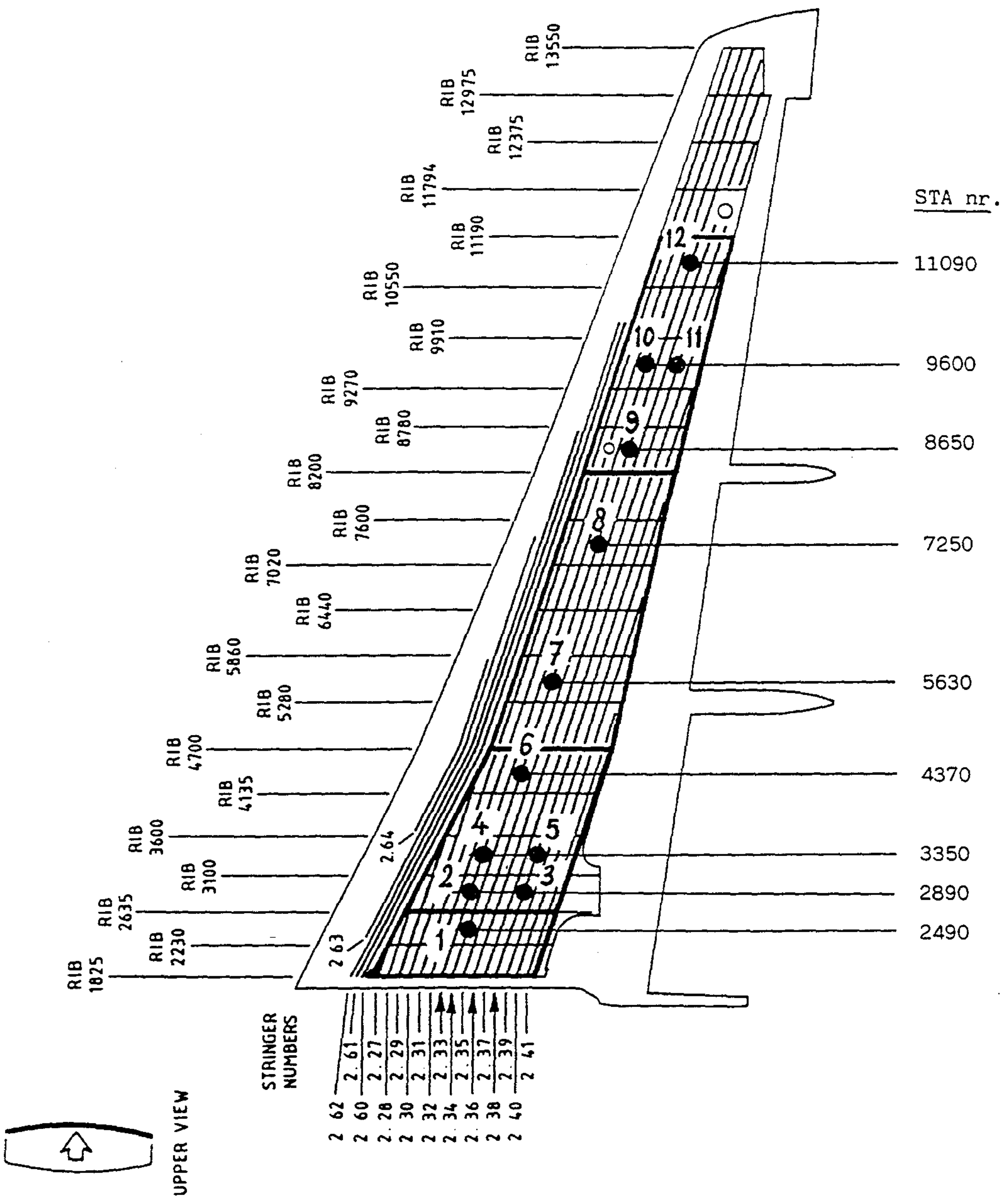

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table 1. Temperature measurement location number

Wing Station number	RH wing Stringer number				LH wing Stringer number			
	Str. 2.33	Str. 2.34	Str. 2.36	Str. 2.38	Str. 2.33	Str. 2.34	Str. 2.36	Str.2.38
2490		1				13		
2890	2			3	14			15
3350	4			5	16			17
4370		6				18		
5630		7				19		
7250		8				20		
8650		9				21		
9600	10		11		22		23	
11090		12				24		

Above table outlines the measurement location number for the LH - and RH wing at each wing station and stringer number (Str. -).

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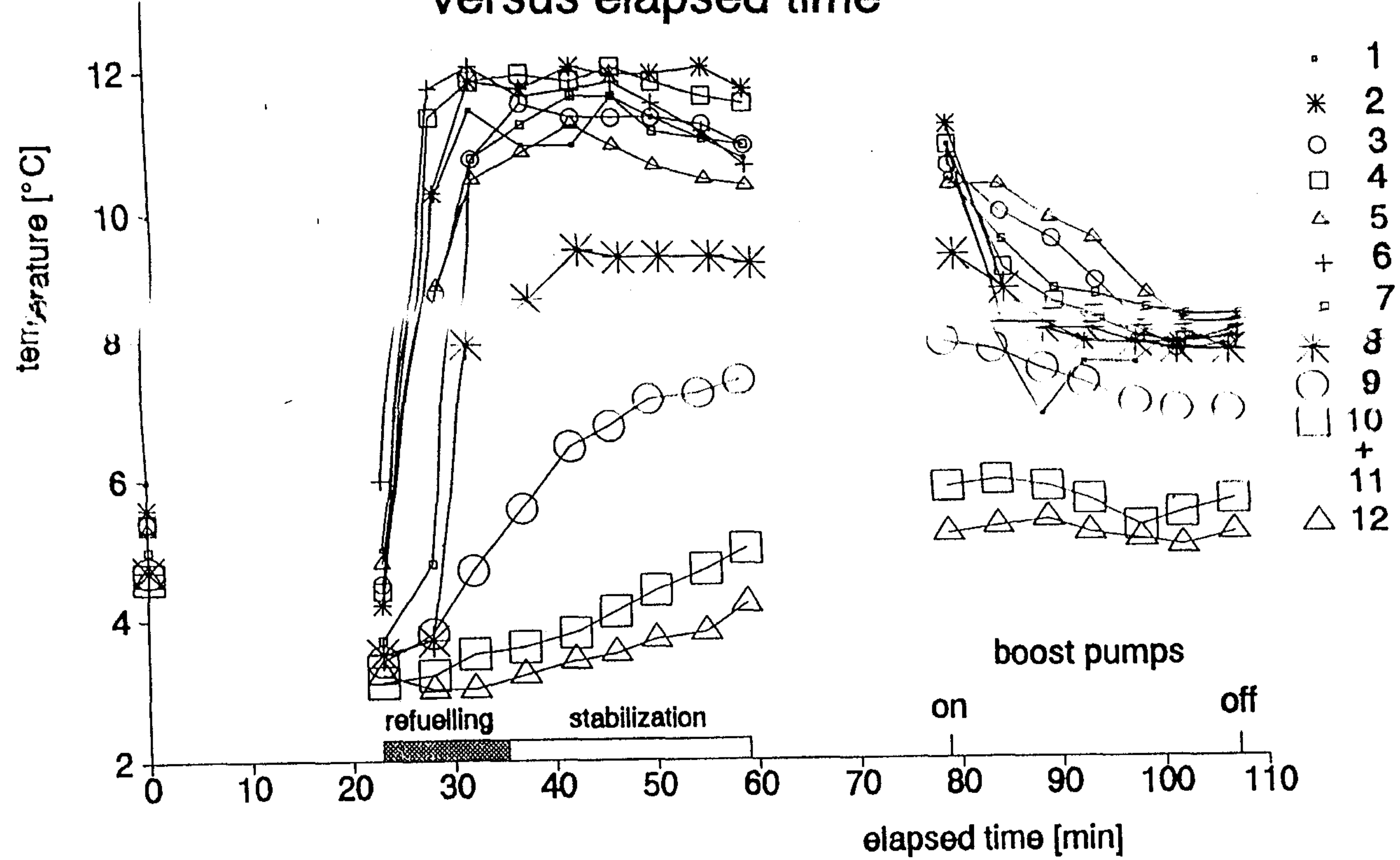
RH wing skin temp. distribution

versus elapsed time



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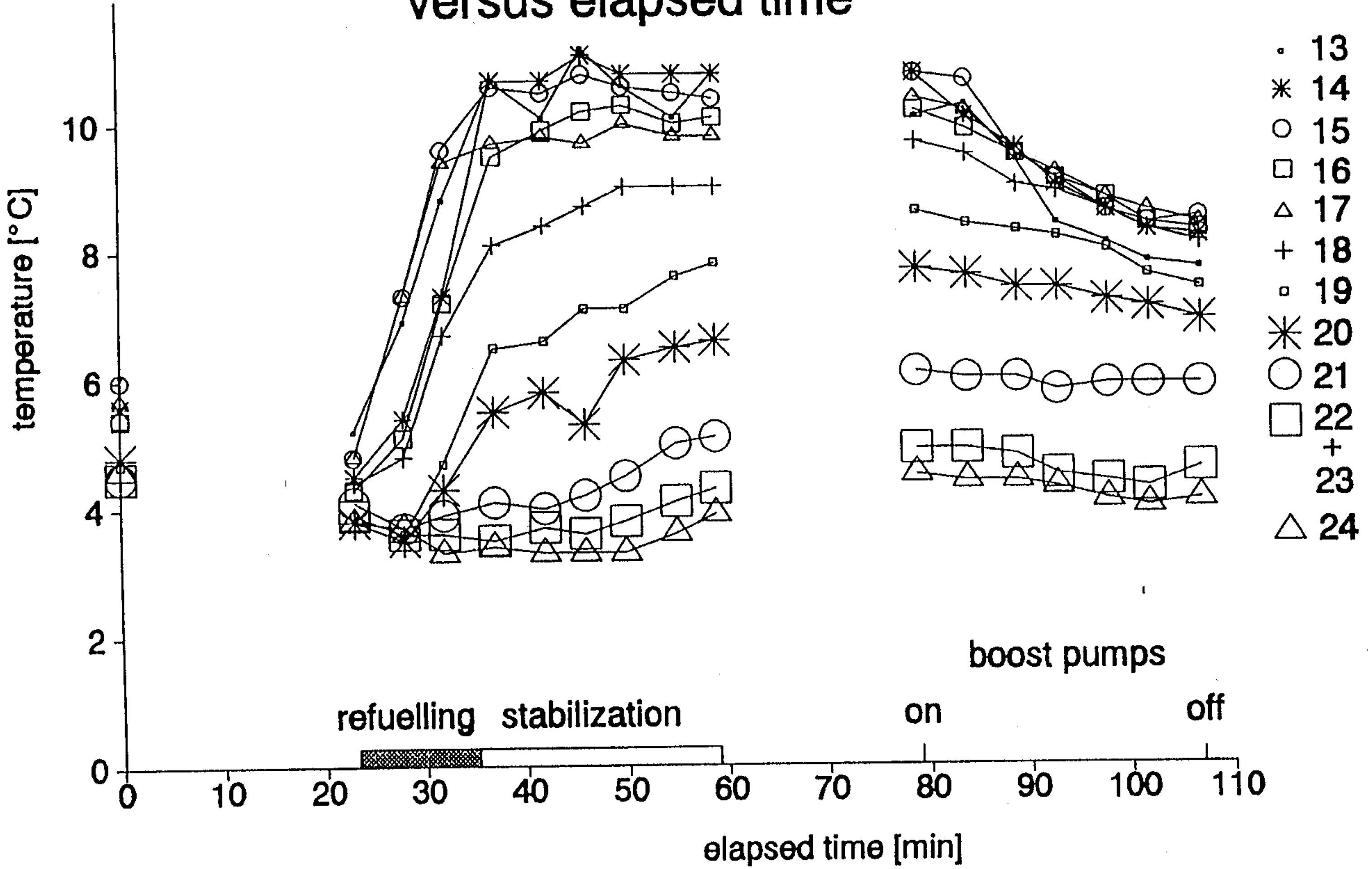
LH wing skin temp. distribution

versus elapsed time



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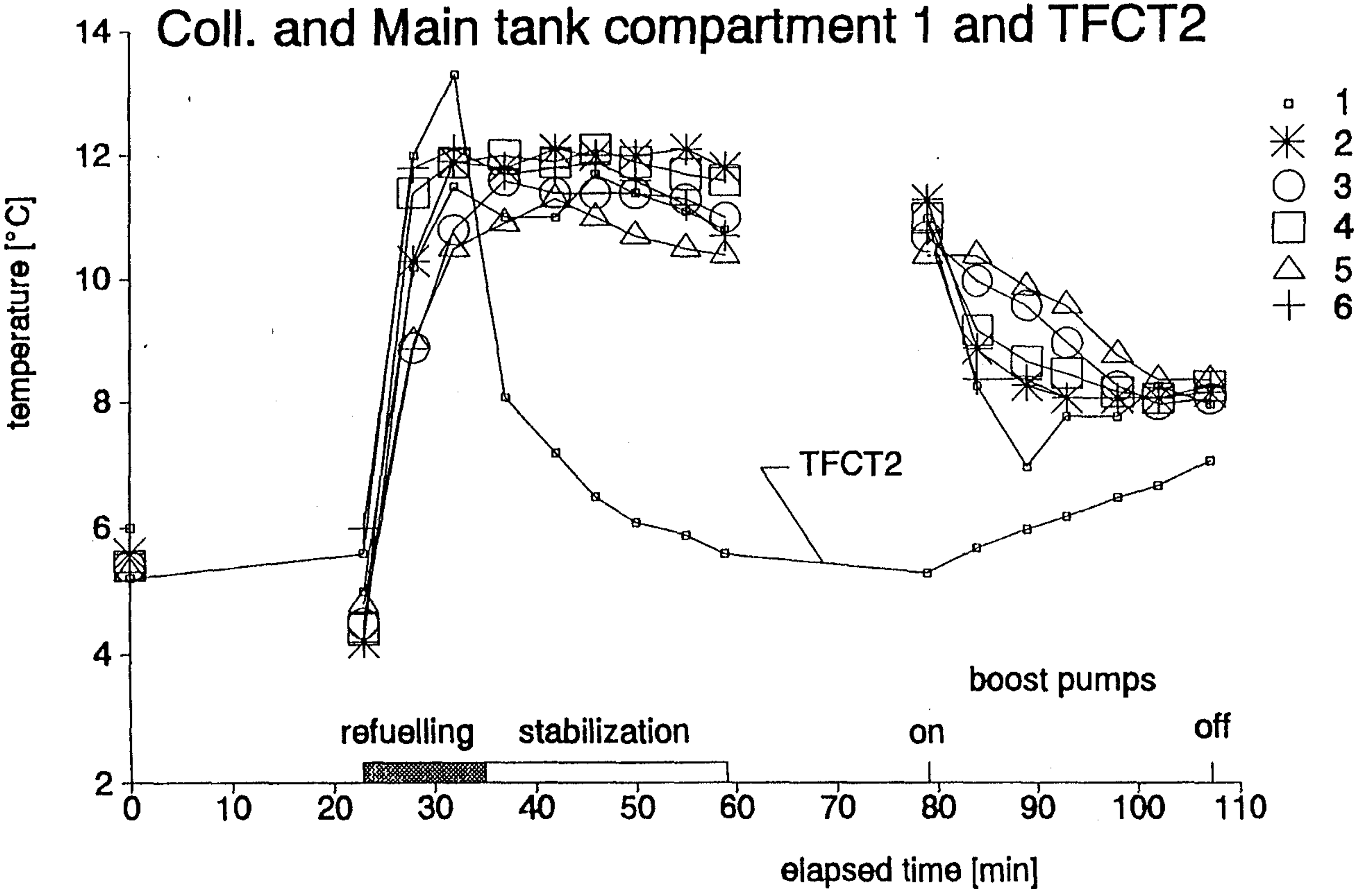
RH wing skin temp. distribution

Coll. and Main tank compartment 1 and TFCT2



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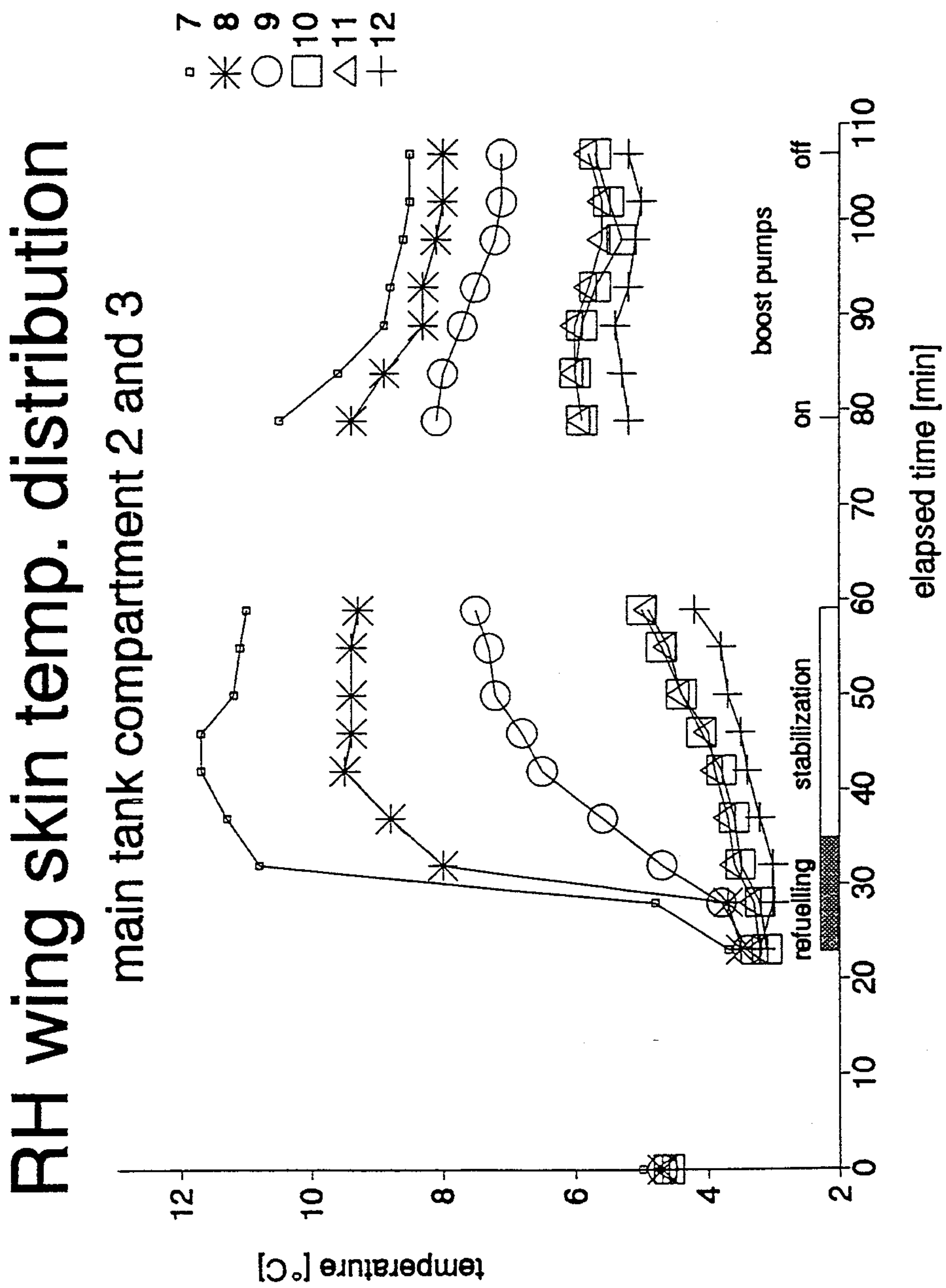

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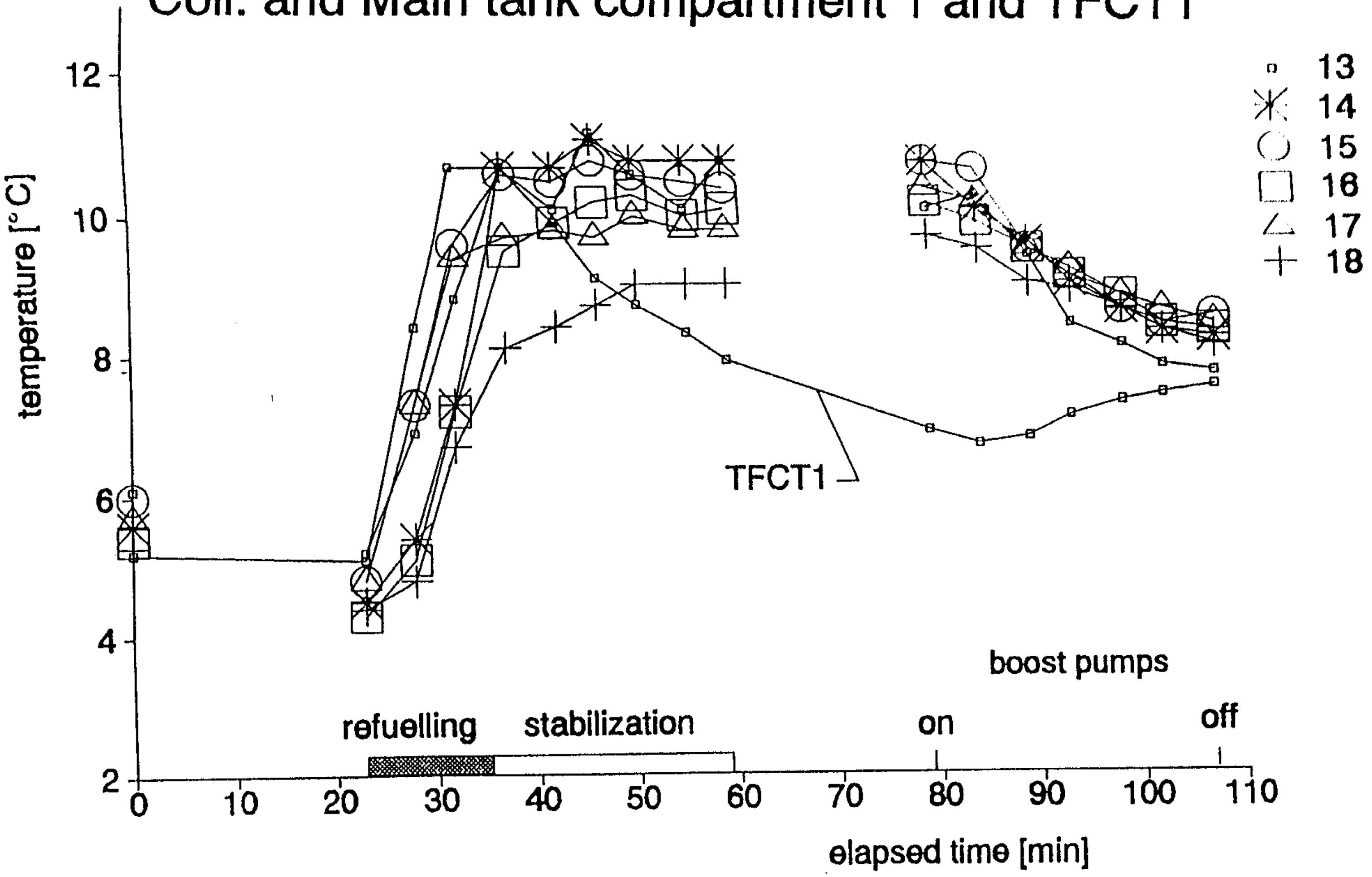
LH wing skin temp. distribution

Coll. and Main tank compartment 1 and TFCT1



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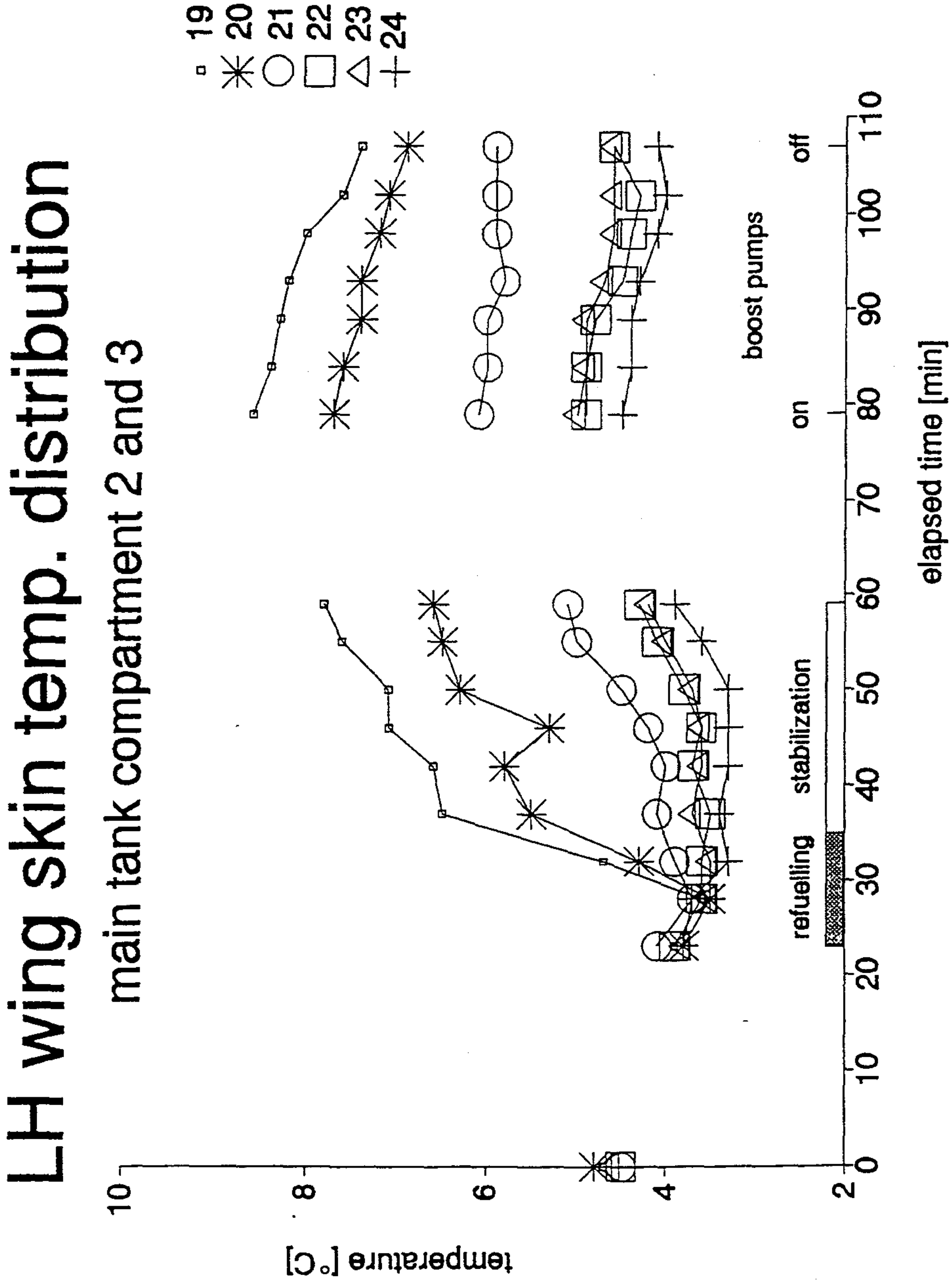

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Appendix A Data tables of measured and corrected skin temperatures.

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Table A1. Skin temperatures of RH wing upper surface, as measured in °C.

Time [min]	Measurement point nr. of RH wing											
	1	2	3	4	5	6	7	8	9	10	11	12
0	6	5.6	5.4	5.4	5.3	5.3	5	4.7	4.7	4.6	4.6	4.6
23	5	4.2	4.5	4.4	4.8	6	3.7	3.5	3.4	3.1	3.2	3.2
28	10.2	10.3	8.9	11.4	9	11.8	4.8	3.7	3.8	3.2	3.3	3
32	11.5	11.9	10.8	11.9	10.5	12.1	10.8	8	4.7	3.5	3.6	3
37	11	11.8	11.6	12	10.9	11.7	11.3	8.8	5.6	3.6	3.7	3.2
42	11	12.1	11.4	11.9	11.3	11.8	11.7	9.5	6.5	3.8	3.9	3.4
46	11.7	12	11.4	12.1	11	11.9	11.7	9.4	6.8	4.1	4	3.5
50	11.4	12	11.4	11.9	10.7	11.6	11.2	9.4	7.2	4.4	4.4	3.7
55	11.1	12.1	11.3	11.7	10.5	11.2	11.1	9.4	7.3	4.7	4.6	3.8
59	10.8	11.8	11	11.6	10.4	10.7	11	9.3	7.5	5	4.9	4.2
79	11	11.3	10.7	11	10.4	10.8	10.5	9.4	8.1	5.9	5.9	5.2
84	8.3	8.9	10	9.2	10.4	8.4	9.6	8.9	8	6	6	5.3
89	7	8.3	9.6	8.7	9.9	8.4	8.9	8.3	7.7	5.9	6	5.4
93	7.8	8.1	9	8.5	9.6	8.1	8.8	8.3	7.5	5.7	5.8	5.2
98	7.8	8.1	8.3	8.2	8.8	8.1	8.6	8.1	7.2	5.3	5.6	5.1
102	8.3	8.1	8	8.1	8.4	8.1	8.5	8	7.1	5.5	5.6	5
107	8	8.2	8.1	8.3	8.4	8.3	8.5	8	7.1	5.7	5.8	5.2

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Table A2. Skin temperatures of LH wing upper surface, as measured in °C.

Time [min]	Measurement point of LH wing											
	13	14	15	16	17	18	19	20	21	22	23	24
0	5.1	4.6	5	4.4	4.7	4.3	3.7	3.8	3.5	3.5	3.6	3.6
23	4.2	3.5	3.8	3.3	3.8	3.4	2.9	2.8	3.1	2.9	2.8	2.8
28	5.9	4.4	6.3	4.1	6.3	3.8	2.6	2.5	2.7	2.6	2.5	2.7
32	7.8	6.3	8.6	6.2	8.4	5.7	3.7	3.3	2.9	2.6	2.5	2.3
37	9.7	9.7	9.6	6.5	8.7	7.1	5.5	4.5	3.1	2.5	2.7	2.4
42	9.1	9.7	9.5	8.9	8.8	7.4	5.6	4.8	3	2.7	2.6	2.3
46	10.2	10.1	9.8	9.2	8.7	7.7	6.1	4.3	3.2	2.6	2.6	2.3
50	9.6	9.8	9.6	9.3	9	8	6.1	5.3	3.5	2.8	2.7	2.3
55	9.1	9.8	9.5	9	8.8	8	6.6	5.5	4	3.1	3	2.6
59	9.8	9.8	9.4	9.1	8.8	8	6.8	5.6	4.1	3.3	3.2	2.9
79	9.1	9.8	9.8	9.2	9.4	8.7	7.6	6.7	5.1	3.9	4	3.5
84	9.3	9.1	9.7	8.9	9.2	8.5	7.4	6.6	5	3.9	3.9	3.4
89	8.4	8.6	8.5	8.5	8.5	8	7.3	6.4	5	3.8	3.9	3.4
93	7.4	8	8.1	8.1	8.2	7.9	7.2	6.4	4.8	3.5	3.7	3.3
98	7.1	7.6	7.6	7.8	7.8	7.6	7	6.2	4.9	3.4	3.6	3.1
102	6.8	7.3	7.4	7.4	7.6	7.3	6.6	6.1	4.9	3.3	3.6	3
107	6.7	7.2	7.5	7.3	7.4	7.1	6.4	5.9	4.9	3.6	3.6	3.1

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Table A3. Skin temperatures of LH wing upper surface, corrected for measurement error.

Time [min]	Measurement point of LH wing											
	13	14	15	16	17	18	19	20	21	22	23	24
0	6.1	5.6	6	5.4	5.7	5.3	4.7	4.8	4.5	4.5	4.6	4.6
23	5.2	4.5	4.8	4.3	4.8	4.4	3.9	3.8	4.1	3.9	3.8	3.8
28	6.9	5.4	7.3	5.1	7.3	4.8	3.6	3.5	3.7	3.6	3.5	3.7
32	8.8	7.3	9.6	7.2	9.4	6.7	4.7	4.3	3.9	3.6	3.5	3.3
37	10.7	10.7	10.6	9.5	9.7	8.1	6.5	5.5	4.1	3.5	3.7	3.4
42	10.1	10.7	10.5	9.9	9.8	8.4	6.6	5.8	4	3.7	3.6	3.3
46	11.2	11.1	10.8	10.2	9.7	8.7	7.1	5.3	4.2	3.6	3.6	3.3
50	10.6	10.8	10.6	10.3	10	9	7.1	6.3	4.5	3.8	3.7	3.3
55	10.1	10.8	10.5	10	9.8	9	7.6	6.5	5	4.1	4	3.6
59	10.8	10.8	10.4	10.1	9.8	9	7.8	6.6	5.1	4.3	4.2	3.9
79	10.1	10.8	10.8	10.2	10.4	9.7	8.6	7.7	6.1	4.9	5	4.5
84	10.3	10.1	10.7	9.9	10.2	9.5	8.4	7.6	6	4.9	4.9	4.4
89	9.4	9.6	9.5	9.5	9.5	9	8.3	7.4	6	4.8	4.9	4.4
93	8.4	9	9.1	9.1	9.2	8.9	8.2	7.4	5.8	4.5	4.7	4.3
98	8.1	8.6	8.6	8.8	8.8	8.6	8	7.2	5.9	4.4	4.6	4.1
102	7.8	8.3	8.4	8.4	8.6	8.3	7.6	7.1	5.9	4.3	4.6	4
107	7.7	8.2	8.5	8.3	8.4	8.1	7.4	6.9	5.9	4.6	4.6	4.1

note: temperatures in °C.

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Table B1. Measured and corrected TFCT1 and TFCT2 fuel temperatures.

Time [min]	TFCT as measured in °C		TFCT corrected for measurement error	
	LH wing TFCT1	RH wing TFCT2	LH wing TFCT1	RH wing TFCT2
0	7.18	7.18	5.2	5.2
23	7.07	7.59	5.1	5.6
28	10.41	13.95	8.4	12
32	12.7	15.3	10.7	13.3
	13.85	12.07	11.9	10.1
37	12.7	10.09	10.7	8.1
42	11.87	9.16	9.9	7.2
46	11.14	8.53	9.1	6.5
50	10.72	8.12	8.7	6.1
55	10.3	7.91	8.3	5.9
59	9.89	7.59	7.9	5.6
	9.36	7.39	7.4	5.4
79	8.89	7.28	6.9	5.3
84	8.74	7.7	6.7	5.7
89	8.84	8.01	6.8	6
93	9.05	8.22	7.1	6.2
98	9.26	8.53	7.3	6.5
102	9.37	8.74	7.4	6.7
107	9.47	9.05	7.5	7.1

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APPENDIX 8

SECTION ADVERSE WEATHER OPERATION OF THE FOKKER 100 AOM

COLD WEATHER

General

Small ice and snow deposits on the aerodynamic surfaces which accumulate during a ground stop might appear insignificant but can seriously affect the maximum lift of the wing, and the controllability and performance of the aircraft. Thin layers of ice resulting from frost or freezing fog may cause a certain sandpaper roughness on the wing and tail upper surfaces. This roughness may cause airflow separation resulting in control problems, wing drop, or even a complete stall shortly after rotation.

Relatively warm fuel, uplifted during a ground stop, may cause dry snow falling on the wing to melt. After a subsequent cooling period, this water may refreeze, forming an invisible ice coating under the dry snow. When the tanks contain sufficient fuel of subzero temperatures, as may be the case after a long flight, water condensation or rain will freeze on the wing upper surface during the ground stop, forming a smooth, hardly visible, coating. During take-off, this ice may break away and at the moment of rotation enter the engine causing damage to the fan.

Snow falling on 'warm' leading edges will melt and may under certain wind conditions form 'run-back ice' on wings and stabilizer causing loss of lift and control problems.

Black strips are painted on the wing leading edges. The purpose of the black strip is to assist the pilot to detect the buildup or the existence of certain types of ice on the wing leading edge in flight by providing a contrast with the shiny surface of the wing leading edge. The wing inspection lights are directed at the black strip to assist the captain and the first officer to detect ice accumulation in flight at night. On the ground, visible ice conditions on the black strip are not necessarily representative of the condition of the whole wing leading edge, or of the wing upper surface.

Exterior Inspection

Pay special attention during the exterior inspection to those areas where snow or ice could affect system operation.

- Remove all protective covers
- Check that all wings and control surfaces are free of ice and snow
- Check gear and gear doors for impacted snow or ice
- Check that the following areas are free of snow or ice:
  - . Flight controls and surrounding areas
  - . Air conditioning inlets and exhausts
  - . Fuel tank vents
  - . Angle of attack vanes, pitot heads and static ports
  - . Engine and APU intakes.

NOTES:

1. Water rundown following snow removal may refreeze forward of the static ports and may cause airflow disturbances and consequently, errors in instruments and systems using static air pressure.
2. Dispatch with frost at the underside of the wing is allowed on condition that the frost layer does not extend outside the fuel tank area and its thickness does not exceed 3 mm/0.125 inch.

De-icing

Ensure that there is a minimum of time between de-icing and take-off. When de-icing with engines and/or APU running, switch the air conditioning packs OFF. Keep engines at idle and switch APU off if no longer required. When using a 'taxi-through' de-icing facility, use lowest possible engine thrust.

ter de-icing switch the packs back ON. Cycle the flaps fully down and up prior to setting r take-off. Check flight controls and stabilizer for full and free movement. The APU should t be started immediately following de-icing. Allow a few minutes for draining of the de- ng fluid and the dissipation of the de-icing fluid vapour.

UTION: Holdover times of de- and anti-icing fluids vary depending upon fluid type and prevailing weather conditions. Refer to operator procedures for allowable time between de-icing and take-off.

gine Starting

in oil temp for starting is - 40 degrees C.
elow this temperature, the engine has to be pre-heated.
the oil temperature is below - 20 degrees C the following start procedure is recommended.

Motor the engine for 30 seconds.
Start engine.
Check N1 indicating.
At 20 per cent N2 or max attained N2 select fuel lever to OPEN.

N1 rotation is not confirmed, abandon the start and apply external heat to unfreeze the n. Ice can form on the fan rotor path lining causing freezing of the blade tips to the fan asing.

AUTION: High TGT's may be expected when starting a cold soaked engine.

il pressure will be slow to rise and may reach higher than normal values. If no oil pressure is indicated at idle RPM, shut the engine down and allow internal heat to warm up the il. Do not apply thrust for taxying until oil temperature is above - 30 degrees C.
idle N2 is below normal, advance the thrust levers slightly to obtain normal idle speed. Monitor TGT while doing this.

tarting a cold soaked engine requires a longer time until light-up and may be accompanied by white smoke from the engine exhaust during the start cycle.

t extremely low temperatures the generators may not supply steady AC power during the rst minutes after starting. If this results in a generator fault, wait approximately 2 minutes efore resetting.

the TAT is below + 5 degrees C and moisture is visible or the runway is wet, select engine anti-icing ON after engine start.

axying

When the aircraft was parked in snow or slush at temperatures below freezing, brake disc freezing may occur. Have the ground crew confirm that all four main wheels rotate when starting to taxi.
More than normal 'break-away' thrust may be required when tyres have frozen to the ground.

Maintain greater than normal distance between aircraft when taxiways are slippery. Taxi slowly, do not make abrupt or large steering inputs. Be prepared to use reverse thrust if brakes become ineffective.

Prior to take-off, a cold soaked engine (first flight of the day) requires a 4 minute warm up period at low (taxi) thrust before applying take-off power.

WHEN TAXYING OR HOLDING IN ICING CONDITIONS AT TEMPERATURES BELOW + 1 DEGREE C, ACCELERATE THE ENGINES TO 85 PER CENT N1 FOR ONE MINUTE PRIOR TO TAKE-OFF AND AT INTERVALS OF NOT MORE THAN 60 MINUTES DURING PROLONGED HOLDING ON THE GROUND.

NOTE: For allowable hold-over times of the de- and anti-icing fluids see the CAUTION in the subsection De-Icing.

Take-off

General

Use TOGA (rated) thrust. Do not use FLX thrust in icing conditions.

If necessary, wing and tail anti-icing can be preselected prior to take-off. The system will become active 60 seconds after lift-off. Apply the relevant performance restrictions.

The recommended maximum wind components for take-off and landing are:

Friction coefficient	Braking Action	Wind component (kt)	
		Cross	Tail
0.40 and above	5 good	30	10
0.39 - 0.36	4 good/medium	*	*
0.35 - 0.30	3 medium	15	5
0.29 - 0.26	2 medium/poor	*	*
0.25 and below	1 poor	5	0

* Intermediate speeds may be used.

WARNING: WINGS, ENGINE INTAKES, TAIL SURFACES, ALL CONTROL SURFACES AND IN PARTICULAR THE LEADING EDGES OF THE WINGS MUST BE COMPLETELY FREE OF ICE AND SNOW BEFORE TAKE-OFF.

If, although all possible precautions have been taken, it is not completely certain that wings and tail are free of ice or snow but take-off is still thought feasible and runway length or obstacle clearance are not limiting, rotate slowly to a lower pitch angle in order to obtain a higher lift-off speed.

Take-off from Contaminated Runways

To avoid structural damage and to limit performance degradation, do not take-off if more than 12.7 mm / 0.5 inch of standing water (or the equivalent of that for slush or snow) covers a significant part of the runway length and width.

Use TOGA (rated) thrust. Flexible thrust is not permitted.

Select AUTO ignition or for aircraft not so equipped select CONT ignition (not required for aircraft equipped with the automatic relight system) and if required, engine anti-icing ON.

To reduce the adverse effect of slush drag on take-off distance a flap setting of 15 deg is recommended, ensuring the lowest V_1, V_R and V_2 speeds with a consequent reduction in required take-off distance. Moreover the engines are better shielded from possible wheel spray.
The use of flap 0 for take-off from a contaminated runway is not allowed.

When taking off in slush, delay gear retraction slightly to allow wheels and brakes to be blown free of slush.

If the take-off has to be abandoned use the standard rejected take-off technique. Apply full brakes to take advantage of the anti-skid system. If directional control problems occur, release the brakes, reduce to idle reverse and use rudder pedal steering to return to the centerline. When re-aligned, re-apply brakes and reverse thrust as required. If necessary, emergency maximum reverse may be used until standstill.

imb - Cruise - Descent

ıgine anti-icing should be activated when icing conditions exist and following an "ICING" ert at MFDS.
ıe system should be switched off one minute after leaving the icing conditions or when e "ICING" alert is no longer showing.

ı increase in the engine vibration level may be observed during icing conditions. The fan ıll normally shed any ice formation and the vibration should diminish. To assist in ice ıedding (and operational circumstances permitting), quickly retard one thrust lever at a ne to idle. Hold it there for approx. 5 seconds and then advance the thrust lever momen-ırily to 85 per cent N1. This procedure will eliminate or reduce the vibration, and the ırust levers may be re-adjusted to their original positions.

Ving and tail anti-icing systems must be activated when icing is observed or thought to xist. The system has been designed for continuous operation and may be used for ice hedding provided ice build up on wings does not exceed 1 cm / 0.5 inch. If a thicker ayer has developed because of late activation, the shed ice may be ingested by the en-jines. If this is the case select RELIGHT ignition before activating the wing anti-icing sys-em.

Vith ATS engaged, engine thrust is maintained at the level required to provide the A-ICE ;ystems with bleed air of adequate pressure. A-ICE "LO CPTY" alerts warn for too low ıleed pressure.

3efore approach, wings and stabilizer must be free of ice.
f prolonged icing is encountered during descent, confirm correct engine response prior to commencing approach for landing.

With landing gear down, flight idle RPM is increased to approx 70 per cent N2 (approach idle). The resulting increase in engine thrust may necessitate landing with flap 42 instead of flap 25 in low weight/low temperature conditions.

Landing on Contaminated Runways

The recommended procedure:

- Select AUTO ignition - or for aircraft not so equipped, select CONT ignition (not required for aircraft equipped with the automatic relight system).
- Use longest runway compatible with the recommended maximum wind component.
  In a crosswind, the wind component at right angles to the landing direction tends to push the aircraft to the downwind side of the runway. In addition the aircraft tends to behave like a weather vane and yaws into wind. This creates a side component of reverse thrust which also pushes the aircraft downwind. The counter-acting side force required to keep the aircraft on the centerline is provided by tire traction. However on wet and/or slippery surfaces, tire traction is considerably reduced. So when directional control becomes doubtful, release the brakes and reduce to reverse idle or even forward idle. Use rudder pedal steering to re-align with the centerline. Re-apply reverse thrust and use brakes as required to stop the aircraft.
- Use flap 42 for landing.
- Avoid long landings. Do not bleed off excess speed during the flare.
- After touch-down, select reverse thrust without delay to ensure manual lift dumper extention .
- Apply brakes firmly and symmetrically. Anticipate slow, initial deceleration after brake application. Do not pump the brakes; under all runway conditions the anti-skid system will stop the aircraft in a shorter distance than the pilot can by modulating the brakes.
- Avoid large and abrupt nose wheel tiller inputs as these can result in overcontrolling and skidding.

- Keep slight forward pressure on the control column to improve nose wheel traction.
- Reduce to taxi speed before vacating the runway.

NOTES:
1. Do not hold the nose up, as aerodynamic braking is negligible and directional stability is reduced.
2. If necessary emergency maximum reverse thrust may be used until standstill.

- Do not raise the flaps beyond 25 degrees until it has been checked that flap and flapvane are free of ice and impacted snow.

Parking

Park in a clear or sanded area and have the wheel chocks placed in position. Before shut down, idle the engines until TGT's have stabilized. This may take up to a minute, depending on the thrust level used during taxying. To prevent brake freezing, do not use the parking brake.

If the aircraft is to be left unattended for an extended period, take the following actions:
- Install protective covers and plugs.
- Drain all galleys and toilets.
- Close all doors and windows.

HOT WEATHER

For improved cabin cooling it is recommended to keep the APU running until cleared for take-off and to start the APU shortly before landing.

The use of "overspeed" V_2's (V_2/V_S ratios between 1.20 and 1.30) will increase the climb limited take-off weight.

Operating a series of short flights may cause excessive brake temperatures as the energy absorbed at each landing is accumulated and brake cooling with gear up is negligible. To prevent ground delays due to overheated brakes, it is recommended to lower the gear early on the approach, to use the longest runway and to adhere to the recommended landing technique.

During ground operation, select the recirculation fans off if OAT is above 18 degrees C / 65 degrees F.
Select airconditioning ECON mode off when passengers are boarding.

WIND SHEAR

General

This sub-section contains recommendations and procedures which the aircraft manufacturer considers best suitable for early recognition and avoidance of wind shear, and recovery from a wind shear encounter.
However, Fokker Aircraft does not guarantee that application of the recommended procedures always results in a safe recovery from all possible wind shear conditions.

NOTE: The recovery techniques as described in this section are not valid for aircraft equipped with a wind shear detection and recovery system.

Wind shear is a rapid change in wind speed and/or direction over a short distance along the flight path. Wind shear causes a severe hazard to aircraft during take-off, approach, and landing.
Wind shear results from a large variety of meteorological conditions such as temperature inversion, sea breezes, frontal systems, topografical conditions, strong surface winds, rain showers and thunder storms. The most dangerous type of wind shear is known as a downburst or its smaller, even more vicious form, the microburst.

APPENDIX 9

SWISSAIR V-CHECK (VORFLUG CONTROLLE)

swissair

Engineering & Maintenance
23.02.94

Telefax

to
Mr F.J. Erhart
Accident Investigation Bureau
Barentzbuilding, Saturnusstraat 5
2132 HB Hoofddorp
Fax 0031-02503-23048

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from
Hans Ulrich Beyeler
Member of Executive Management
Engineering and Maintenance
SWISSAIR
CH-8058 Zurich-Airport
Fax 0041-1-812 91 00

Palair Fokker 100
Accident at Skopje on 5.3.1993
V-Checklists F100

Dear Mr Erhart,

Checklist HIE-04, ISSUE 1, valid since start of operation (28.2.88) for **Line Stations.**
Checklist HI-113, ISSUE 4, in use since 28.7.92 at **home base Zurich.**

At the time of the accident both checklists mentioned above were valid.
Since Mr Egli was in possession of both checklists, we assume that he was performing his duty according to the english edition, considering the fact that he was working together with three Palair mechanics.

Yours sincerely,

SWISSAIR
Engineering & Maintenance

Hans Ulrich Beyeler
Member of Executive Management

Enclosure 2a

V - CHECK

Fokker 100

Valid for: Line Stations

ISSUE 1

1	Logbook Maintenance Release / Fuel Order	COMPLETED
2	Tire Pressure acc. Tire Pressure Checklist By wheel mounted manometer	CHECKED
3	MLG- & corresp. Service Doors	CLOSED
4	NLG & MLG Lockpins (3)	REMOVED
5	TOW Switch	OFF
6	Reversers	RETRACTED
7	Pitot Tube Covers (3)	REMOVED
8	Aircraft for Damage by Ground Equipment	CHECKED
9	All Exterior Doors & Service Panels Incl. nose bay, FWD & AFT avionics bay	CLOSED LOCKED
10	Engine Inlets & Exhausts for Foreign Object	CHECKED

Additional Check in Winter

For Snow & Ice

11	Engine Inlet LH & RH With ladder	SPC
12	Wing Upper & Lower Surfaces, Landing Gear	SPC

Note: There could be INVISIBLE ICE on the wing upper surface & wing roots area. Take a ladder and check carefully.

V - CHECK

Fokker 100

Gültig für: ZRH

ISSUE 4

1 Pneudrücke (am Rad montierten Manometer) .... CHECKED

2 Hauptfahrwerktore & deren Service Tore .... CLOSED

3 Fahrwerk Sicherungsstifte (3) .... REMOVED

4 TOW Switch Position .... OFF

5 TW Ein- & Auslass (vom Boden aus) .... CHECKED

6 TW Tore .... CLOSED

7 Reverser eingefahren .... CHECKED

8 Pitot Tube Schutzhüllen (3) .... REMOVED

9 Radom .... CLOSED

10 Flugzeug auf Beschädigungen .... CHECKED

11 Sämtliche Deckel & Servicepanels .... CLOSED
- Incl. Nose Bay, FWD & AFT Avionics Bay
- Ausgenommen GPU-Anschlusspanel.

Vor jedem Abflug

Clear Ice Kontrolle ausführen, wenn Temperatur tiefer als 15 °C ist.

R Die Zone im Bereich vor den Eis-Indikatoren muss unter Zuhilfenahme einer Leiter mit der Hand berührt, und auf Eis kontrolliert werden. Die Eis-Indikatoren können mittels eines geeigneten Stabes (Schaber) auf freie Bewegung und Eis kontrolliert werden.

Vorhandenes Eis MUSS entfernt werden!

12 Flügel Oberseiten im Bereich Ice Indicators .... CHECKED

Winterbetrieb

Auf Schnee & Eis kontrollieren.

13 LH/RH TW Einlass mit Leiter .... CHECKED

14 Fahrwerke .... CHECKED

swissair

CHECK MECH.

Fokker 100

Gültig für: ZRH / GVA

ISSUE 4

Transit Check = Pos. 1 - 8

Daily Check = Pos. 1 - 14

Nur wenn Parkzeit 4 Std. und Aussentemp. +5°C überschreitet.

1 Pitot Tubes Schutzhüllen (3) .... INSTALL

Fahrwerk

2 NLG & MLG .... CHECKED
Inklusive Tore, Hydr. Leitungen, Federbeinhöhe, Bremsen.

3 Pneus auf Abnützung, Schnitte .... CHECKED

4 Rad-Felgen & Bolzen .... CHECKED

Triebwerk (vom Boden aus)

5 Verschalungstore, Reverser, Stubwings .... CHECKED
Auf Leak, Fluchtung

6 TW Einlass / Auslass .... CHECKED

Rumpf & Heck

7 Flugzeug Aussen .... CHECKED
Radom, Rumpf, Flügel, Heck, Steuerflächen & Tore.

8 Oxygen Anzeigescheibe .... CHECKED

Daily zusätzlich

N 9 Oel Press. Filter Pop-Out Anzeige (TW 1 & 2) .... CHECKED
Ref.: FHB 79-33-01 601 01

Frühestens 2 Std. nach der Landung

10 Pneudrücke mit Manometer .... CHECKED

11 Bremsen Abnützung .... CHECKED

N 12 Shimmy Damper .... CHECKED
Oelstand und Festsitz

CHECK MECH.

Fokker 100

ISSUE 4

Gültig für: ZRH / GVA

13 **Wasser Service Panel Caps** .... INSTALL

Nur an ungeraden Tagen (Datum) ausführen.
14 **Fuel- Sump-Drains (6) eine Flasche ablassen** .... PERFORM
Auf Wasser kontrollieren.

swissair

APPENDIX 10

RLD AIRWORTHINESS DIRECTIVE NO. 93-167/3(A)

Airworthiness Directive of the Netherlands

Bijzondere Luchtwaardigheids Aanwijzing (BLA)

Ministry of Transport, Public Works and Water Management
Directorate-General of Civil Aviation
Aeronautical Inspection Directorate

Caution

In accordance with the Civil Air Navigation Regulations (RTL), Articles 76 and 88, the following Airworthiness Directive (BLA) is issued by the Director-General of Civil Aviation of the Netherlands (Directeur-Generaal van de Rijksluchtvaartdienst -RLD). Airworthiness Directives affect aviation safety. They are regulations which require immediate attention. You are cautioned that no person may operate an aircraft to which an Airworthiness Directive applies, except in accordance with the requirements of the Airworthiness Directive.

BLA nr : 93-167/3 (A)
Date : December 07, 1994

FOKKER AIRCRAFT B.V.
Model F.28 series, all marks

Type Certificate Nr.: A23F; T-100-87

OPERATING LIMITATIONS & TAKE-OFF PROCEDURES IN ICING CONDITIONS

Description:
Service experience has shown that, notwithstanding the operational requirement that a take-off should not be attempted unless it has been assured by the flight crew that the airplane surfaces are free of ice, frost, and snow accumulation, take-offs with Model F.28 series airplanes with contaminated surfaces have occurred, resulting in several fatal accidents. This Airworthiness Directive (BLA) adds a Limitation to the RLD-approved Airplane Flight Manual (AFM) or Flight Handbook (FHB), as applicable, to explicitly prohibit take-off with ice or other contaminations on Model F.28 series airplane surfaces.
In light of this, the RLD has determined that for the Model F.28 series airplanes an extra degree of protection is necessary beyond reliance solely on operation in accordance with current national operational de- and/or anti-icing requirements.
The RLD has determined that one acceptable method of addressing the noted icing problems is a physical (hands-on) and visual check of the leading edge and upper wing surfaces to verify that there is no accumulation of ice, frost, and or snow prior to take-off. If the physical (hands-on) part of the inspection can not be accomplished, an alternative take-off procedure must be adhered to.
As indicated previously, the RLD has determined that the accomplishment of these types of additional actions are necessary in order to provide an extra degree of protection for Model F.28 series airplanes, beyond that provided by the current national operating requirements.

Applicability: **Fokker Aircraft B.V.** Model F.28 series airplanes, all marks, all serial numbers.

Effective date: December 12, 1994

Compliance: Required as indicated, unless accomplished previously.
To prevent degradation of aerodynamic lift during take-off when ground icing conditions exist, accomplish the following:
Within 10 days after the effective date of this AD, revise the Section LIMITATIONS of the RLD-approved AFM or FHB, as applicable, to include Appendix I of this AD. This may be accomplished by inserting a copy of this AD into the AFM or FHB, as applicable.

Reason for revision: The previous issue of this AD contained two elements:
1) A limitation prohibiting take-off with contaminated airplane surfaces; and
2) An optional alternate take-off technique to improve stall margin during take-off.

The alternate take-off technique was intended to improve safety margins during take-off under ground icing conditions and not intended to replace operational de-/anti-icing programs. However, service experience has shown that this take-off technique was not used as intended.
Therefore, issue 2 of this AD has been revised to mandate either a physical hands -on check that the wing leading edge and wing upper surfaces are free of ice or other contaminations before take-off or that the alternate take-off technique is adhered to. These alternatives are considered equivalent.
It should be noted, that this AD is issued under the assumption, that the airplane is operated under an approved de-/anti-icing program to clear the airplane surfaces from ice, frost, snow accumulation etc., such as contained in FAR 91.527, FAR 121.629 and its corresponding AC 120-60 or an equivalent program.

Remarks:

- Operators of the affected aircraft may obtain copies of the revised AFM pages upon request directly from the manufacturer.
- Compliance with this AD must be recorded in the proper Aircraft Log Book(s) and the Airplane Flight Manual (AFM), or Flight Handbook (FHB), as applicable.
- This revision supersedes and cancels Airworthiness Directive (BLA) 93-167/2 dated April 29, 1994.

Address inquiries concerning this AD to:
Bureau Coordination & Technical Information (CTI)
Telephone 31-(0)2503-63155; Facsimile 31-(0)2503-40741; Telex 74592 rldli nl

APPENDIX I

WING DE-ICING/ANTI-ICING PRIOR TO TAKE-OFF

> **WARNING:**
> SMALL QUANTITIES OF ICE OR OTHER CONTAMINATION (EQUIVALENT TO MEDIUM GRID SANDPAPER) ON THE UPPER PART OF THE LEADING EDGES OF THE WING CAN CAUSE SIGNIFICANT LOSSES IN MAXIMUM LIFT AND CAN CAUSE THE AIRPLANE TO STALL AT A LOWER THAN EXPECTED ANGLE OF ATTACK. STALL SPEEDS CAN BE INCREASED BY UP TO 30 KNOTS AND DRAG CAN BE INCREASED CONSIDERABLY, RESULTING IN CONTROL PROBLEMS, WING DROP OR EVEN A COMPLETE STALL SHORTLY AFTER LIFT-OFF.
> BECAUSE A CONTAMINATED WING CAN STALL BELOW THE ANGLE OF ATTACK FOR STICK SHAKER ONSET, THE STICK SHAKER WILL PROBABLY NOT BE ACTIVATED BEFORE THE STALL.

Take-off shall not be attempted, unless the pilot-in-command has ensured that the wings, tail, control surfaces, engine inlets and other critical surfaces of the airplane are free of ice, frost, and snow, as required by national operational regulations.

IN ADDITION, when the Outside Air Temperature (OAT) is below 6°C (42°F) and either the difference between dewpoint temperature and OAT is less than 3 degrees C (5 degrees F) or visible moisture (fog, rain, drizzle, sleet, snow, ice crystals, etc.) is present, DO NOT TAKE OFF UNLESS the operator complies with either **OPTION 1** or **OPTION 2** below:

OPTION 1:

The leading edge and upper wing surfaces have been physically checked for ice/frost/snow and the flight crew verifies that a visual check and a physical (hands-on) check of the leading edge and upper-wing surfaces has been accomplished and that the wing is clear of ice/frost/snow accumulation.
This 'after- de-icing' check must be accomplished after the de- and/or anti-icing treatment of the airplane and within the applicable holdover times of the de- and/or anti-icing fluids applied.

or

OPTION 2:

The following take-off procedure is used:

> **WARNING:**
> **The following technique cannot be used unless the pilot-in-command has ensured that the wings, tail, control surfaces, engine inlets and other critical surfaces of the airplane are free of ice, frost, and snow, as required by national operational regulations.**

APPENDIX I, OPTION 2 continued:

- (All Marks, except Mark 0100 and Mark 0070) When using flight director for take-off, select HDG mode and 10 degrees pitch attitude.
- (Mark 0100 and Mark 0070) Select flap setting 8 or 15
- (Mark 1000 through 4000) Select flap setting 11 or 18
- (All Marks, except Mark 0100 and Mark 0070) Use rated take-off thrust.
- (Mark 0100 and Mark 0070) Use take-off/go-around (TOGA) thrust.
- Do not use FLEXIBLE thrust.
- At V_R rotate slowly (less than 3 degrees per second) to 10 degrees pitch attitude.
- When positively climbing, select gear UP.
- DO NOT EXCEED 10 DEGREES PITCH UNTIL AIRSPEED IS ABOVE V_2 + 20 KTS.
- When above V_2 + 20 KTS, slowly increase the pitch attitude, keeping the speed above V_2 + 20 KTS.
- Retract the flaps at or above V_{FR} + 20 KTS.

NOTES TO OPTION 2:

1. THE AVAILABLE FIELD LENGTH SHOULD NOT BE LESS THAN 120 PERCENT OF THE TAKE-OFF DISTANCE REQUIRED BY REGULATION FOR THE ACTUAL GROSS WEIGHT. Also, the 20 percent increase in take-off distance must be accounted for in the obstacle clearance analysis.
   WEIGHT MUST BE OFF-LOADED, IF NECESSARY, TO MEET THESE CONDITIONS.
2. (Mark 0100 and Mark 0070) Do not follow the Flight Director pitch command during rotation for take-off and initial climb, as this will result in exceeding the recommended maximum pitch angle of 10 degrees before reaching the speed of V_2 + 20 KTS.
3. (Mark 0100 and Mark 0070) Do not engage the auto-pilot until leaving the AFCAS TO mode.
4. For the case of an engine failure, refer to the applicable procedure in Section 4.17.01 SINGLE ENGINE OPERATION of the F.28 Mk.0100 (Fokker 100) AFM and F28 Mk. 0070 (Fokker 70) AFM, or Section 1.7.4 OPERATION UNDER ABNORMAL CONDITIONS of the F.28 FHB, as applicable.
5. During take-off the first indication of wing contamination will probably be airframe buffet when the pitch angle is increased above 10 degrees, followed by wing drop and insufficient climb rate.
   DO NOT EXCEED 10 DEGREES PITCH UNTIL AIRSPEED IS ABOVE V_2 + 20 KTS.