
In-Flight Icing Encounter and Loss of Control, Simmons Airlines, d.b.a. American Eagle Flight 4184, Avions de Transport Regional (ATR) Model 72-212, N401AM, Roselawn, Indiana, October 31, 1994, PART II

Micro-summary: This ATR-72 crashed after a severe icing incident.

Event Date: 1994-10-31 at 1559 CST

Investigative Body: National Transportation Safety Board (NTSB), USA

Investigative Body's Web Site: <http://www.nts.gov/>

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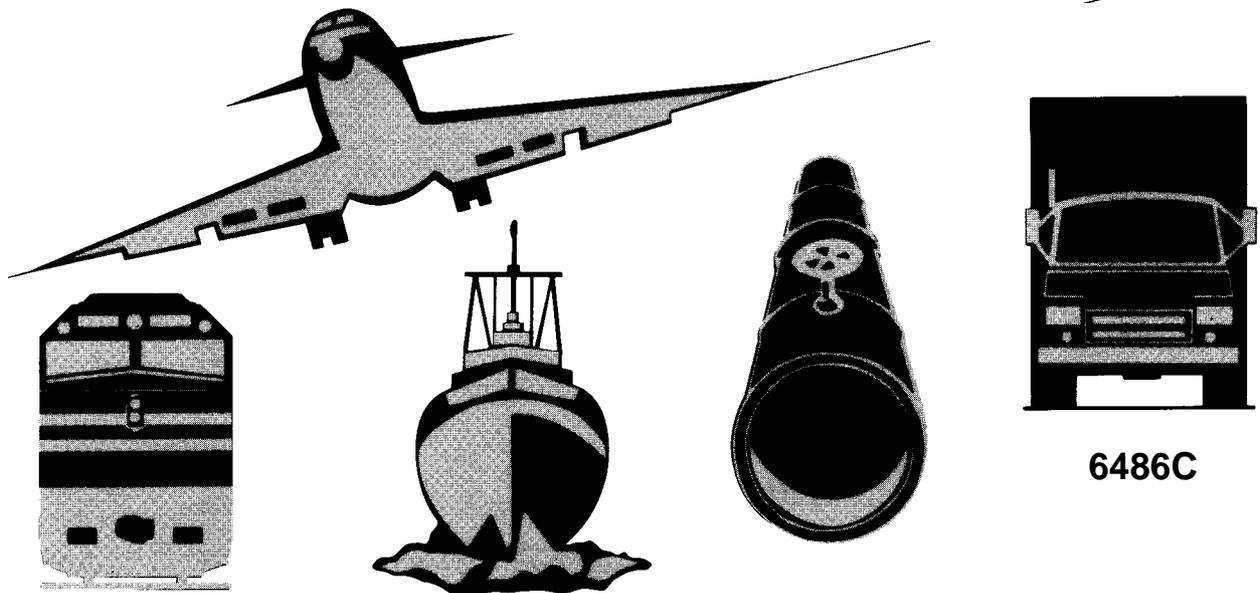
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

IN-FLIGHT ICING ENCOUNTER AND LOSS OF CONTROL
SIMMONS AIRLINES, d.b.a. AMERICAN EAGLE FLIGHT 4184
AVIONS de TRANSPORT REGIONAL (ATR)
MODEL 72-212, N401AM
ROSELAWN, INDIANA
OCTOBER 31, 1994

VOLUME II: RESPONSE OF BUREAU ENQUETES-ACCIDENTS
TO SAFETY BOARD'S DRAFT REPORT



6486C

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ROSELAWN, INDIANA

OCTOBER 31, 1994

Adopted: July 9, 1996

Notation 6486C

Abstract: Volume II contains the comments of the Bureau Enquetes-Accidents on the Safety Board's draft of the accident report. The comments are provided in accordance with Annex 13 to the Convention on International Civil Aviation. Volume I of this report explains the crash of American Eagle flight 4184, an ATR 72 airplane during a rapid descent after an uncommanded roll excursion. The safety issues discussed in the report focused on communicating hazardous weather information to flightcrews, Federal regulations on aircraft icing and icing certification requirements, the monitoring of aircraft airworthiness, and flightcrew training for unusual events/attitudes. Safety recommendations concerning these issues were addressed to the Federal Aviation Administration, the National Oceanic and Atmospheric Administration, and AMR Eagle.

INSPECTION GENERALE DE L'AVIATION CIVILE
ET DE LA METEOROLOGIE

BUREAU ENQUÊTES-ACCIDENTS

CONFIDENTIEL

Le Bourget. le 13 mai 1996.

518

COMMENTS OF THE BUREAU ENQUETES ACCIDENTS (FRANCE)

ON THE NATIONAL TRANSPORTATION SAFETY BOARD

DRAFT FINAL REPORT ON THE ACCIDENT

OF SIMMONS AIRLINES FLIGHT 4184

AT ROSELAWN, INDIANA ON OCTOBER 31, 1994

**SUBMITTED PURSUANT TO ANNEX 13 TO THE
CONVENTION ON INTERNATIONAL CIVIL AVIATION**

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INTRODUCTION

The BEA appreciates the invitation extended to it by the NTSB, as required by Annex 13 to the Convention on International Civil Aviation, to comment on the draft accident investigation Final Report. This will serve as the BEA's comments on that draft Final Report. We understand that the Board, as required by Section 6.9 of Annex 13, will either amend the draft Final Report to include the substance of these comments, or append these comments to the Final Report.

However the BEA wishes to express its disappointment about its absolute non participation to the investigation phase related to analysis, findings, causes and safety recommendations, despite the initial commitment from the NTSB and despite its repeated efforts to provide the NTSB investigators with relevant views and documentation. This presently leads to a major disagreement between two Investigative Authorities on facts, analysis and on the accident causes, and, moreover, to the risk that the safety recommendations will not be properly taken into account by all the parties of the aviation community worldwide, because they will be based on an arguable report.

EXECUTIVE SUMMARY

General

The BEA strongly disagrees with substantial portions of the Factual, and with the Analysis, Conclusions, and Probable Cause sections of the report. In the BEA's view, except for the Recommendations section, the present report is incomplete, inaccurate, and unbalanced. It appears to have been influenced by an a priori belief on the probable cause of this accident. The BEA strongly believes that today one-sided approach is detrimental to the cause of international aviation safety.

The Factual section selectively reports the facts of this accident. Some relevant facts are omitted and some other which are included are simply not accurate or their presentation is misleading. The BEA regrets it, since it had already advised the NTSB of a number of significant omissions, inaccuracies, and misrepresentations through his three sets of comments to the earlier drafts of this section, and since it was agreed that many of these errors would be rectified.

The Analysis and Conclusions sections are hampered by the incomplete and inaccurate Factual section. "Many of the issues which are discussed are addressed in an incorrect or incomplete manner. Those sections also regrettably omit any discussion of several highly relevant issues for safety and for the understanding of this accident and fail to address a true combination of factors which has caused it. They clearly are inconsistent with the safety recommendations which follow.

Given the facts of this accident, the current Probable Cause statement, which ignores critical causal factors, is unbalanced, not correct, and detrimental to the public concern for safety.

Accordingly, the BEA considers that the report requires substantial reworking. Acknowledging the necessity, for achieving true aviation safety to take into consideration all relevant aspects of the aviation system, outside any national consideration or any a prior¹ sharing of blame or liability, it has expended significant efforts to prepare in these comments such a substantial reworking of all or part of the quoted sections, to assist the NTSB in making the necessary revision and facilitate the inclusion of the comments.

Probable Cause Statement

This accident was caused by a combination of factors, as reflected in the following BEA-proposed Probable Cause Statement :

The Probable Cause of this accident is the loss of control of the aircraft by the flight crew, caused by the accretion of a ridge of ice aft of the de-icing boots, upstream of the ailerons, due to a prolonged operation of Flight 4184 in a freezing drizzle environment, well beyond the aircraft's certification envelope, close to VFE, and utilizing a 15 degree flap holding configuration not provided for by the Aircraft Operating Manuals, which led to a sudden roll upset following an unexpected Aileron Hinge Moment Reversal when the crew retracted the flaps during the descent.

The contributing factors to this highly unusual chain of events are :

1. The failure of the flight crew to comply with basic procedures, to exercise proper situational awareness, cockpit resource management, and sterile cockpit procedures, in a known icing environment, which prevented them from exiting these conditions prior to the ice-induced roll event, and their lack of appropriate control inputs to recover the aircraft when the event occurred :

2. The insufficient recognition, by Airworthiness Authorities and the aviation industry worldwide, of freezing drizzle characteristics and their potential effect on aircraft performance and controllability ;

3. The failure of Western Airworthiness Authorities to ensure that aircraft icing certification conditions adequately account for the hazards that can result from flight in conditions outside 14 CFR Part 25, Appendix C, and to adequately account for such hazards in their published aircraft icing information ;

4. The lack of anticipation by the Manufacturer as well as by Airworthiness and Investigative Authorities in Europe and in the USA, prior to the post accident Edwards AFB testing program, that the ice-induced Aileron Hinge moment reversal phenomenon could occur.

5. The ATC's improper release, control, and monitoring of Flight 4184.

Associated Findings and Analysis

The NTSB's record in this investigation clearly shows that this flight crew had entered icing conditions, and yet failed to comply with mandatory requirements pertaining to such conditions contained in the applicable flight manuals, Federal Aviation Regulations, and explicit company policies, which, if followed, would have prevented this accident.

The situation was greatly exacerbated by the lack of proper situational awareness, cockpit resource management, and sterile cockpit procedures, which resulted in their failure to exit the known icing conditions prior to the ice-induced roll event and their subsequent surprise and lack of appropriate control inputs to recover the aircraft when the event occurred.

In the BEA's view, the operation of any airplane with unpowered flight controls in this fashion and environment, would severely jeopardize the safety of the flight. Accordingly, the BEA believes that these factors must be the focal point of the analysis, findings, and probable cause statement in this accident report. This is particularly true in light of the other more recent accidents involving cockpit failures by flight crews, which led to the FAA's pending in-depth review of a flight crew training program.

Thus, the BEA strenuously disagrees with the current Analysis, Findings, and Probable Cause Statement sections, which ignore, or address in a very shallow fashion, very important issues in this accident, and only addresses in an excessive mode the aircraft and the manufacturer's and Airworthiness Authorities' responses to certain prior incidents. This excessive approach is simply not supported by the NTSB's own record of investigation.

Report Causal Factor No. 1:

ATR failed to completely disclose to operators and incorporate in the ATR- 72 AFM and FCOM and training programs, adequate information concerning previously known effects of freezing drizzle and freezing rain conditions on the stability and control characteristics, autopilot and related operational procedures when the ATR-72 is operated in such conditions.

Comment :

This probable cause finding (and the associated analyses and findings) is not supported by the record of investigation and is wrong.

ATR disseminated to its operators extensive information and warnings reminding them that prolonged exposure to freezing rain conditions is to be avoided. ATR also provided operators and flight crews with additional information designed to facilitate the recognition and avoidance of such conditions, which exceed the certification limits of all turboprop aircraft. ATR very specifically advised operators that such conditions could effect roll control forces leading to an autopilot disconnect and a resulting roll to a large bank angle until the crew took over the controls. ATR described appropriate recovery procedures and introduced them into ATR training programs. ATR also modified simulator packages for icing operations to simulate such roll departures.

In fact, the investigative record clearly shows that American Eagle/Simmons passed on to its flight crews these ATR warnings that, in icing conditions outside those specified in 14 CFR Part 25, Appendix C, the ATR 42/72 aircraft performance and controllability may be affected in such a way that autopilot self-disconnect and subsequent roll excursions could occur; that roll efficiency would nevertheless be maintained; and that recovery could be readily achieved by making firm aileron inputs to counter the roll excursions, and by applying basic stall recovery techniques.

In addition to stating that ATR did not provide operators with the above-referenced information, the report also states that an “aileron hinge moment reversal” mechanism was disclosed in the icing related incidents it reviews, and criticizes ATR for failing to issue warnings to specifically describe such an event. These “facts” are wrong and this assertion is untrue.

The basis for this assertion is the claim that an “aileron hinge moment reversal” was involved in the incidents of Mosinee, Ryanair, Air Mauritius, Burlington, and Newark and was therefore known to ATR.

On the contrary, the DFDR data from Mosinee, Ryanair, Air Mauritius and Burlington incidents confirm that they were all stall departures following ice accumulations which resulted from flight crew failures to follow the basic procedures for operation in icing conditions by failing to select aiframe de-icing, to maintain minimum airspeeds or proper propeller speed settings.

No “aileron hinge moment reversal” was involved in Ryanair or Air Mauritius. The momentary modification of the aileron hinge moment in Mosinee and in Burlington which occurred after the asymmetrical stall commenced had no direct effect on these incidents. Both the NTSB and ATR determined that the Newark incident involved severe turbulence. From a review of the Newark DFDR data after Roselawn, because of the high level of turbulence, it cannot be determined whether or not any aileron hinge moment modification was involved in the incident,

The incorrect assertion of prior knowledge is all the more surprising that the NTSB was the primary investigation authority for the Mosinee incident, with full access to the facts and data involved. It had full access to the BEA's report, which incorporated ATR's own analysis and was involved with the FAA in several meetings with the BEA, the DGAC and ATR. The NTSB's level of participation and knowledge of the Mosinee incident was at least as great as any other entity investigating the incident. The NTSB had absolutely no recommendations or suggestions for any other corrective action, warnings, or any other response to the incident.

This assertion is also surprising because the NTSB not only received the full and open cooperation of the manufacturer, but also encouraged and participated in the manufacturer's extensive efforts after the Roselawn accident that led to the initial discovery of the ice-induced “aileron hinge moment reversal” phenomenon.

The NTSB knows of the extensive wind tunnel testing, high speed taxi tests, flight testing, and considerable efforts spent by the manufacturer after Roselawn for the first-ever USAF tanker freezing drizzle/rain testing program for civil or military aircraft at Edwards AFB. The NTSB knows from its own involvement in the testing that the phenomenon of an “ice-induced aileron hinge moment reversal” and its associated flow separation behind the boots at low Angle of Attack was discovered for the very first time as a result of this exhaustive post-Roselawn investigation

The BEA also wonders about the differences which a previously disseminated information on the phenomenon of an “ice-induced aileron hinge moment reversal” had it been identified, would have brought to the crew’s behaviour. The warnings which were provided to all operators, and which in turn were provided by Simmons to its flight crews, identified that the weather environment of concern could affect roll control forces leading to an autopilot disconnect and a resulting roll to a large bank angle until the flight controls were taken over by the crew. The fact that such a change in aileron control forces might or might not be caused by an “aileron hinge moment reversal” is not a piece of information which would have added to the warning provided to the flight crews.

What is most disturbing about the report's position on this point is that it obscures the safety concern disclosed in this accident that this flight crew was so oblivious to the icing conditions they encountered that they ignored the multiple warnings, instructions, and regulations they already had received regarding proper operations in such conditions. To suggest that a more specific warning about an "aileron hinge moment reversal" phenomenon would have had any impact on this flight crew is not supportable by the NTSB's record of investigation,

Report Causal Factor No 2:

The French DGAC's inadequate oversight of the ATR-42 and ATR-72 and necessary corrective action to assure continued airworthiness in icing conditions.

Comment :

The BEA strongly disagrees with this erroneous probable cause finding (and the associated analyses and findings) The DGAC has consistently fulfilled its obligations as the primary certification Authority for the ATR-42 and ATR-72 aircraft. The joint FAA/DGAC Special Certification Review Report confirmed that the ATR 42 and 72 were properly certified in full accordance with both US and European certification standards, that the DGAC acted correctly and properly in its certifications of the different ATR model aircraft, and that the DGAC and FAA properly applied the Bilateral Airworthiness Agreement ("BAA") between the U.S. and France in their certifications of the aircraft.

Despite this, the report's findings state that ATR airplanes have a unique susceptibility to ice-induced aileron hinge moment reversals. This is not accurate. The concern about ice-induced aileron hinge moment reversals caused by freezing drizzle droplets applies to all aircraft with unpowered controls.

This is amply evidenced by (I) the Post-Roselawn review of other turboprop icing related events, which has disclosed similar characteristics for those airplanes, and (II) the FAA's recently proposed Airworthiness Directives relating to restrictions on operations in icing conditions, which result from the FAA's post-Roselawn accident investigation of how ice accretion resulting from freezing drizzle impacts on different models of aircraft. These proposed AD's apply to virtually every model of turboprop aircraft in the world.

The suggestion that the DGAC provided inadequate oversight and inadequate corrective action with respect to the ATR aircraft also, is not supported by the NTSB's investigative record regarding prior ATR icing incidents. The investigative record demonstrates that the DGAC was actively involved in investigating the ATR previous icing events, considered whether these events warranted any corrective actions, and required that the manufacturer take decisive corrective action whenever this was appropriate.

This probable cause finding, and the associated analyses and findings, to the effect that the DGAC failed to require the manufacturer to take additional corrective actions and that this "led directly to this accident" appears to be based on the erroneous assumption that the DGAC had identified, from earlier ATR icing incidents, the "ice induced aileron hinge moment reversal" which was involved in the Roselawn accident.

Neither the DGAC nor the NTSB, FAA, BEA, or ATR identified, from their investigation of these earlier incidents, the “aileron hinge moment reversal” phenomenon which was involved in the Roselawn accident. This phenomenon was not identified until after the Roselawn accident.

Thus, the BEA entirely disagrees with the statement that the DGAC’s failure to require ATR to take additional corrective action “led directly to this accident. ”

Report Causal Factor No. 3:

The French DGAC's failure to provide the FAA with timely airworthiness information developed from previous ATR incidents and accidents in icing conditions, as specified under the BAA and ICAO Annex 8.

Comments :

This probable cause finding (and the associated analyses and findings) appears to be based on a misunderstanding of the BAA and ICAO Annex 8, is not supported by the record of investigation, and is wrong.

The pertinent sections of the BAA (section 6) and of Annex 8 (Section 4.2.2), require the Exporting State to provide to other airworthiness authorities information obtained during the investigation of major incidents or accidents only where those incidents or accidents "raise technical questions regarding the airworthiness of [the aircraft]" or otherwise identify information which is "necessary for the continuing airworthiness of the aircraft and for the safe operation of the aircraft. "

There is no factual basis whatever in the NTSB's record of investigation to support the suggestion that the DGAC failed to provide the FAA on a timely basis with critical airworthiness information developed from previous ATR icing events. Prior to the Roselawn accident there had never been an ATR-72 accident of any type, nor had there been any ATR-72 icing incidents involving roll control issues.

With regard to the ATR-42 icing related incidents which were reviewed by the NTSB and occurred prior to the Roselawn accident, the facts demonstrate that the DGAC fully complied with its obligations under the BAA and Annex 8. In the one incident which did disclose an airworthiness issue (Mosinee -- S/N 91), the DGAC worked closely with the FAA to identify corrective actions, passing on adequate information to the FAA and other Airworthiness Authorities. In the other incidents, no investigative Authority including the BEA and the NTSB determined that any aircraft airworthiness or safe operation issue was involved.

To the extent that the report is suggesting that the DGAC failed to disclose to the FAA information indicating that the ATR was susceptible to an aileron hinge moment reversal of the type which caused the Roselawn accident, this suggestion simply ignores the fact that none of the parties which had investigated any of the prior incidents, including the NTSB, had identified this phenomenon before the Roselawn accident.

Recommendations

The BEA notes with interest the disparity between the broad scope of the recommendations which the NTSB makes as a result of this accident and the selective focus of the report's statements of the findings and proposed Probable Cause. The BEA generally does not disagree with the NTSB recommendations, but suggests several changes. To supplement its proposed revisions to the current recommendations, the BEA suggests the addition of recommendations to ensure that (1) flight crews "report icing conditions to ATC/FSS, " as required by the Airman's Information Manual; (2) air traffic controllers solicit PIREPS regarding "icing of light degree or greater, " as required by FAA Order 7110.65, Air Traffic Control; (3) NTSB and FAA provide on a timely basis all pertinent information from their accident and incident investigations respectively to the Investigative and Airworthiness Authorities of the country of certification and manufacture of the aircraft involved; and (4) FAA take all necessary steps to recall to the Airlines and Flight crews, the rules and procedures regarding cockpit discipline, cockpit resource management and situational awareness, which were missing in this accident.

Conclusion

The BEA firmly believes that if the draft Final Report is reworked as suggested here, then the long-term legacy of the Roselawn accident and its investigation will be the development of critically important safety lessons with regard to not only the dangers posed by freezing drizzle and the need to modify icing certification and operational standards, but the other important issues discussed herein as well. Such safety lessons will benefit the entire aviation industry worldwide.

1. FACTUAL INFORMATION

1.1. HISTORY OF THE FLIGHT

The BEA believes that the NTSB's *History of Flight* section omits critical factual information which is necessary for a complete analysis and understanding of this accident. In this regard, the BEA has set forth below its comments in respect to what it believes is a more complete History of Flight.

American Eagle Flight 4184 was a scheduled FAR Part 121 flight from Indianapolis Airport, Indiana (IND) to O'Hare International Airport in Chicago, Illinois (ORD) on October 31, 1994. The aircraft was an ATR 72-212, MSN 401, registered by Simmons Airlines as N40 1AM and operating as American Eagle.

Flight 4184 was the second of five flight segments scheduled for the first day of a five day pilot trip pairing. The First Officer was scheduled to fly the entire five days. The Captain, who had flown the previous three days, was scheduled to fly only the first four legs on the first day, and was to be replaced thereafter by another Captain. Several pilots indicated that this was possibly the first time the Captain and the First Officer had flown together.

The first officer was the flying pilot for this leg.

The pilots reported for duty before 10.39 (CST)(1). They flew Flight 4101, departing Chicago O' Hare, (ORD) at 11.39 and arriving at Indianapolis, IN (IND) at 12.42 CST. The accident occurred at 15.59 during their subsequent return flight (Flight 4184) en-route from IND to ORD.

Prior to the departure of Flight 4184, the flight crew received a combined flight plan and weather package. According to Simmons/American Airlines' policy, the meteorological information provided by American to the crew of Flight 4184 in the Flight Release did not contain AIRMET information, nor did it contain any information regarding forecast turbulence or in-flight icing conditions along Flight 4 184's intended route of flight. In this regard, *AIRMET Zulu Update 3 for icing and freezing level* was applicable to Flight 4 184's route of flight from Indianapolis to Chicago, but was not included in the Flight Release, This AIRMET stated :

Light occasional moderate rime icing in cloud and in precipitation, freezing level to 19,000 feet. Freezing level 4,000 to 5,000 feet northern portion of area sloping to 8,000 to 11,000 feet southern portion of area.

Flight 4184 was scheduled to depart the IND gate at 14.10 and arrive at the ORD gate at 15.15. Flight 4184 blocked out of the IND gate at 14.14. However, because of airport reconfiguration due to anticipated deteriorating weather conditions, the aircraft was held on the ground for approximately . 42 minutes. In this regard, the flight crew requested and received taxi instructions from the ground controller at 1417:15.

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(1) All times are Central Standard Time (CST) unless otherwise specified.

At 1452:31, the Clearance Delivery controller called the ZAU TMC for release of the flight. The TMC said “. . . he is released, that fix (LUCIT intersection) in the hold so he might do some holding when he gets up here but he’s released”. At 1453:19, the Ground Controller advised the flight crew”. . . you can expect a little bit of holding in the air and uh you can start’em up, contact the tower when you’re ready to go”.

Flight 4184 was cleared for take off at 1455:20 and became airborne at 14.56. There were 64 passengers, 2 flight attendants, and the 2 pilots on board the aircraft. The zero fuel weight was 40,586 pounds, the takeoff gross weight was 45,586 pounds and the center of gravity was 22 percent mean aerodynamic chord.

As established by the aircraft’s Digital Flight Data Recorder (DFDR), the aircraft climbed to its cruise altitude at 170 kts indicated airspeed (KAIS). The autopilot was engaged one minute after takeoff during the climb.

About 16 minutes after take off, the aircraft leveled off at an altitude of 16,300 ft and accelerated to 190 kts KIAS, One minute later, the aircraft initiated a descent toward an altitude of 10,000 ft. During the descent, the propeller speed was increased from 77% NP to 86% NP which is required whenever the aircraft encounters icing conditions. At 1516:32, the aircraft airframe deicing system was activated taking the aircraft anti-icing/ deicing system to Level 111 which is required whenever the aircraft is accreting ice,

At 1517:50, the aircraft reached the altitude of 10,000 ft. At 1518:07, Flight 4184 was cleared by the Chicago TRACON BOONE Sector Controller to enter a holding pattern at the LUCIT Intersection located 19 miles south of the Chicago Heights VOR. An expect further clearance (ECF) of 15:30 was given which was revised one minute later to 15.45 by the BOONE Controller.

The recorded sound on the Cockpit Voice Recorder (CVR) began at 1527:59. The CVR recorded the next 30 minutes of the flight. However, only some 15 minutes of the CVR recording was transcribed by the NTSB. The remainder of the CVR's recorded information was severely edited out of the transcript provided to the BEA.

At 1524:39, the Captain advised the BOONE Sector Controller that Flight 4184 was entering the hold. The first holding pattern circuit was flown between 1524 and 1532:20. DFDR data established that the first holding pattern was flown at an airspeed of approximately 175 KIAS with the wing flaps in the retracted, 0 degree position, which is the only flap configuration for which performance data is provided in the ATR- 72 Airplane Operating Manual (AOM) for holding. The Airframe deicing system was deactivated at 1523:12, just before entering the holding pattern. The propeller speed was reduced to 770/0 NP at 1525:00. The Total Air Temperature (TAT) at this time was +2. 5°C.

The ATR-72 AFM requires that “Level II” anti-icing measures be activated and that the propeller speed be maintained at 860/0 NP whenever the aircraft is being operated in icing conditions. The ATR-72 AFM Limitations Section (Section 2.06.0 1) defines “icing conditions” as existing whenever the TAT in flight is below +7 degrees C and visible moisture in the air in any form is present. The definition of visible moisture expressly includes clouds. At the time Flight 4184 entered the hold and throughout the rest of its flight in the holding pattern the DFDR recorded the in flight TAT below +7 degrees C. The meteorological data for the area of the holding pattern establishes that Flight 4184 was operating in and out of clouds for most of the 33 minutes it was in the hold prior to the accident.

At the time the CVR recording commenced at 1527:59, the Junior Female Flight Attendant is present in the cockpit conversing with the crew and “loud music similar to a standard broadcast radio station” is being played in the cockpit. The “loud” radio music continues for the next 18 minutes of the holding pattern and cockpit conversations with the Junior Female Flight Attendant continued for approximately 15 minutes.

The second holding pattern circuit was flown between 1532:20 and 1541:47. At 1533:13, the Captain stated : “man this thing gets a high deck angle in these turns”. At 1533:17, the Captain said : “we’re just wallowing in the air right now”. The DFDR data traces do not show any indication of “wallowing”. The First Officer then stated at 1533:19 “you want flaps fifteen ?” The Captain then said : “I’ll be ready for that stall procedure here pretty soon”. In response, the first officer “chuckled”. At 1533:24, the Captain stated : “do you want kick’em in (it’ll) bring the nose down”. At 1533:25, the First Officer responded by stating “sure”.

The CVR transcript then records the “sound of several clicks similar to flap handling being moved” at 1533:26 followed by the Captain stating at 1533:29 “guess Sandy’s going ‘ooo”.

At 15.33:26, DFDR data indicates that the flap handle was moved to select the Flap 15 configuration. The ATR-72 AFM does not provide for a Flap 15 configuration for holding. After extension of the flaps, the IAS was 175 kts and the AOA (angle of attack) decreased down close to zero degrees. The DFDR traces, again, do not reveal any evidence that the aircraft was “wallowing” before or after flap extension.

At 1533:56, a single tone which could have been the caution alert chime of the aircraft Anti-icing Advisory System (AAS) was recorded on the CVR. There is no discussion regarding the chime by the flight crew. However, during this same time, the Captain was engaged in extensive discussions with the Junior Female Flight Attendant in the cockpit regarding warning systems demonstrating the Ground Proximity Warning System (GPWS) to her. The GPWS warning “too-low, terrain, too-low terrain” was recorded by the CVR at 1534:23.

At 1538:43, the crew received an updated EFC (Expect Further Clearance) of “two two zero zero” (16:00 CST) from the BOONE Sector Controller. This extended Flight 4 184’s anticipated holding time by 30 minutes by moving the EFC from 15:30 to 16:00.

Between 1538:55 - 1542:34, the CVR transcript indicates that the Pilot and Junior Female Flight Attendant's "non-pertinent conversation continues". During this time, at 1541:07, a second single tone similar to the Caution Alert Chime was recorded on the CVR. The DFDR indicates that the TAT was +2 degrees C.

The chime for the aircraft's Anti-Ice Advisory System (AAS) provides the flight crew an aural indication that ice was accumulating on the aircraft. There is no indication on the CVR or DFDR that the flight crew had or had not previously activated the Level 11 anti-icing measures required to be used in icing conditions, and before ice actually accretes on the aircraft. The flight crew at 1541:09 selected Level 111 activating the airframe de-icing system followed by an increase in the propeller speed to NP 86°/0. At 1542:20 the "sound of eight clicks" was recorded by the CVR, which are not identified on the CVR transcription. The CVR transcript contains no comment from the crew about icing conditions at this time or about having previously entered icing conditions.

The third holding pattern circuit was flown between 1541:47 to 1551:55. Shortly after the third holding pattern was commenced at 1541:47, the Junior Female Flight Attendant apparently left the cockpit (at 1542:40, the CVR recorded "clicks similar to cockpit door being opened and closed"). The NTSB provides the full CVR transcript only after the Junior Female Flight Attendant departed from the cockpit, The full transcript commences at 1542:41.

At 1543:27, the crew received information from dispatch through the ACARS system and the ACARS system was discussed by the Captain and First Officer while the First Officer made an attempt to transmit the EFC time and the fuel data. It appears that the flight crew had difficulties in operating the ACARS system

At 1545:48, the radio music playing in the cockpit stopped, and the Captain made a cabin announcement through the Public Address system. He apologized for the delay and advised that connecting flights might also be delayed. The First Officer continued to operate the ACARS system. Thereafter, the Captain and the First Officer continued to discuss the ACARS system through 1548:26.

At 1548:34, the First Officer commented to the Captain: "that's much nicer, flaps fifteen". At 1548:46, the Captain replies : " I'm sure that once they let us out of the hold and forget they're down, we'll get the overspeed". The First Officer responded with a "chuckle" at 1548:48.

At 1548:43, one pilot (not identified in CVR transcript) mentioned : "I'm showing some ice now". There is no response to this comment transcribed, nor is there any discussion whatsoever between the pilots regarding this icing observation

At 1549:05, 22 seconds after the comment “I’m showing some ice now”, the Captain unfastened his seat belt and he left the cockpit at 1549:07. The Captain did not provide the First Officer with any instructions before leaving the Flight Deck. The Captain was then absent from the cockpit for over 5 minutes (1549:07 - 1554:20),

The fourth holding pattern circuit commenced immediately after the Captain left the cockpit. This holding pattern was flown between 1550:44 and 1557:22.

Between 1549:05, when the CVR recorded the “sound of ding along similar to flight attendant call bell” and 1552:00, while the First Officer was alone in the cockpit, he was involved in at least two, and possibly three separate intercom conversations, with the Junior Female Flight Attendant, the Senior Female Flight Attendant, and the Captain.

At 1551:39, the Captain, still out of the cockpit, used the aircraft intercom system to communicate with First Officer and engaged in the following conversation :

INT-1 (1551:40) : “getting busy with the ladies back here”,

INT-2 (1551:41) : “oh.”

INT-4 (1551 :43) : [sound of snicker]

INT- 1 (155 1 :45) : “yeah, so if I don’t make it up there within the next say, fifteen or twenty minutes you know why”.

INT-2 (1551 :49) : “OK”

INT- 1 (1551 :50) : “OK”

INT-2 (1551:51) : “I’ll uh, when we get close to touchdown I’ll give you a ring”

INT-1 (1551:53) : “there you go”

INT-2 (1551:54) : unintelligible word.

INT-1 (1551:55) : “no, I’ll be up right now. There’s somebody in the bathroom so (unintelligible words).

CAM (1551:55) : “[wailing sound similar to “whooper” pitch trim for two seconds]”

INT- 1 (1551 :59) : “talk to you later”

INT-2 (1552:00) : “OK”

At no time during his intercom conversation with the First Officer did the Captain inquire about the status of the flight. In this regard, there was no discussion about the icing conditions the flight was operating in.

At 1554:20, a sound similar to Captain’s seat moving laterally and forward was heard, and at 1554:47, following the Captain’s return to his seat, he resumed discussions with the First Officer about ACARS messages. There is no indication that the Captain had used the opportunity while walking through the aircraft to observe the status of the ice on the aircraft.

At 1555:23, the Captain asked : “and you haven’t heard anymore from this chick in, this controller chick, huh ?” The First Officer replied : “no, not a word. . .“

At 1555:42, the First Officer states : “we still got ice” without further comments. The First Officer’s statement was not acknowledged by the Captain. There was no discussion whatsoever regarding the icing conditions being encountered either at that time, or since the First Officer’s first mention that the aircraft was operating in icing conditions and the activation of Level 111 de-icing equipment over 14 minutes before (at 1541 :07). Throughout this time, the DFDR shows that the TAT was +2. 2°C.

There is no indication at this time, or at any other time during the flight, that the flight crew notified ATC that they had encountered and were operating in icing conditions.

Following the First Officer’s statement “we still got ice”, the CVR transcript indicates the next sound is “similar to paper being torn from ACARS printer” which is followed by the Captain saying “here” (1555:47), the First Officer’s reply “get a message ?” (1555:58), and the Captain saying “you did” (1555:59). The Captain then decides to call the American Eagle Chicago Operations Control (AEC), saying “I’ll be right back. K, I’m a talk to the company”. (1556: 11) He asked whether AEC was aware of the Flight 4184 delay and discussed flight connections.

At 1556:14, the BOONE Sector Controller attempted to contact Flight 4184 to issue a clearance saying “descend and maintain eight thousand”. The flight crew did not respond. The Captain proceeded with his call to AEC.

At 1556:24, the CVR recorded a TCAS (Traffic Alert Collision Avoidance System) warning : “traffic, traffic”. There was no acknowledgment of this warning by the flight crew nor was there any discussion whatsoever between them regarding the alert.

At 1556:27.8, while the Captain was still speaking to the AEC, Chicago ATC again issued a clearance to Flight 4184 to descend to 8000 ft and advised the crew to expect 10 more minutes “till you’re cleared in”. The First Officer acknowledged at 1556:50.1 saying only “thank you”. At 1556:45, the aircraft initiated a descent to 8000 feet in the V/S (vertical speed) AP mode.

At 1557:16.3, three minutes after returning to the cockpit and 12“ before the upset, the Captain asked the First Officer : “are we out of the hold ?“. He was told by the First Officer : “no we’re just goin’ to eight thousand”.

At 1557:20, during the descent, the DFDR data indicates that the power was reduced to Flight Idle. The propeller rotation speed was 86 % and, TAT was 4 degrees C. The autopilot was still engaged in V/S - HDG SEL AP modes. The aircraft initiated a right turn and the bank angle stabilized at 15 degrees. The airspeed was 176 KIAS.

At 1557:22.1, the CVR records the sound of “repeating beeps similar to overspeed warning” (the flap overspeed warning) at an airspeed of 186 KIAS. At 15.57:26.2, the Captain stated : “I knew we’d do that”. The flaps were then retracted to the flaps O position. During the flaps retraction, the AOA increased gradually from -1 degree to 6,5 degrees, the speed was maintained, the bank angle was maintained, and the left aileron deflection slightly increased to 2 degrees upwards, then decreased rapidly towards neutral position.

At 15.57:28.5, the autopilot disconnected. The left aileron then deflected abruptly downwards. The aircraft rapidly rolled to the right to a maximum bank angle of 77 degrees. The airspeed was 187 KIAS, propeller rotation speed was 86%, and the TAT value was 4 degrees C.

The First Officer was flying the aircraft when the roll occurred. The Captain said “oh” at 1557:29.9 with the First Officer saying “oops, #“ at 1557:32.8. Following the initiation of the roll, there was no discussion between the flight crew members regarding what was occurring nor was there any conversation between them in respect to aircraft’s attitude. The First Officer did not ask for any help in controlling the aircraft or in responding to the event.

The DFDR further indicated that as the AOA decreased through 6 degrees, the ailerons moved to a nearly neutral position while the aircraft stopped rolling at 77 degrees, right wing down. Shortly thereafter, the aircraft rolled back to the left to a minimum angle of approximately 59 degrees right wing down. The AOA was reduced down to 1.2 degrees, then increased again to 6 degrees.

At 1557:33, the left aileron deflected again to 8 degrees downwards and the aircraft rolled again to the right. At this point, according to the DFDR, the Captain was twice briefly pulling more than 10 DaN (22 lbs) on the pitch control column. DFDR data further shows that the First Officer and the Captain were pulling on the control column at different times without coordination. The CVR records no attempt to either transfer the controls to the Captain, or to coordinate flight control inputs.

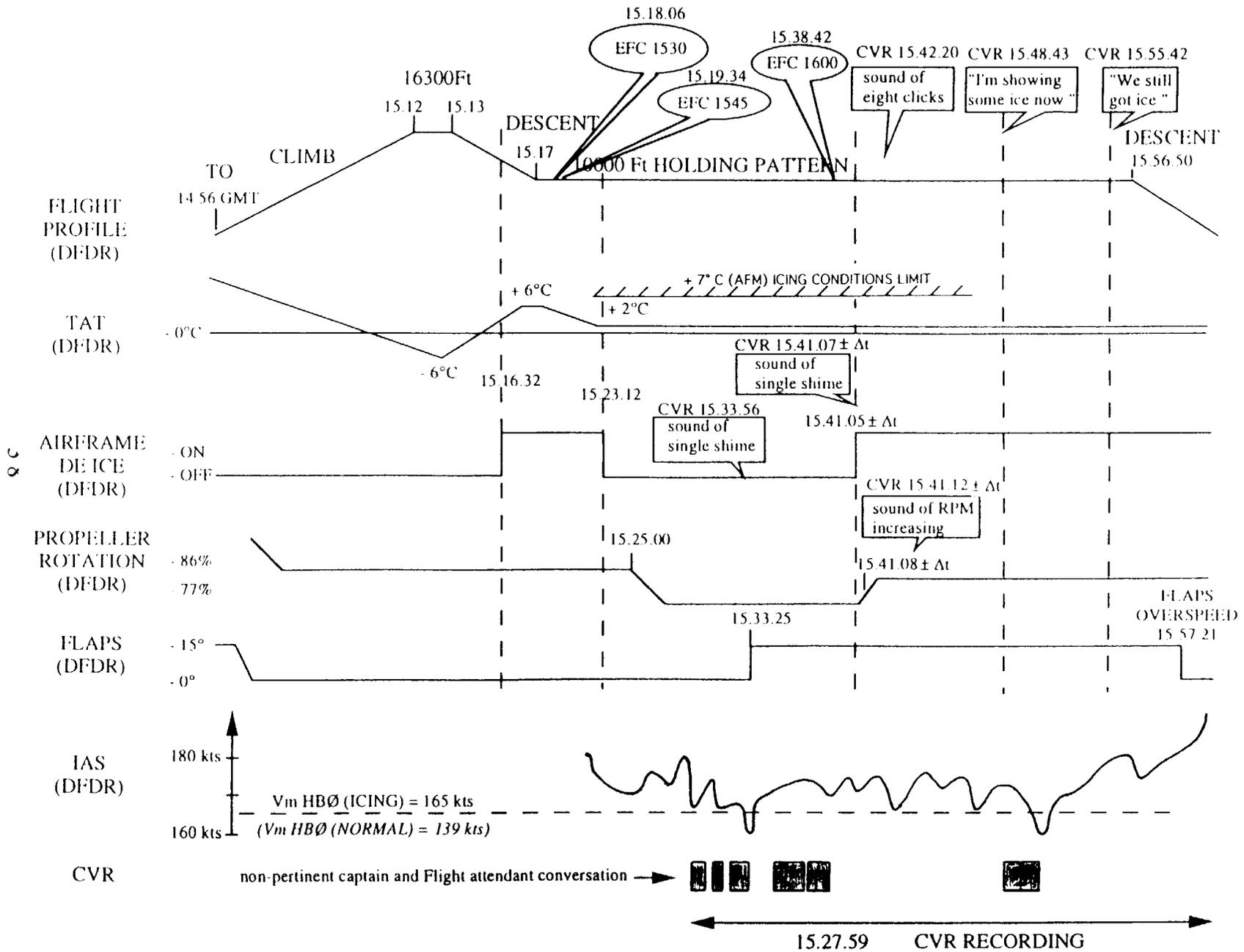
The aircraft rolled rapidly to the right and continued to roll through an inverted position and through wings level, while simultaneously the aircraft's pitch attitude decreased to 55 degrees nose down. The aircraft continued to roll to the right an additional 144 degrees, while the airspeed steadily increased to over 260 KIAS.

At 1557.44, the DFDR data revealed the aircraft began to roll to the left and that the pitch attitude reached a maximum of 73 degrees nose-down. The airspeed increased to 296 KIAS.

From the time of the autopilot disconnection, the DFDR data indicates nine momentary spikes on the pitch axis corresponding to either the Captain's or the First Officer's inputs in excess of 10 daN (22 lbs). However, the elevator deflection momentarily spiked to 8 degrees "nose up" with a mean value of approximately 3 degrees "nose up". During the entire time from the roll initiation, the rudder deflection was erratic and never exceeded 2 degrees. The maximum available rudder deflection was 3.5 degrees. During the same time period, the aileron deflected erratically fluctuating between an 8 degree "left wing down" position and the "right wing down" stop, and returning to the 0 degree position for 6 seconds at 1557:43. During this entire time, the Power Level Angle (PLA) was left at the Flight Idle position.

The last seconds of DFDR data indicate a rapid, large input on the elevator.

FIGURE 1 : FLIGHT 4184 PROFILE AND MAJOR DFDR EVENTS



FLIGHT 4184 - CVR TIME HISTORY

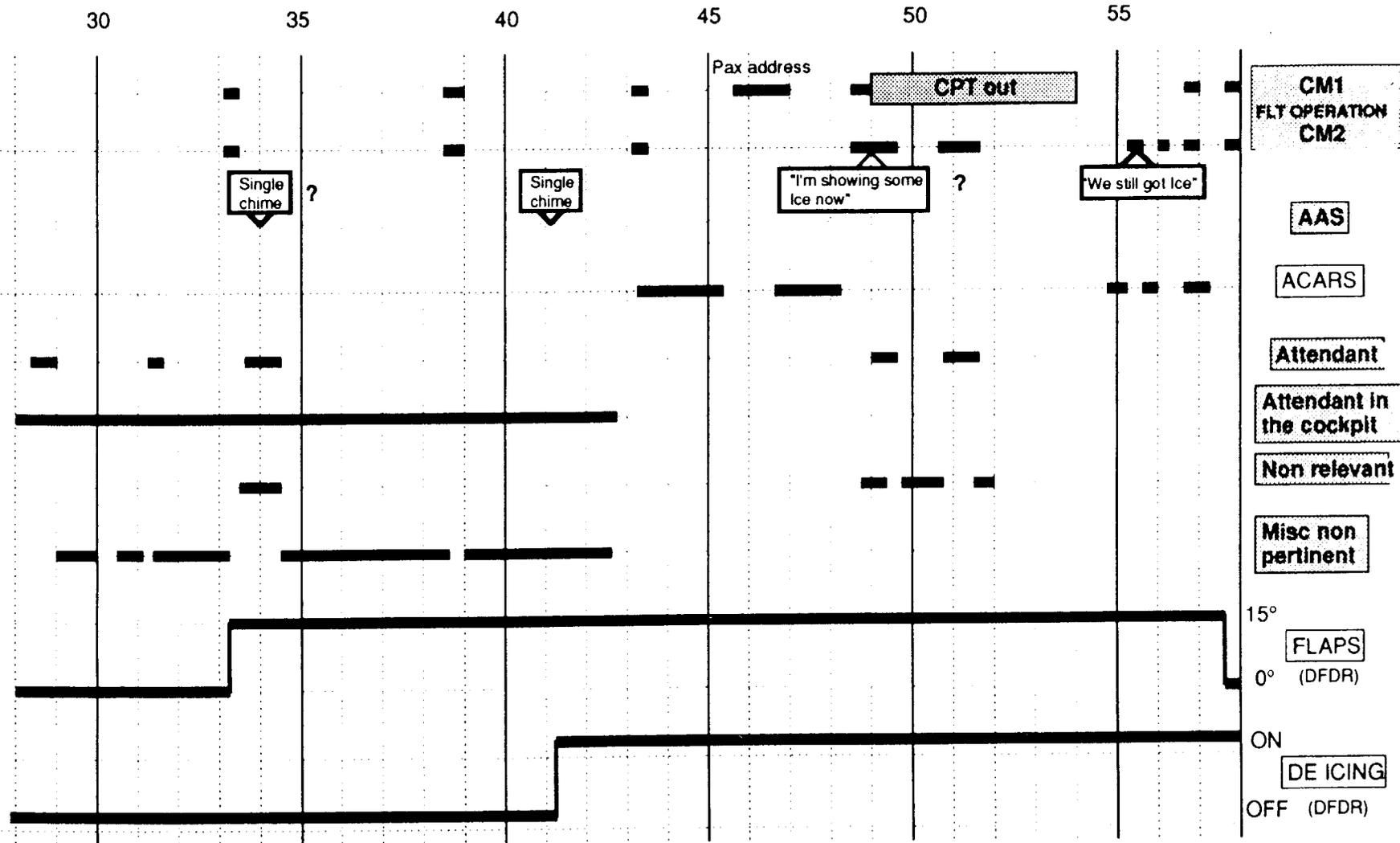


FIGURE 2 : FLIGHT 4184 CVR TIME HISTORY

Flight 4184 CVR transcript by NTSB was highly unedited

FIGURE 3 : FLIGHT 4184 DESCENT TO LUCIT - HOLDING

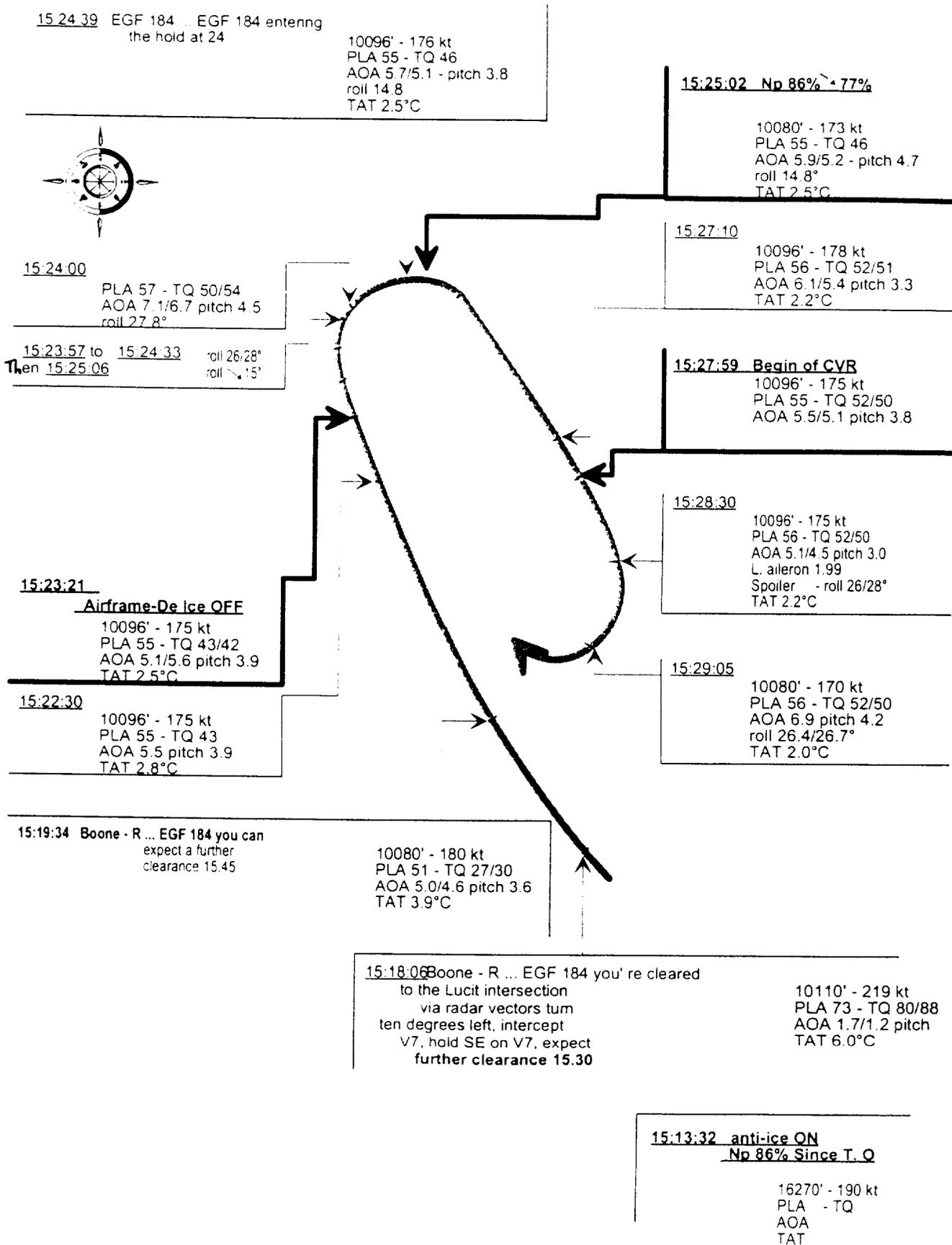


FIGURE 4 : FLIGHT 4184 SECOND HOLDING PATTERN TIME HISTORY



Fm 15:33 to 15:33:28 flaps 15° AOA 7.0/6.1 TO 1.6/1.0

15:33:05
10080' - 162 kt
PLA 59 - TQ 58/62
AOA 9.1 pitch 5.2
roll 29.9/29.2
TAT 2.0°C

15:33:13 Cpt. Man this thing gets a high deck angle in these turns
15:33:17 Cpt. We're just wallowing in the air right now?
15:33:19 F. O. You want flaps 15?
10096' - 167 kt
PLA 59 - TQ 59/63
AOA 8.1/7.6 pitch 5.0
roll 27.1/27.4
TAT 2.0°C

15:33:02 Vc min. 16.1 kt

15:32:30
10096' - 168 kt
PLA 56 - TQ 51/50
AOA 7.4/7.3 pitch 4.4
L. aileron 0.95 pitch trim -2
roll 25.7/26.7 28
TAT 2.0°C

15:33:56 Single tone similar to caution alert chime
10096' - 16 kt
PLA 59 - TQ 60/63
AOA 0.9/0.3 pitch 1.1
TAT 2.0°C

15:31:00
10096' - 174 kt
PLA 56 - TQ 52/50
AOA 5.9/5.4 pitch 3.8
TAT 2.5°C

15:29:30
10080' - 172 kt
PLA 56 - TQ 51/50
AOA 6.4/6.0 pitch 5.2
roll 14 - pitch trim -2
TAT 2.3°C

15:36:00
10096' - 170 kt
PLA 59 - TQ 60
AOA 1.0/0.2 pitch 0.1
TAT 2.5°C

15:37:30
10096' - 174 kt
PLA 59 - TQ 60
AOA 0.0/0.2 pitch -0.2
roll 14.1/16.9
TAT 2.0°C

15:37:40 Waiting Sound for 1.0 s Similar to whooler pitch trim movement
10096' - 173 kt
PLA 59/58 - TQ 60
AOA 1.2/0.6 pitch 0.1
roll 26.4/26.0
TAT 2.0°C

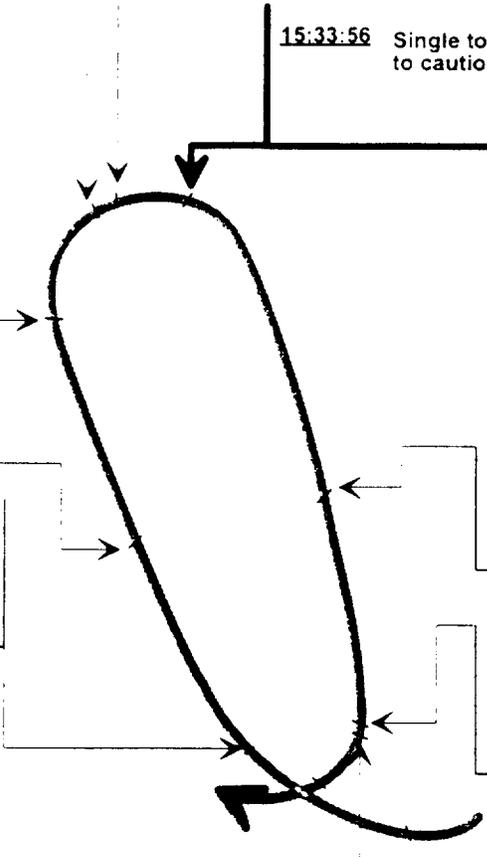


FIGURE 5 : FLIGHT 4184 THIRD HOLDING PATTERN TIME HISTORY

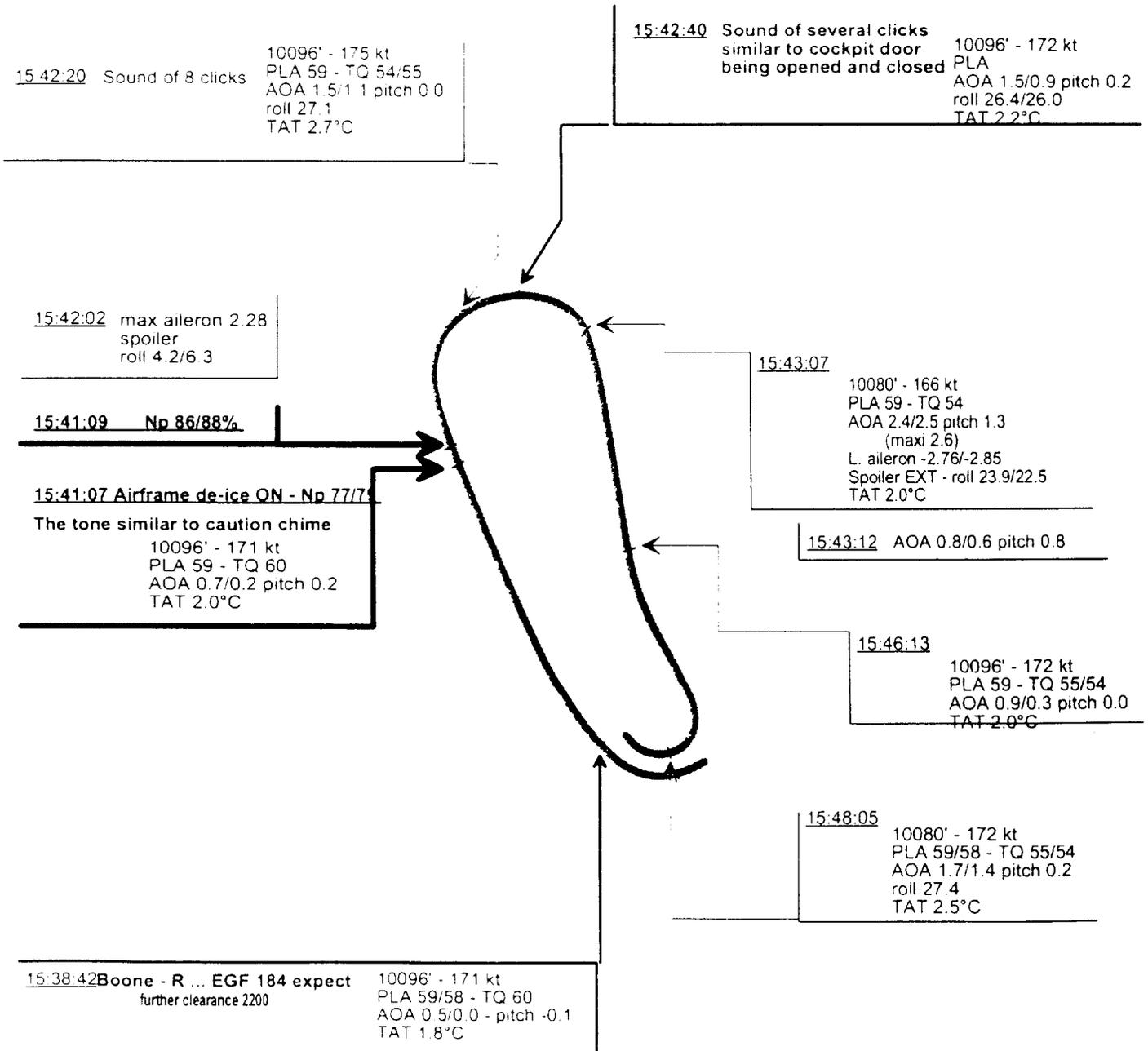


FIGURE 7 : FLIGHT 4184 - ROLL CONTROL ACTIONS AT ROLL UPSET

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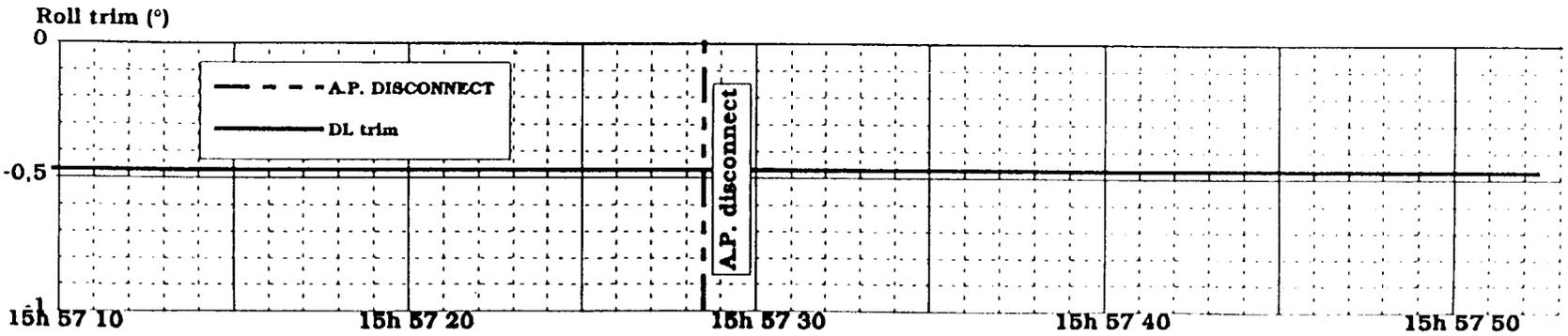
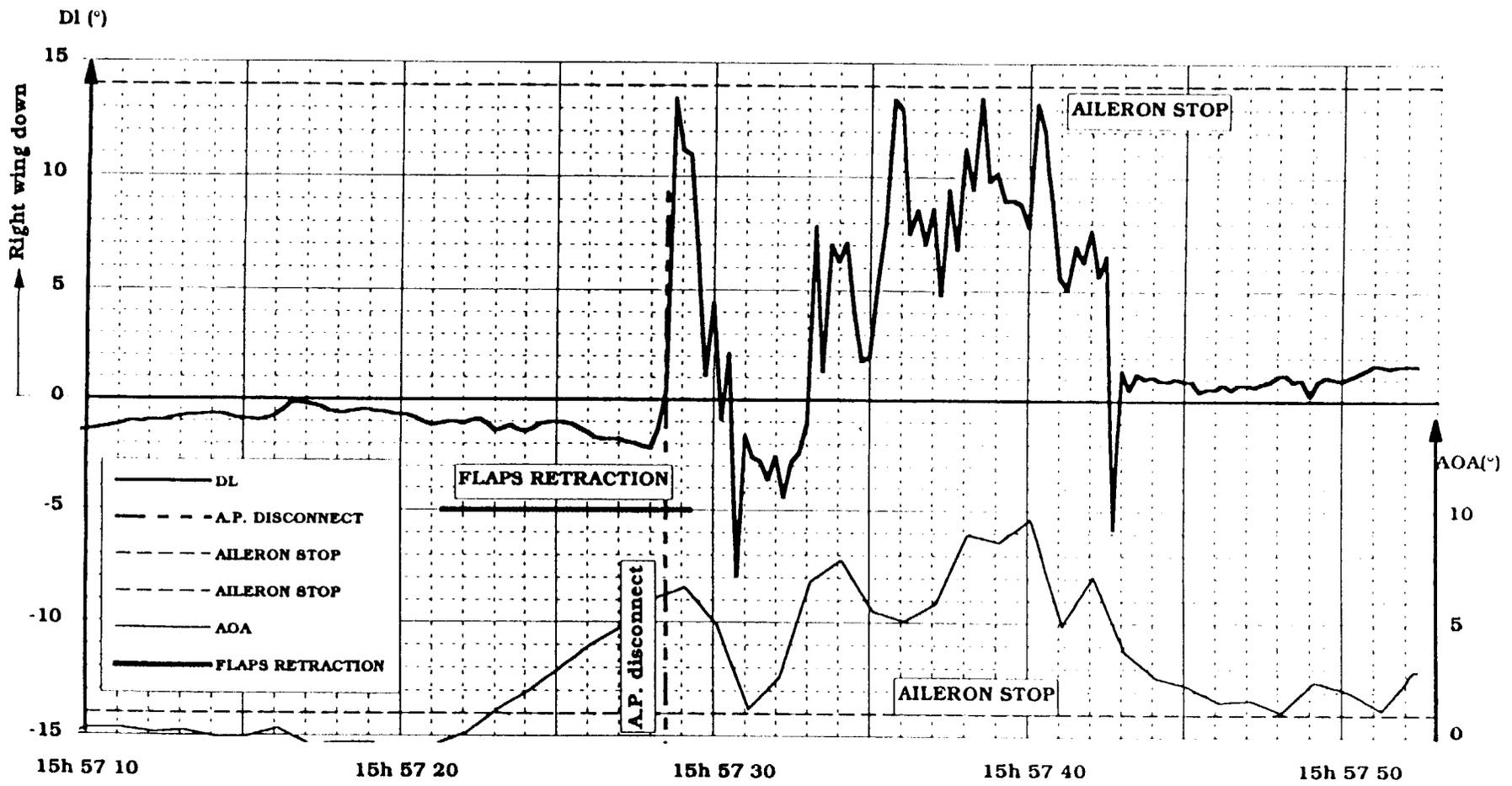
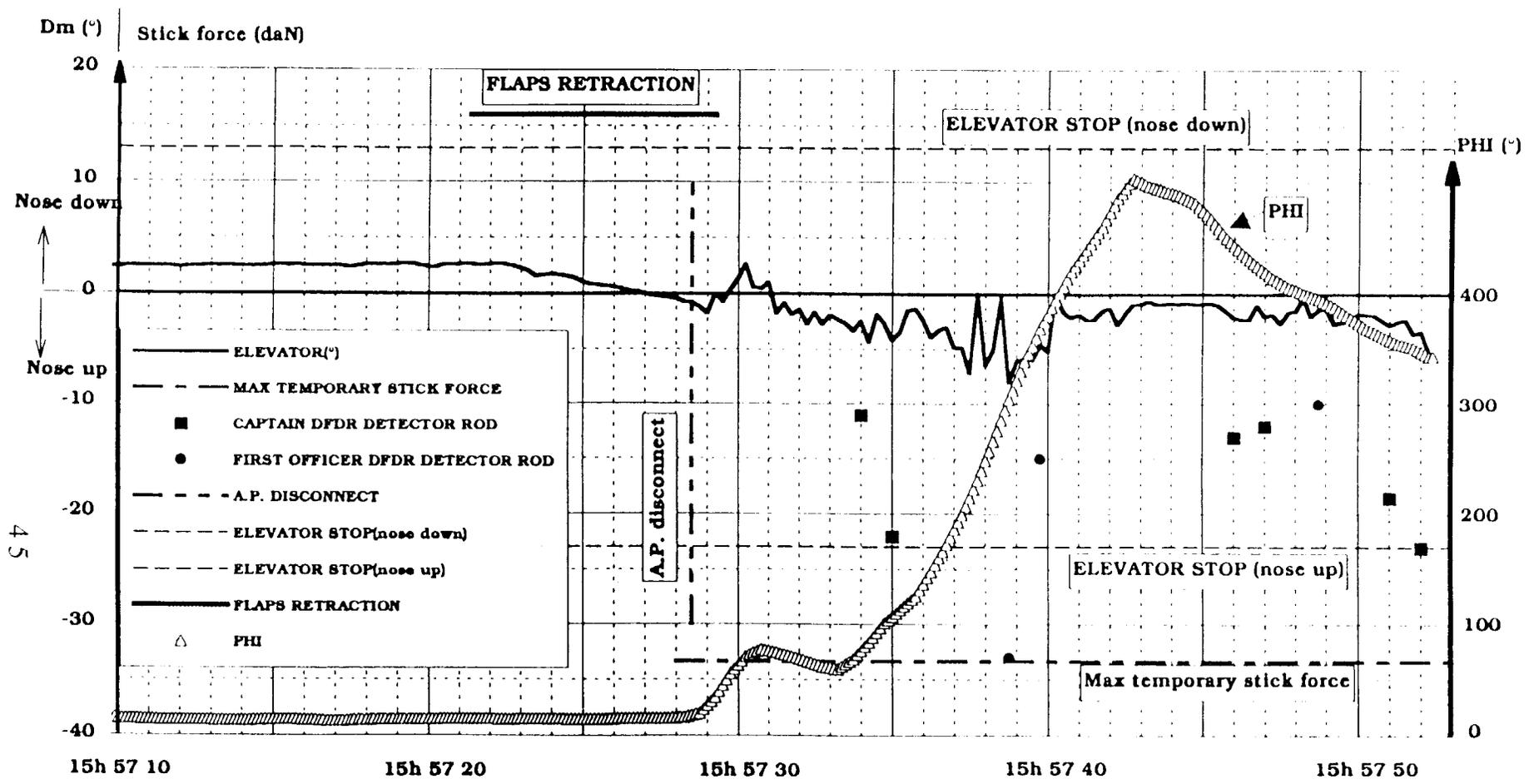


FIGURE 8 : FLIGHT 4184 - PITCH CONTROL ACTIONS AT ROLL UPSET



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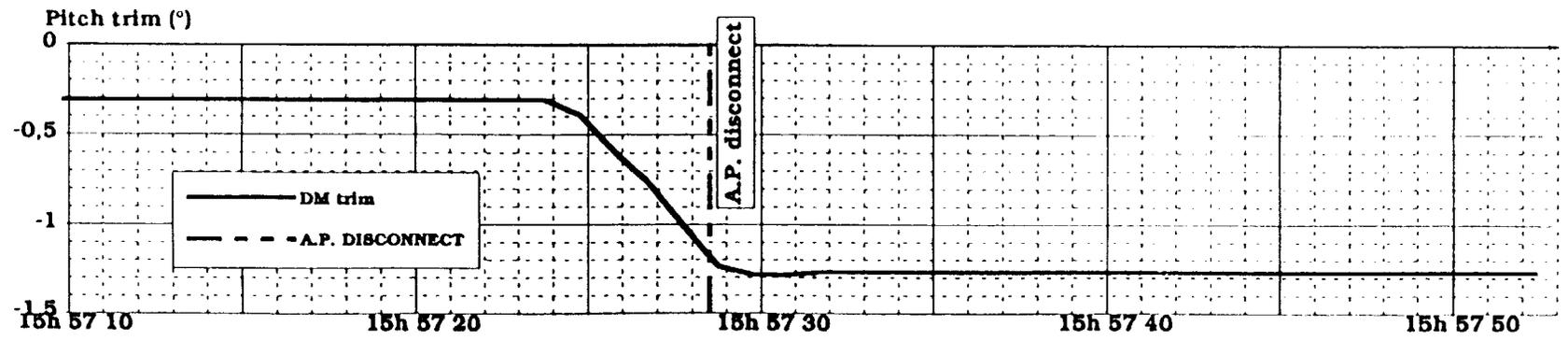
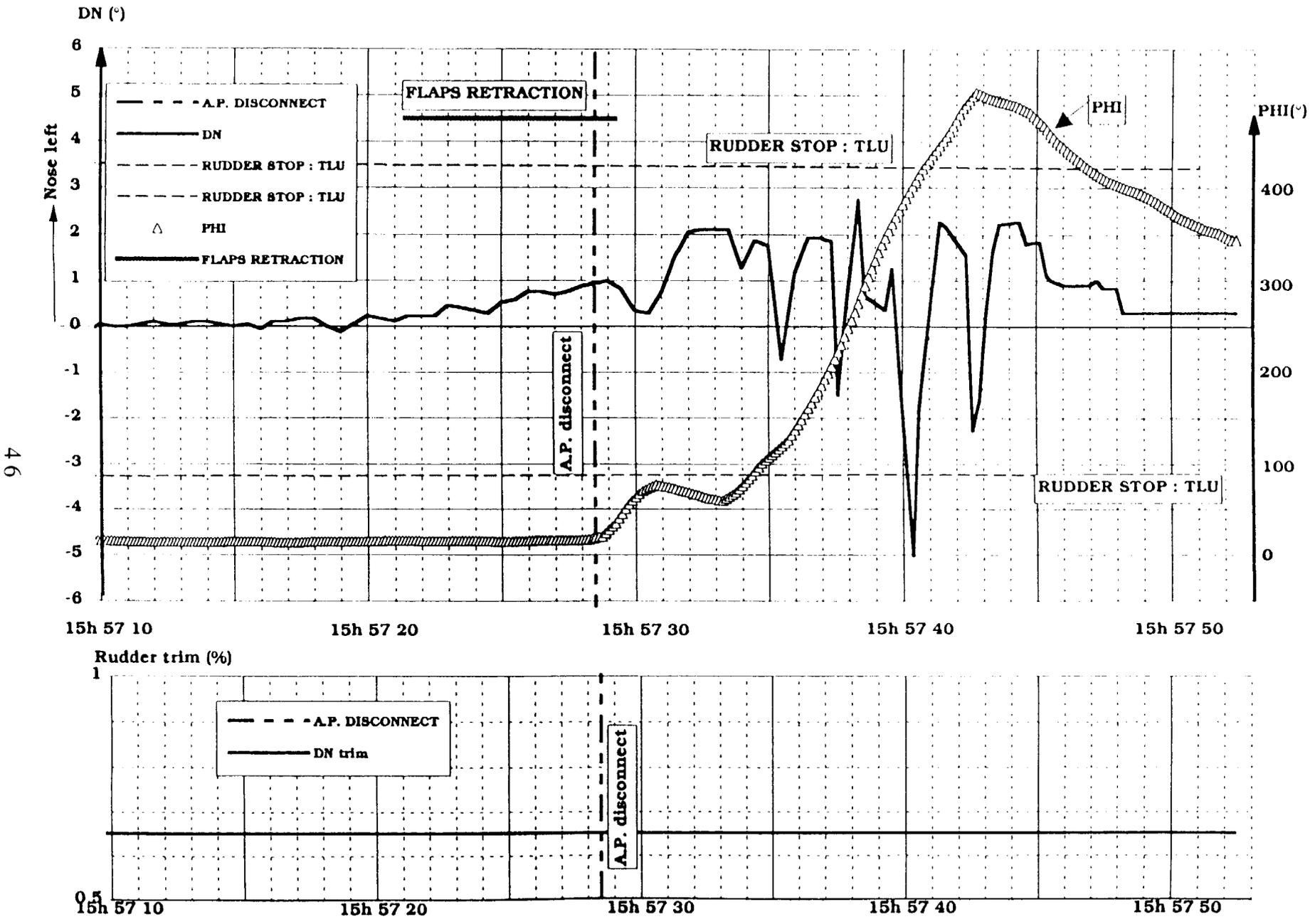


FIGURE 9 : FLIGHT 4184 - YAW CONTROL ACTIONS AT ROLL UPSET



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1.2. PERSONNEL INFORMATION

1.2.1 THE CAPTAIN

The NTSB's Report states that the Captain's airman certification history was "found to be unremarkable". However, the NTSB has not mentioned that the FAA's Airman Certification Records for the Captain show that on March 10, 1993, he failed an ATR-42 check ride. The FAA's records indicate that the Captain attempted to add an "additional aircraft rating" for the ATR-42 and that he failed to competently demonstrate a single engine non-precision approach. In this regard, FAA Form 8060-5, dated March 10, 1993, listed the reason for disapproval as :

"Failed - S.E. [single engine] non precision approach". The Captain passed the aural exam satisfactory on 03-10-93.

1.2.2 THE FIRST OFFICER

The NTSB's Report states that the First Officer's airman certification history was "found to be unremarkable". However, the NTSB's Report does not set forth facts which would explain how the First Officer could accumulate over 3,657 hours of flight time in the ATR, well over two-thirds of his total flight time of 5,176 hours, and yet not have been type certificated for the ATR and was not a licenced A.T. P.

1.3. AIRPLANE INFORMATION

The NTSB's report omits critical factual information in respect to the ATR 72 icing certification criteria (Special Condition B6) and certification process, as well as information regarding the ATR 72's anti-icing advisory system (AAS) and stick pusher stall protection system. This important factual information is necessary for a complete analysis and understanding of this accident. The BEA provides its comments in respect to these issues in sections 1.3.1, 1.3.2 and 1.3.3 below.

1.3.1. ATR 72 ICING CERTIFICATION

1.3.1.1. PURPOSE

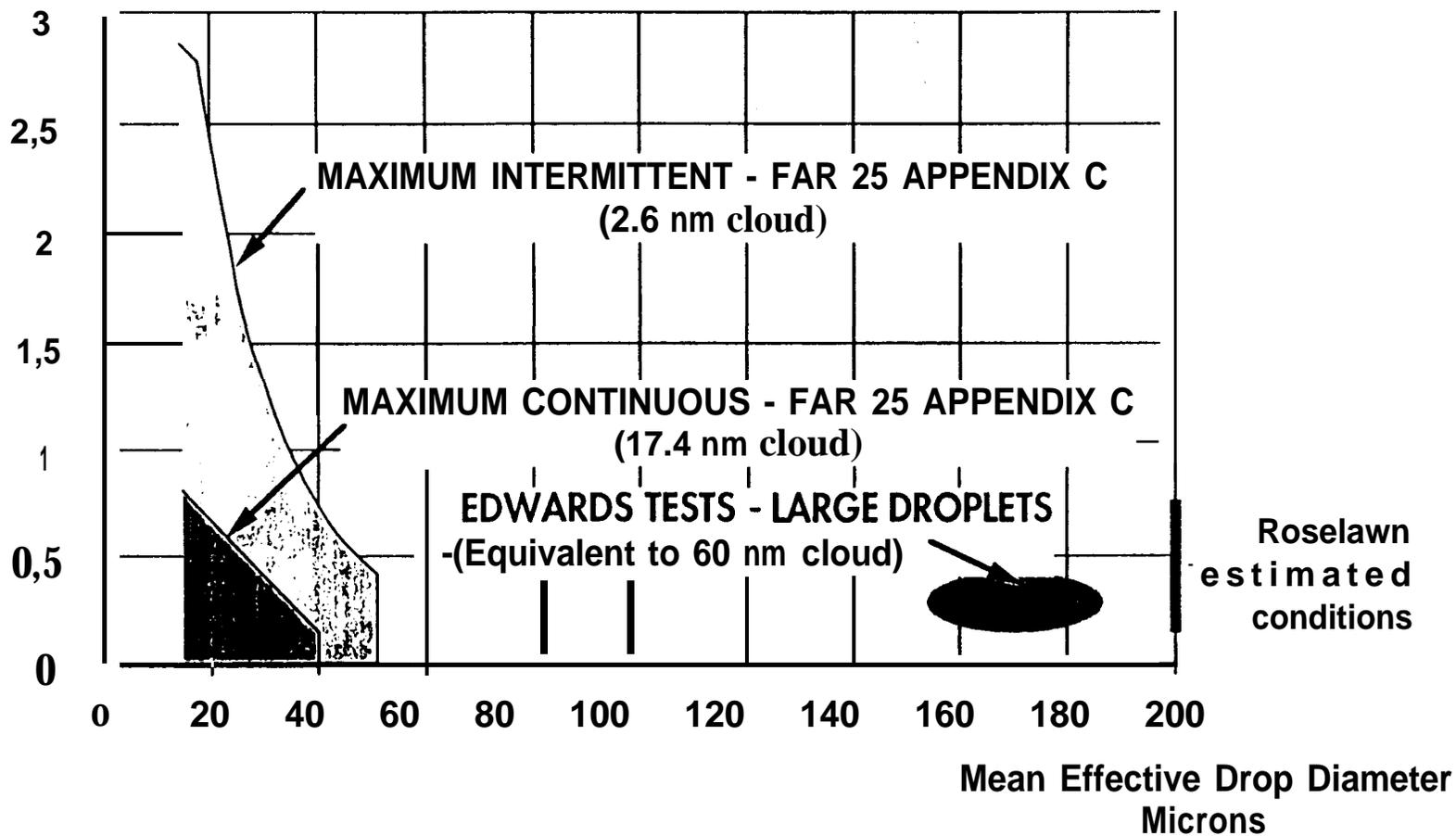
Since certification for flight in icing conditions was desired for the ATR-72, a comprehensive certification plan was established and agreed upon by the Airworthiness Authorities for the demonstration of compliance with the applicable airworthiness requirements.

1.3.1.2. AIRWORTHINESS REQUIREMENTS

1.3.1.2.1. Standard Regulatory framework

Current JAR/FAR 25 airworthiness standards are very explicit in respect to the definition of icing conditions and the related demonstrations which must be performed to demonstrate compliance of the systems with the requirements. (Refer to JAR/FAR 25.1419 and associated Appendix C). However, FAR 25, Appendix C is vague in respect to aircraft handling and performance requirements in icing conditions.

Liquid Water Content
(g per cu m)

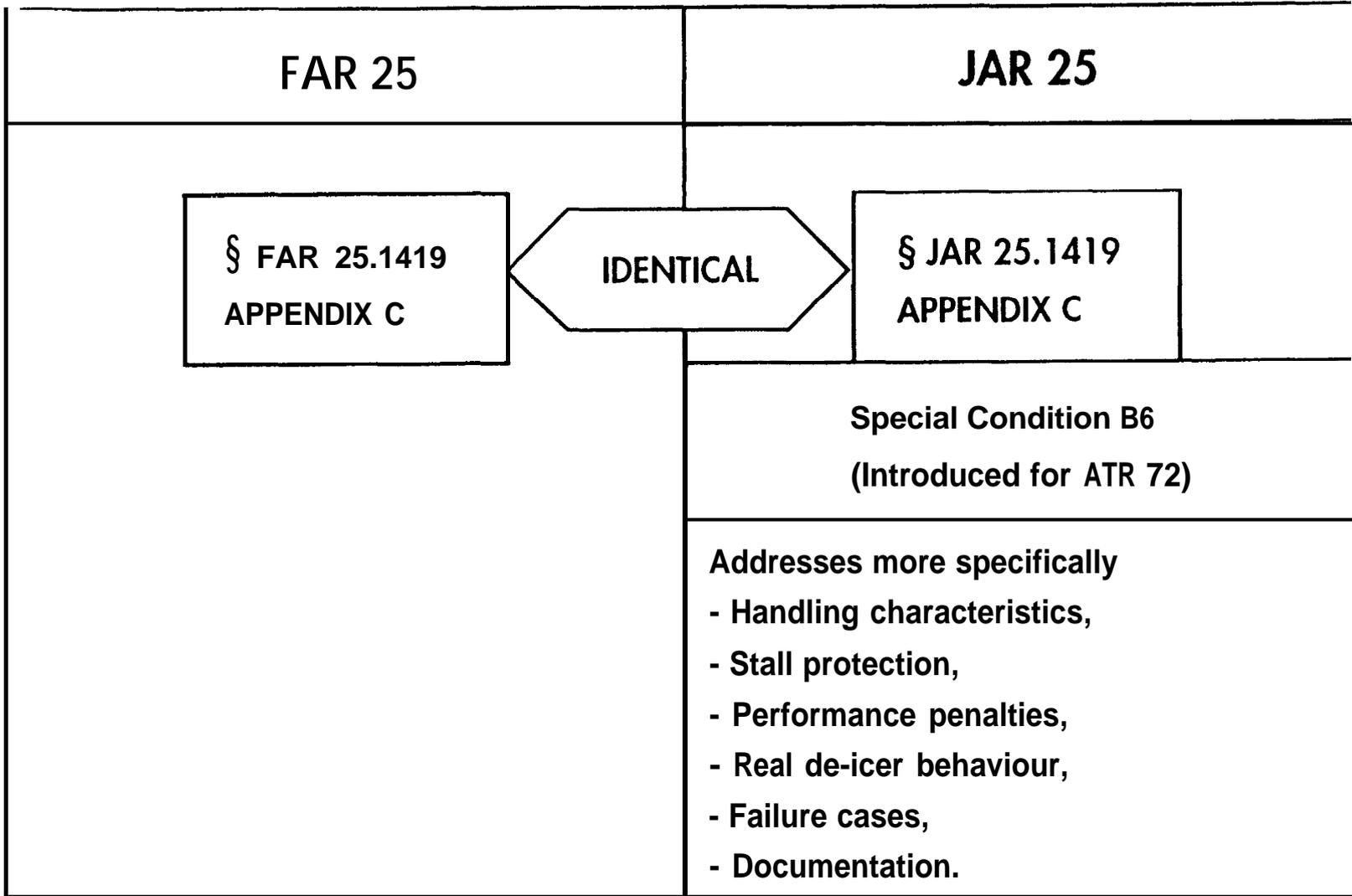


ROSELAWN conditions were far outside App "C" certification envelope

1.3.1.2.2. DGAC ATR 72 B6 Special Condition

Because JAR/FAR 25.1419 does not address aircraft handling and performance requirements in icing conditions, a comprehensive Special Condition was established by the DGAC and was part of the ATR 72 certification basis. The main purpose of Special Condition B6 is to assess handling characteristics and performance aspects which take into account the aerodynamic penalties due to ice accretion in terms of drag, lift and other aerodynamic characteristics, This Special Condition included interpretative material to define a methodology and associated criteria for :

- a) definition for ice shapes in typical flight phases according to the applicable meteorological conditions (JAR/FAR 25, Appendix C), taking into account “intercycle “ ice shapes, as well as the possible failure or malfunction of the ice protection system.
- b) the assessment of ice shape effects on performance and handling qualities. This assessment included flight test demonstrations with simulated ice shapes, with special attention on the determination of tailplane stall margins, and
- c) confirmation of the validity of previous theoretical ice shapes leading to flight tests in natural icing conditions to ensure that performance and handling degradations have been established on a conservative basis, with special attention to stall warning.



ATR 72 Icing Certification Standard encompassed current FAR 25.1419

1.3.1.3. ICING CERTIFICATION PROCESS

The icing certification process was conducted utilizing the following tools

ice codes

“artificial” ice shapes tests

“natural icing” tests.

* Ice codes, were validated by icing wind-tunnel and natural icing tests and approved by Airworthiness Authorities. The ice codes were used to determine impingement limits and to define accretion shapes with the most critical droplets (within appendix C conditions). The corresponding most critical ice shapes create a double horn accretion on the unprotected parts of the leading edge.

* Flight tests with simulated ice shapes were performed in order to identify :

a) aircraft performance, for a given flight phase, with the most critical simulated ice shapes.

b) Establish the stall characteristics and stall speeds, the stall warning settings, the minimum operational speeds (V_2 , V_{FTO} , V_{RF}) and realize the push over tests with full flaps.

c) Demonstrate that the ATR aircraft can safely operate in the event of de-icing system failure.

* Flight tests, in identified natural icing conditions (liquid water content, droplet diameter, temperature) through a dedicated flight test program, were performed in order to demonstrate the systems performance against a variety of required icing conditions.

1.3.1.4. CERTIFICATION APPROVAL PROCEDURE

All the results and findings of the agreed certification program were formalized in recorded certification documents which were reviewed and approved by the Airworthiness Authorities. In addition specific certification flights were performed with representatives of various Airworthiness Authorities flights crews.

Approval of the engine and propellers for use in icing conditions was the responsibility of the powerplant suppliers who worked directly with their primary certification authorities; ATR also had to demonstrate the proper integration of the engine and propeller on the aircraft in icing conditions. Flight tests in natural icing conditions substantiated this demonstration.

Icing Wind Tunnel tests were also used to demonstrate the regulatory compliance of, among other items, the effectiveness of the snow ingestion protections and to validate the effectiveness of the ice protection systems.

1.3.1.5. CERTIFICATION FLIGHT IN NATURAL ICING CONDITIONS

Two flight test campaigns (14 + 14 flights) under measured natural icing conditions were conducted for the certification of the basic ATR72-200 (with 14SF propeller) and ATR 72-210 (with 247F propeller).

Over these two campaigns the ice protection systems and the aircraft behavior were thoroughly evaluated. From the 28 flights performed in icing conditions, 17 have been retained as certification flights (10 +7) which cover a wide range of conditions within the Appendix C :

- Altitude : from 6500 ft to 17000 ft,
- Airspeed : from 120 kts to 200 kts
- SAT : from - 14°C to -5°C.
- MVD : from 15 μ m to 47 μ m*,
- LWC : from 0.12 g/m³ to 1.80 g/m³,
- Both Maximum Continuous and Maximum Intermittent Icing.

Note*

During the certification flight V418 of A/C 98, freezing drizzle or rain had probably been encountered. The basic instrumentation did not allow to identify accurately these conditions (the FSSP measurement is limited to 47 μ m) but the visual cue identified at Edwards was present on the side windows. Only performance degradation was noticed. No detrimental handling repercussion was experienced.

The selected tests in natural icing conditions aim at covering the range of cloud characteristics specified in JAR 25 Appendix C. In particular, this wide range of conditions respect the recommendation of ACJ 25-149 52.55 with states :

“The critical ice accretion on unprotected parts will normally occur during the hold near 15000ft at about -10°C so as to give a total temperature of around 0°C”.

FSSP : Forward Scattering Spectrometer Probe to measure the diameter of the supercooled droplets.

Further, the acceptability of these tests conditions is qualified in ACJ 25-1419 §3.4 as follows :

“The natural icing tests carried out on the airplane will be judged for their acceptability by the evaluation of the icing conditions through which the aeroplane has flown in relation to the envelope of conditions of Appendix C”. The selected tests in natural icing conditions were agreed by DGAC and FAA.

Since the most critical ice shapes were double horn types, natural conditions prone to their appearance were searched for. These conditions are characterized by medium size droplets (20µm) and temperature (SAT) close to - 10°C. This explains why a large proportion of the Flight Tests Condition covered these conditions.

Furthermore, in the NTSB Memorandum of the Airplane Performance Group dated December 2, 1994 it is recorded : “The coverage of the certification was, however, described by the NASA/FAA group members as typical to above average for a turboprop certification effort given the apparent difficulty in finding natural icing conditions in certain areas of the certification envelope”.

The ice protection systems have demonstrated acceptable performance.

Handling characteristics and performance flight tests were conducted in the continuous maximum and intermittent maximum icing conditions to demonstrate the compliance with the French DGAC Special Condition B6. The Special Condition requirements which address handling characteristics and performance, exceed normal certification and industry practices.

1.3.1.6. FAA/DGAC Special Certification Review Report Conclusions

(Source SCR)

The Special Certification Review Team appointed by the FAA and the DGAC to conduct a complete review of the ATR 42 and ATR 72 aircraft Certification after the accident, performed an in depth analysis and concluded :

The Certification program for the ATR72 was conducted in a manner consistent with other FAA icing certification program and demonstrated the adequacy of the anti-ice and de-icing systems to protect the airplane against adverse effects of ice accretion in compliance with the FAR/JAR 25.1419.

The ATR42 and ATR72 series airplanes were certificated properly in accordance with the FAA and DGAC certification bases as defined in 14 CFR parts 21 and 25 and FAR25, including the icing requirements contained in Appendix C of FAR/JAR25 under the provisions of the BAA between the United States and France.

1.3.1.7. Freezing Rain and Freezing Drizzle.

NACA TN 1855 served as the basis to establish FAR 25 Appendix C icing conditions. NACA TN 1855 (1949 ISSUE) gives only limited information about "Freezing Rain"precipitations. In this regard, the associated physics were qualified as purely speculative since"observational data are not available for this class ".. ."for this reason , the values for the proposed Condition (item 50, table I) were calculated ".

The term "Freezing Drizzle" is not at all mentioned in the a.m document. The FM document ADS-4 "ENGINEERING SUMMARY OF AIRFRAME ICING TECHNICAL CONDITION DATA", Issue 1964, calls NACA TN 1855 as a basic reference.

It does neither suggest any knowledge about "freezing drizzle".

Moreover, the a.m document page 1-24 § 1.4.6 "freezing rain design considerations" requires that :

"The possible effects of freezing rain should be considered for components not usually protected - such as airspeed static vents, fuel vents , fuel tank vents, exposed control horns, cables . . ."

The FAA AC20-73 "AIRCRAFT ICE PROTECTION" issued in 1971 does neither address "Freezing rain" nor "Freezing Drizzle".

All above mentioned documentation were part of the basic Certification package for ATR 42 & ATR 72.

As a matter of fact, at the time of Certification of both ATR 42/72, neither the ATR A/C manufacturer nor the Aeronautical Community had a clear knowledge about the definition and associated conditions which now correlate to the "Freezing Drizzle" icing conditions.

. Moreover, the Tail-plane Icing Workshop II, San Jose April 21-23, 1993 referred to this lack of standards to characterize Freezing Rain and Drizzle. Refer to the FAA Technical Center, Dick JECK, Communication entitled "Characterization of Freezing Rain and Freezing Drizzle Aloft"

quoting :

-“Another question to ask is whether we want to characterize freezing rain physically for the engineering purposes. At the moment, no design values . . are officially promulgated anywhere”.

“We don’t know what the mean value is, there are so few measurements on drop size in freezing rain”.

“Freezing drizzle is listed separately here because it is generally thought that it differs mainly in drop size. The other characteristics are probably about the same. ”

Therefore Freezing Drizzle only differed by the droplet size 50 μm to 1000 μm , respectively 250 μm to 5000 μm for Freezing Rain, while being generated by the same ice process. A new "Coalescence" process for Freezing Drizzle started to be identified by 1992 thanks to CASP II research program (ref. AGARD LS-197 Issue 1994 § 4.3 "Winter Storms Research in Canada ").

In between, FAA CT-88/ 8-1 March 1991 provided improved information on Freezing Drizzle/Rain Conditions over previous ADS - 4 (page I 1-9 § I.1.7). Subsequent recommendations common to "Freezing rain" and "Freezing Drizzle" were made : "Glaze icing is major concern in both freezing rain and freezing drizzle. Care should be exercised both in - flight and taxiing since glaze ice can collect quite rapidly on all surfaces even during short time".

Whereas the Freezing rain section § 1.1.6 states that :

“pilots are cautioned to avoid flying in freezing rain conditions because rapid ice accretion on all surfaces results in rapid reduction of aircraft performance and loss of windshield visibility”. It is quite clear that only drag is of concern with no reference to any Handling Qualities problem.

Edwards flight tests were the very first opportunity as to identify accretion related to Freezing Drizzle and its consequential effects. This was no doubt a major contribution to the Aeronautical Community’s understanding of Freezing Drizzle.

These tests clearly put into perspective the major difference between ice accretions induced by captation at positive AOA’s (flap 0° configuration) - leading mainly to drag penalty - as opposed to collection at negative AOA (flaps 15°) which produce upper wing ice accretions potentially leading to aileron hing moment reversal.

1.3.2. ATR72 ANTI-ICING ADVISORY SYSTEM

- General description

In order to assist the crew when operating in icing conditions, an Anti-icing Advisory System (AAS) is installed on the ATR 42 and ATR 72 aircraft.

This system mainly includes an Ice Detector located on the left wing under surface which delivers a signal to the aircraft Multi Function Computers (MFC) when ice accretion is detected, which in turn generate indications in the cockpit.

The AAS is an advisory system only and it first belongs to the crew, to observe the atmospheric conditions, to visually monitor the ice accretion and to apply the relevant procedures.

- Cockpit indicating and control

The AAS indicating and control are located on the cockpit center panel (See Figure 1) and include :

- ICING amber light and associated FAULT amber light,

ICING AOA pushbutton (AOA=Angle Of Attack) including a green light.

The AAS also illuminates the DE ICING blue light on the center panel. This DE ICING light is illuminated whenever the AIRFRAME de-icing is selected.

The AAS also illuminates the master CAUTION light on the crew alerting panel, associated with a single chime caution.

- Ice Detector and ICING signal

The Ice Detector, located on the left wing leading edge lower surface, includes a 1/4 inch diameter and one inch long probe, vibrating along its axis at a given frequency. The ice accretion on the probe changes this frequency and the Ice Detector triggers a signal when the ice accretion reaches 0.5 mm thickness.

The probe is heated during seven seconds, just following a detection, and it is ready to collect ice again, if icing conditions still remain.

The ice signal is kept present during one minute after the last detection in order to deliver a continuous signal while icing conditions exist

(See Figure 12).

The ice detector signal illuminates the cockpit ICING amber light.

The associated FAULT amber light is illuminated together with an aural single chime warning and master CAUTION light on the crew alerting panel when a fault is detected by the Ice Detector internal monitoring.

- Ice protection Warnings

In all cases, the ICING light is illuminated each time some ice accretion is detected.

When ice is detected but the Flight Controls Surfaces Horns anti-icing were not previously selected ON, the ICING light is flashing.

When ice is detected but the AIRFRAME de-icing was not previously selected ON, there is an aural single chime caution and an illumination of the master CAUTION, even if the Horns anti-icing was selected before (See Figure 2).

If ice accretion is not detected for more than 5 minutes and the AIRFRAME de-icing is still selected ON, then the DE ICING blue light flashes in order to avoid an unjustified use of the airframe de-icing boots.

- stall warnings

The stall warning threshold (cricket sound and stick shakers) is decreased in icing conditions.

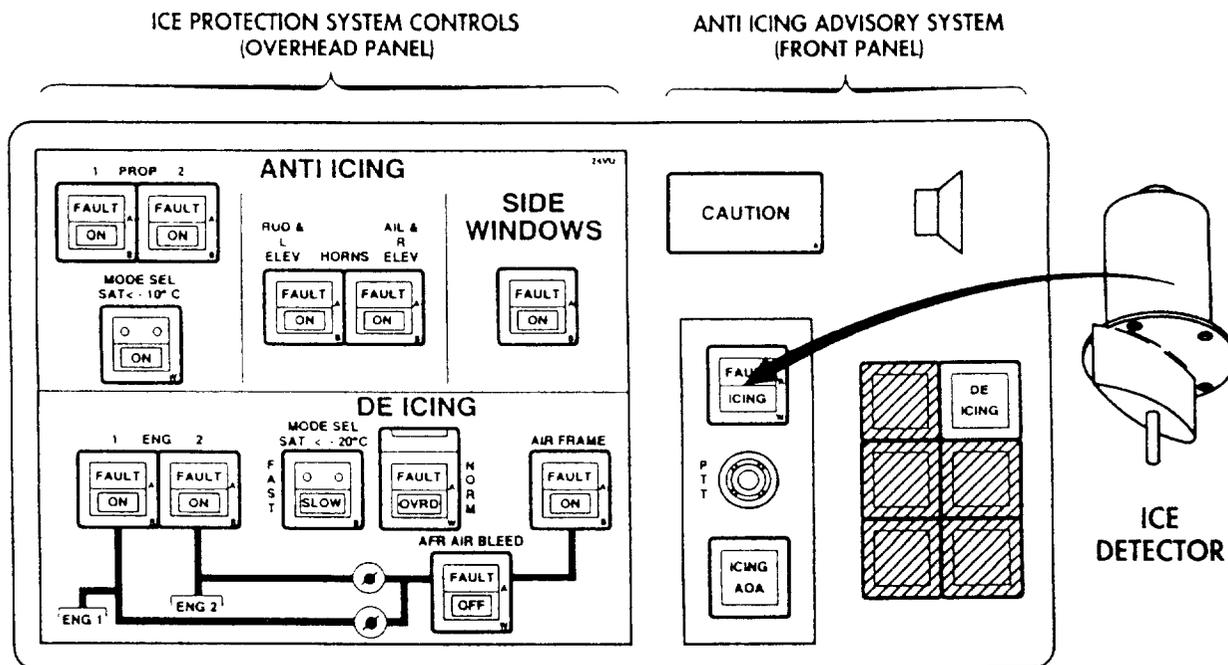
The ICING AOA is illuminated when the Horns anti-icing is selected and at this time the stall warning threshold is lowered to the icing conditions setting.

In order to extinguish the ICING AOA, the reselection of the Horns anti-icing is not sufficient, the crew must still push the ICING AOA button and at this time only the stall warning threshold returns to the normal setting.

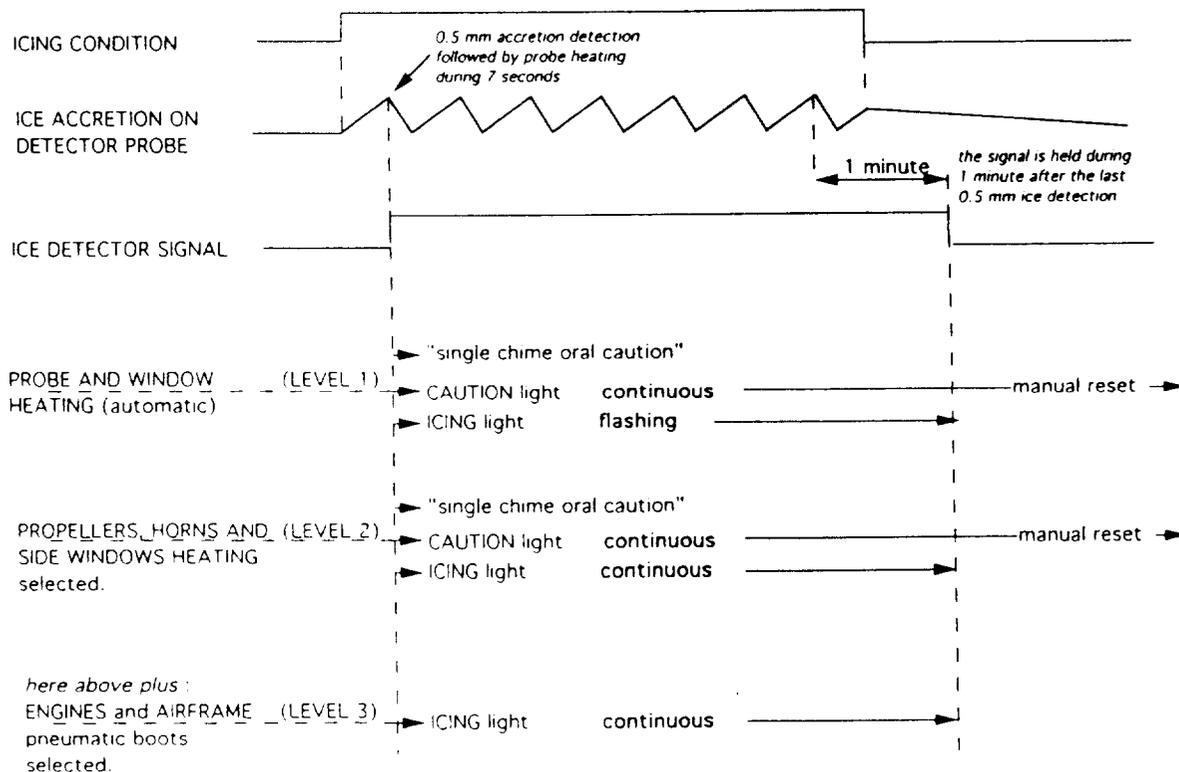
- Propeller rotation speed

The propeller rotation speed is not controlled nor monitored by the AAS. The normal procedure requires the increase in the propeller rotation speed, from 77% to 86%, as soon as and as long as icing conditions are present. This should be done when the propeller anti-icing is selected as part of the Level II procedure.

FIGURE 12 : ATR 72 ANTI-ICING ADVISORY SYSTEM (AAS)



ATR 72 ANTI-ICING ADVISORY SYSTEM (AAS) : An effective warning logic to back up crew awareness



1.3.3. ATR 72 STICK PUSHER STALL PROTECTION SYSTEM

As the NTSB knows, the stick pusher is now well recognized in aircraft design and was initially introduced for other aircraft which could present catastrophic characteristics at high A.O.A. Such unacceptable characteristics were typical of the T-tail configuration, which can be prone to locked deep stall phenomena.

The object of the stick pusher concept is to restore an artificial stall identification triggered before the critical A. O.A is reached, by applying a powerfull nose down input on the pitch axis as soon as the aircraft A.O.A reaches a preset value. The selection of this pre-set A.O.A is the result of extensive progressive stall demonstrations. Due to the catastrophic consequence of a locked deep stall, it was obviously not desirable nor requested, to demonstrate aircraft behavior beyond the stick pusher setting. Numerous development flight accidents with other aircraft models confirmed the possible catastrophic consequence of flight demonstrations beyond stick pusher A. O. A..

Since this concept was first introduced, to prevent the occurence of such a phenomenon, new less radical applications were adopted in the aviation industry to prevent appearance of marginally acceptable phenomena occuring at high angles of attack.

For the ATR aircraft, the stick pusher concept was fully incorporated in the design before first flight in anticipation of possible deep stall problems. This phenomena was not revealed during the development testing, while wing dropping tendencies were detected at very high A.O.A. The available stick pusher function was therefore selected to prevent any appearance of this phenomena within the certificated flight envelope.

The stick pusher A.O.A setting was the result of extensive flight test demonstrations ; including Power ON dynamic stall demonstrations in turn,

The selected A.O.A insures that all certification criteria are met during this demonstration which, due to its dynamic aspect, causes A.O.A to go beyond the stick pusher setting.

These demonstrations were performed for each flap configuration up to angle of attack values 100/o higher than the pusher activations thresholds.

The results were fully notified to the Airworthiness Authorities :

- on ATR 42 within the frame of the basic certification process,

- on ATR 72 the results were also specifically given to the FAA in response to a specific request from the FAA.

This information was also provided to the NTSB in answer to the Review item F2- 1 raised by the NTSB Performance Group in charge of the Flight 4184 investigation.

1.4. ATR 72 ICING OPERATING PROCEDURES

The NTSB's Report omits important factual information in respect to the warnings which were provided to American Eagle/Simmons' flight crews by both ATR and American Eagle regarding the hazards of conducting flight operations in icing conditions, including icing conditions which exceed Appendix C conditions. This factual information is critical to a complete investigation and analysis of this accident because it has a direct bearing on the flight crew's performance vis-a-vis the warnings they had been provided about flight operations in such conditions. The BEA provides its comments in respect to this issue in sections 1.4.1 and 1.4.2 below as an addition to the NTSB's Draft Report, section 1.17.6. Flight and Airplane Operating Manual.

1.4.1. AFM/FCOM AND MANUFACTURER INFORMATION

The following information was contained in ATR's Airplane Flight Manual (AFM) and Flight Crew Operating Manual (FCOM) at the time of the accident.

ATR's AFM and FCOM provide specific procedures in respect to the operation of the ATR-42/72's anti-icing system (Level II) and de-icing system (Level III). In respect to the ATR's Level II anti-icing system, the AFM and FCOM provides instructions under the section entitled *Operation in atmospheric icing conditions*. In this regard, the AFM states :

Operations in atmospheric icing conditions require SPECIAL CONCERNS as ice accretion on airframe and propellers SIGNIFICANTLY modifies the aerodynamic characteristics.

The main aspects to consider are as follows :

Even small ice accretion, which may be difficult to detect visually, are enough to affect the aerodynamic efficiency of airfoils. For this reason, ALL ANTI ICING PROCEDURES and SPEED LIMITATIONS MUST BE COMPLIED WITH as soon as and as long as ICING CONDITIONS are met and even before ice accretion actually takes place.

The ATR-42 AFM also contains the express prohibition that :

Operation in freezing rain must be avoided.

This same prohibition was not included in the ATR-72 AFM by inadvertence. However, for Simmons Airlines and their flight crews, the prohibition was clearly applicable to both aircraft types. The American Eagle Flight Manual Part I Information Bulletin specifically states :

“the AFM will not specify” light or moderate icing only... ” and furthermore, there are generally no AFM restrictions prohibiting flight in a certain type of ice (i.e, Rime ice, clear ice, glaze ice, freezing rain, etc.) The only existina exception is the ATR-42/ 72 AFMs, which state that flight in freezing rain ‘... SHOULD BE AVOIDED. . . “

With respect to holding, ATR's Flight Crew Operating Manual (FCOM), and the applicable performance charts for holding, do not provide for the use of a Flap 15 degree configuration in holding. The FCOM specifically states :

Holding charts are established:

in clean configuration

- *with air conditioning in normal mode*
- *with NP=86% and NP=77% propeller speed*
- *at VmHBO in icing conditions*

This minimum maneuvering speed covers the whole flight envelope in normal conditions and in icing conditions without appreciable increasing of consumption.

When using air conditioning in high mode, fuel consumption is increased by 2.5%.

All charts are established with a center of gravity location corresponding to 25%.

The temperature effect is negligible.

ICING CONDITIONS

Tables are computed only with NP = 86%

The only holding speed provided for in ATR's FCOM, therefore, is the VmHBO for icing conditions covering both normal and icing conditions. The selection of this minimum speed for both non-icing and icing conditions was done to avoid crew errors.

In respect to other information provided by ATR, immediately after receiving the DFDR following the Mosinee incident, which was recognized to have occurred in freezing rain outside aircraft certification limits, ATR issued an *ALL OPERATORS INFORMATION MESSAGE* to advise them of the incident and what had occurred. This bulletin fully described the incident and advised all operators that the freezing rain conditions encountered by the aircraft affected aileron forces to the point of disconnecting the autopilot, and caused the aircraft to roll until the pilot took over control. ATR's Message stated :

1. *The A/C was submitted to freezing rain.*
2. *This freezing rain affected control forces on the ailerons in such a manner the autopilot was no longer able to maintain the bank angle in the procedure turn.*
3. *As a consequence, the A.P. was normally disconnected by its monitoring system.*
4. *The A/C rolled to a large bank angle until the pilot took over the control manually, from that point the response of the A/C to pilot aileron inputs was correct except that wing heaviness was present for about 20 seconds as long as incidence [A. O.A] was not significantly reduced.*

ATR's Message also reminded all operators of the 1982 FAA Advisory Circular AC 20-117, which emphasized to the aviation community that freezing rain will eventually “*exceed the capability of most ice protection equipment*” and that “*flight in freezing rain should be avoided where practical*”. The FAA’s Advisory Circular specifically states :

It is emphasized that aircraft ice protection systems are designed basically to cope with the supercooled cloud environment (not freezing rain). Supercooled cloud water droplets have a median volumetric diameter (MVD) of 5 to 50 microns. Freezing rain MVD is as great as 1300 microns. Large droplets of freezing rain impact much larger areas of aircraft components and will in time exceed the capability of most ice protection equipment. Flight in freezing rain should be avoided where practical. (Emphasis added).

After the Mosinee incident, the FAA issued a Priority Letter AD (89-09-05) restating the warning to avoid freezing rain, and requiring that the AD be placed in the ATR-42 Flight Manual. The AD stated :

“When operating in the icing conditions, use of the autopilot is prohibited (for purposes of this AD, icing conditions exist when outside air temperature is between +10 degrees C and -10 degrees C and visible moisture in any form is present.

WARNING: Prolonged operation in freezing rain should be avoided. Ice accretion due to freezing rain may result in asymmetric wing and associated increased aileron forces necessary to maintain coordinated flight. Whenever the aircraft exhibits buffet onset, uncommanded roll, or unusual control forces, immediately reduce angle-of-attack and avoid excessive maneuvering”. (Emphasis added).

In addition to the design modification for the ATR 42 implemented by ATR after the Mosinee incident (vortex generators), ATR also submitted proposed AFM and related FCOM changes to the DGAC. The DGAC, in turn, forwarded the proposed changes to the FAA on March 21, 1989 for its consideration along with the proposed design modifications. (Appendix 1).

ATR's proposed changes to the AFM LIMITATIONS SECTION restated that **“operation in freezing rain shall be avoided”** and warned that freezing rain could result in asymmetrical wing lift. A procedure for exiting freezing rain zones was provided. The proposed procedural language stated :

WARNING : *Ice accretion due to freezing rain may result in asymmetric wing lift and associated increased aileron forces necessary to maintain coordinated flight. Should the aircraft enter into a freezing rain zone, the following procedures must be adhered to :*

- a. autopilot shall not be used,*
- b. Speed shall be increased in keeping with performance and prevailing weather conditions (turbulence), that is :*

flaps retracted: 180 kt minimum

flaps extended: as closed as possible to VFE for the airplane configuration.

- c. excessive maneuvering shall be avoided.*
- d. freezing rain conditions shall be left as soon as possible. This can usually be accomplished by climbing to a higher altitude into the positive temperature region or by altering course.*

The related draft **Operation Engineering Bulletin (OEB)** submitted by ATR to the DGAC gave specific information about freezing rain, repeated the FAA's warning in Advisory Circular AC 20-117, and stated that such zones must be avoided by pilots. The OEB stated in part :

Zones where freezing rain is likely to be encountered MUST BE AVOIDED.

The ATR's OEB also provided the following specific procedures for exiting freezing rain zones :

Procedure

Nevertheless, should the aircraft enter in a freezing rain zone, the following procedures must be applied.

a) Do not use Auto Pilot.

b) Increase speed in keeping with performance and prevailing weather conditions (turbulence]

Flaps retracted : 180 kt minimum

Flaps extended : as close as possible to VFE for aircraft configuration.

c) Avoid excessive maneuvering.

d) Leave freezing rain conditions as soon as possible. This can usually be accomplished by climbing to a higher altitude into the positive temperature region or by altering course.

In accordance with its preference for design changes over special operating procedures for long term operational safety, the FAA adopted and imposed the vortex generator modification, but did not adopt the proposed AFM manual changes. Considering that these procedures addressed a condition outside the certification requirements, the DGAC did not request their insertion in the manuals. Consequently, the corresponding FCOM changes were also not incorporated in the U.S or France. However, the German and Canadian Airworthiness Authorities did incorporate this information in their operation manuals.

The identified warnings and instructions were subsequently incorporated into a comprehensive brochure prepared by ATR for all operators of its ATR-42 and ATR-72 aircraft. In December, 1991, 193 copies of this ATR *All Weather Operations* brochure were sent directly to American Eagle / Simmons Airlines, enough to provide individual copies to each of its pilots. In addition, nine copies were delivered with the accident aircraft, S/N 401, in 1994 when it was delivered to the airline.

The brochure again quotes FAA Advisory Circular 20-117 and states in a bold block :

AS SOON AS POSSIBLE, LEAVE FREEZING RAIN CONDITIONS.
THIS CAN USUALLY BE ACCOMPLISHED BY CLIMBING TO A
HIGHER ALTITUDE INTO THE POSITIVE TEMPERATURE
REGION OR BY ALTERING COURSE.

The brochure reminds ATR-42 and ATR-72 pilots that freezing rain is beyond aircraft certification and lists the steps for pilots to avoid such zones. These steps are the same steps incorporated into ATR's Operation Engineering *Bulletin* discussed above.

Procedures were also given in this brochure for ATR-42 and ATR-72 pilots if they entered into a freezing rain zone. These procedures provided :

*SHOULD THE AIRCRAFT ENTER IN A FREEZING RAIN ZONE,
THE FOLLOWING PROCEDURE SHOULD BE APPLIED :*

A/P engaged.

RETRIM ROLL L/R WING DOWN "messages"

MONITOR

*In case of roll axis anomaly, disconnect AP holding the control stick **firmly**. Possible abnormal rolls will be felt better when piloting manually.*

SPEED INCREASE

Increase the speed as much as performance and weather conditions (turbulence) will allow. Extend flaps as close as possible to respective VFE.

In addition to the above actions, ATR also modified its simulator training data package to introduce a "stall with ice accretion without the icing AOA push-button "ON". This data package incorporated into the flight training simulator program a wing drop to approximately 60 degrees bank which required a firm response by the pilot to stabilize the wings, an increase in speed, and a smooth rotation to recover initial attitude. The same event is also presented in icing conditions without ice accretion with the icing AOA push-button "ON".

1.4.2 AMR EAGLE/SIMMONS' FLIGHT MANUAL AND OTHER PERTINENT DOCUMENTATION

The ATR AFM and FCOM provisions quoted above are also set forth in the American Eagle/Simmons AFM and AOM. Simmons Airlines testified that the ATR ALL WEATHER OPERATIONS brochures were not given to Simmons pilots, however, it is the BEA's understanding that all of the information regarding flight in icing was incorporated into the American Eagle/Simmons Airlines AFM and AOM manuals by the airlines. Therefore, the information set forth by ATR in its All Weather Operations brochure was also incorporated by American Eagle/Simmons into the various manuals it provided to its flight crews.

The BEA has set forth below a list of additional American Eagle/Simmons' documents which demonstrate that ATR provided specific warnings and instructions to Simmons' flight crews in respect to flight operations in icing conditions, and which also establish that American Eagle/Simmons' company policies provided extensive warnings to its flight crews which thoroughly covered the hazards of operating in such conditions.

As discussed in Section 1.4.1 above, immediately after receiving the DFDR data following the Mosinee incident, which was recognized to have occurred in freezing rain far beyond certification limits, ATR issued an All Operators Information Message to advise operators of the incident and what had occurred.

This bulletin fully described the incident and advised all operators that the freezing rain effected aileron forces to the point of disconnecting the autopilot causing the aircraft to roll until the pilot took over control. Simmons incorporated all of this information, along with a complete factual description of the Mosinee incident including the DFDR data, in a January 23, 1989 memorandum entitled Loss of Aircraft Stability. (Appendix 2) This memorandum was provided to “All flight Crewmembers” by Dave Wiegand, Simmons’ Director of Flying. This memorandum, which Mr. Wiegand referred to as “a restatement of company operating policies” contained the following “operating policies” in respect to flight operations in icing conditions :

Simmons Airlines aircraft will not be released or flown into known severe icing conditions.

If icing or adverse weather is experienced. make a PIREP so your fellow pilots may benefit from your experience. This is important if the weather is better or worse than forecast.

Supercooled water droplets in liquid form at temperatures above freezing, can freeze on impact with the aircraft. Exercise caution when operating your aircraft near the freezing level in visible moisture.

If freezing rain is encountered, you should exit the condition immediately. This diversion should consist of a turn towards better conditions and/or a climb to a warmer altitude.

Freezing rain and clear ice can be very difficult to recognize on an aircraft, therefore it is strongly recommended when operating in conditions favorable to this type of icing that an extra vigilance be maintained.

However, our aircraft are not to be operated in known freezing rain or severe ice. If these conditions are experienced, the procedure is to exit these conditions immediately.

The *American Eagle Flight Manual - Part 1 Information Bulletin* dated 10 January, 1994 also states on page 1 :

. . . the AFM will not specify ‘... light or moderate icing only ...’. and furthermore, there are generally no AFM restrictions prohibiting flight in a certain type of ice (i.e. rime ice, clear ice, freezing rain, etc.). The only existing exception is the ATR-42/-72 AFM’s, which state that flight in freezing rain” . . . should be avoided.

The *Simmons Flight Operations News Letter* dated December 1993 (NTSB Exhibit 2T- 1, p. 3-4) entitled *Aircraft Ice* states in part :

The ATR has been tested in all kinds of icing conditions and must demonstrate various performance parameters in conditions corresponding to a failure of the deicing system.

Any time ice accumulates on the aircraft during flight it must be treated seriously. Not only does the performance deteriorate, but any encounter with severe ice - including freezing rain - for a prolonged period of time may cause control problems beyond that of the intended design.

When it is possible stay out of icing conditions. Delaying a descent into a cloud layer or requesting an alternate altitude or route to stay clear of known ice will decrease the amount of total ice build up and any potential problem related to ice accumulation.

The American Eagle Flight Manual - Part 1, Section 6, Page 8, issued 17 November 1992 (NTSB Exhibit 2-A, p. 48 - attachment "O") defines various icing conditions, their effect on airplane performance and actions to be taken under various icing conditions. "Moderate" icing is defined as follows :

The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or flight diversion is necessary.

American Eagle/ Simmons' Flight Manual, Part 1 para. 43 Use of anti-ice/deicing provides further instructions flight crews in respect to the use of anti-icing/de-icing equipment as follows :

Flight crews and dispatchers shall recognize anti-ice/deicing equipment as an aid in descending or ascending through icing conditions and during emergency flight in severe icing conditions. Operations requiring anti-ice/deicing use shall be based on the consideration that such equipment will permit extended operations only in light ice.

The American Eagle/Simmons' ATR-42/72 AOM and the Simmons' *Airlines Winter Operations Handout* provides the pilots with significant company policies to be followed in icing conditions. It addresses the detection of ice and states in part :

Detection of Ice

The presence of ice formation may be detected through either visual cues (e.g. buildup of ice on windshield wipers, prop spinners, engine inlets, wings leading edges or icing evidence probes) or from the Ice Detection System. The Ice Detection System is not a substitute for crew vigilance in detecting ice formation. Certain types of ice formation may be slow to trigger the Ice Detection System or may not trigger it at all. For example, ice which is building slowly and sublimating at approximately the same rate may cause considerable delay in triggering the detector or fail to trigger it at all.

Also, freezing precipitation which tends to flow prior to freezing may flow off the detector prior to freezing, failing to trigger the detector. Yet this same precipitation will flow aft on the wing and freeze creating a potentially dangerous situation Crew vigilance must be used to detect the formation of ice as soon as possible.

The American Eagle/Simmons' ATR-42/72 Operating Manual, issue 04 Nov. 92 provides the following information regarding freezing rain :

Freezing Rain

Freezing rain consists of large supercooled water droplets which may form clear icing after impacting the aircraft in negative temperature conditions. If the static air temperature is slightly negative, these large droplets may not be freezing immediately upon impact with the aircraft. As a result, clear icing can build up behind the leading edges.

The American Eagle/Simmons' ATR-42/72 Operating Manual also discusses crew vigilance in respect to the detection of ice. American Eagle's AOM states :

Crew vigilance in observing formations of ice is the primary means of determining the aircraft has entered ice accretion conditions. Visual indication can usually be detected on such surfaces as windshield wipers, prop spinner [42], ice evidence probe [72], and wing leading edges and engine inlets.

Finally, with respect to **holding speed**, the American Eagle ATR 42/72 AOM provides :

When holding is anticipated to be of short duration, holding should be accomplished with the aircraft clean at the flap zero Conservative Maneuvering Speed. If a hold will be of an extended or indeterminate time period, the VmHBO speed for Icing Conditions should be used as a holding speed.

1.5. ATR FLIGHT TRAINING

The NTSB's report omits critical factual information regarding the training information and simulator data packages provided by ATR for the ATR 42 and ATR 72 aircraft in respect to flight operations in icing conditions and unusual attitude training specifically relating to ice-induced stall and roll departures. This important factual information is necessary for a complete analysis and understanding of this accident since it has a direct bearing on the training information made available to pilots by ATR. Such information has been largely ignored by the NTSB. The BEA provides its comments in respect to these issues in sections 1.5.1, 1.5.2 and 1.5.3 below.

1.5.1. ATR TRAINING CENTER (TOULOUSE - FRANCE)

The ATR Training Center (ATC) located in Toulouse is in charge of the development of training material for its own application within its two simulators as described below, as well as material for worldwide Training Centers.

1.51.1. HARDWARE CONFIGURATION

There are two kinds of simulators :

AMS : This is a fixed base simulator devoted to Systems/Avionics management and procedures training. There is no artificial visual imagery system. That means that only equivalent IFR flight conditions are allowed for training.

FFS : Full Flight Simulator aims at crew training for basic flight dynamics and handling skills throughout a city pair leg from take-off up to cruise level down to approach/landing.

A synthetic imagery system is used to render the visual cues necessary to close the crew flight control loop.

1.5.1.2. SOFTWARE CONFIGURATION

a) general

. The data package consists of a 6 degrees of freedom (D.O.F) modelling based on combined data from Wind Tunnel and Flight Testing.

. Upon qualification by ATR Flight Test Center, any revised data package is then approved for release and readily incorporated in ATC simulators.

. A proposal for data package update is then submitted to airlines training centers.

b) ATR Icing Data Package for Simulators.

As early as 10/21/1988, an effective ATR42 ICING MODELISATION (Document GO 5 D04826) was added to the basic aerodynamic model to obtain a representative performance of known icing effects on the ATR 42 further to the experience gained from former icing event investigation.

- It comprized a post stick shaker stall with random roll upset (intensity and direction).

- Three icing severity levels were afforded (high-medium-low) to take care of cruise or de-icer failure ice shapes.

- Final tuning was done in Toulouse AMS with flight test pilots.

- It was first implemented by Flight Safety International on the ATR 42 simulator in HOUSTON by 08 Feb 1989 prior to completion of the ATC Simulator on 18 May 1989.

- It allowed flight crew familiarization with the roll upset situation and subsequent stall recovery procedures.

. An additional Icing Modelization package (D05 147) was further made available at FSI Houston by 29 August 1989 and updated on the ATC Simulator as well.

. Furthermore, the ATR 72 aerodynamic Data Package Icing Complement (DO 5481) was integrated into the ATR 72 ATC simulator by 26 June 1990 further to the knowledge gained from the MOSINEE incident investigation. This coding was forwarded to the ATR 42/72 Houston Simulators at the same time as well :

- Three icing severity levels were still afforded,

- The icing formulation and aerodynamic data were providing :

- . An abrupt asymmetrical stall with roll upset.

- . Increased Roll control forces during the recovery.

. This package in Particular allowed flight crew training for unusual attitude situation as depicted in item 12 of the training syllabus referred to in parag. 1.5.1.3 hereafter.

Moreover, a additional data package ATR72 DO 6243” Anti-Icing Fluid Type II” was integrated on both ATC et FSI Simulators since 7 January 1993.

1.5.1.3. ATC TRAINING SYLLABUS

The ATR Flight crew Training documentation, at december 1993 ISSUE page 34/35 shows that the Full Flight Simulator (FFS) briefing notes for session 8 “handling and stall demonstration” are clearly addressing unusual situations such as :

- **item 11** : stick pusher presentation with stall recovery technique
AP ON & OFF

- item 13 : stall in icing conditions Level II activated (A.O.A light ON) to observe the speed diference due to the lower stall alert threshold then followed by a stall recovery procedure.

- item 14 : stall approach / recovery technique to apply everytime the stick shaker is activated.

The item 12 hereafter is even more significant as it anticipates the unusual situation resulting from a lack of selection of level II/III de-icing configuration although ice may be accreting :

- position HIGH will generate a rapid speed decay,

- no warning until stick shaker / pusher apart from an instability on ailerons,

- an abrupt wing drop (random),

- the recovery technique Max Power / Wings level follows.

ITEM 12 : STALL WITH ICE ACCRETION WITHOUT AOA ON

- *A/C preparation is same as above and instructor should insert ice accretion in HIGH position.*
- *PF is advised of approaching stall by the aileron instability.*
- *When stick-pusher is triggered one wing drops to around 80° bank.*

Procedure :

- *PF advances PL's forward to white marks and requests "Max power, flaps 15 °", and simultaneously, he levels the wings.*
- *He stabilizes the wings, using both hands, allowing the IAS to increase to white bug speed , and then smoothly rotates in order to recover initial altitude.*

He requests "Flaps 0°" at RED BUG speed.

At any time, the instructor has control on the time of occurrence and severity of icing conditions.

. On the AMS simulators from ATC, actual ice build up on the Ice Evidence Probe (IEP) is simulated by a light "switched on" within the same vision area from the Captain.

- A few seconds time lag was implemented before the AAS is triggered.
- Therefore, a fast pilot reaction to select Level III would avoid triggering of the AAS single chime.

On the FFS simulators, the perception of icing conditions would rely entirely on the synthetic imagery system, close to vision through windshield, where penetration in clouds is rendered quite realistically.

- It therefore allows for detection of “visible moisture in the air in any form”.

The crew has to determine if “icing conditions” are then prevailing.

In summary, the identification of any aerodynamic phenomena since 1988 led ATR manufacturers to readily improve their training facilities in a continuous manner.

1989 - Crew training to A/C recovery technique after a post-stall roll upset.

- 1990- Training to recover from abnormal icing encounter as derived from MSN 91 MOSINEE with abrupt roll upset after failure to select Level II.
- 1992- Training to the effect of de-icing fluids type II
- 1992- Training to recover out of trim situation further to a bad ground de-icing of tail plane airfoil.

1.5.2. AMR EAGLE TRAINING CENTERS

The following gives the delivery dates of ATR icing model for Simulators.

	FSI HOUSTON ATR 42	FSI HOUSTON	FSI WILMINGTON ATR 42/72	AMR (EX ATI) ATR 42
ATR 42 ICING MODEL DOC 4826 DOC 5147 (ADD TO 4826)	8 FEB 89 29 AUG 89	18 MAY 89 29 AUG 89	18 MAY 89 29 AUG 89	18 APR 89 4 JUL 89
ATR 72 ICING MODEL DOC !5481	N/A	26 JUN 90	26 JUN 90	N/A

Flight Safety International also gave evidence that ATR icing document DO 4826 was received in January 1989 and readily implemented prior to the completion of the ATC simulator,

It was further updated with DO 5147 as well.

It is also confirmed that by February/March 1993, date of the last check of the flight 4184 Captain, FSI had implemented ATR 72 icing model D05481 and was also currently running an “Handling and stall demonstration”FFS training session equivalent to ATC FFS8 session (stalls and unusual attitudes as for ATC items 11 to 14).

1.6. METEOROLOGICAL INFORMATION

This section consists in a brief summary of the BEA “STUDY OF METEOROLOGICAL INFORMATION AS A CONTRIBUTION TO THE NTSB REPORT (dated April, 1996), appended to the present Document, as Appendix 3.

The NTSB provided the BEA numerous data and documents which were used in this study :

- general plotted and analysis and ground charts,
- available data issued from radiosoudings,
- weather radar and satellite imagery,
- available ACARS data transmitted during the flight, pertinent PIREPS and testimonies,
- CVR and ATC records and DFDR environment parameters.

1.6.1. GENERAL SITUATION

A low pressure area covered the United States to the east of the Mississippi. An active disturbance was associated to this low pressure area.

Between 15:15 and 15:58, the ATR 72 was flying in this area, in the layer between 12000 and 9000 ft, in and out the clouds, then from 15:45 in the dense cloud layer.

1.6.2 CLOUDS CONDITION

The flight took place at the edge of a stable cloud layer whose mean top was at 9 000 ft and the maximum at 10 500 ft. Turbulence did not exist or was very light, certainly limited to the maximum level of the tops, possibly associated with an effect of the strong wind whose laminarity was disturbed by the proximity of the warm frontal surface (wind shift).

A more unstable layer was located just above, adjoining the previous one (top 14000 ft), reaching 18000 ft at the level of the warm sector. **After 15:50 these layers thickened noticeably, while the rainy area linked to the depression was moving to NE, this being revealed by the intensification of the precipitation echoes detected on the Lockport weather radar. This confirms the detection of supercooled rain and drizzle drops as precipitation.**

1.6.3. CONDITIONS OF TEMPERATURE AND LIQUID WATER CONTENT

The precipitation detected on the Lockport radar was partly generated by the cloud layers located above 10 000 ft and played a role in the enlargement of water droplets and drops contained in the layer in which Flight 4184 was flying, where temperatures varied between -2 and -4 °C (SAT). This can be directly linked to the water vapor and liquid water contents through the air mass mixing ratio (saturating or not), depending on the aircraft location in time and space (holding pattern legs) :

- outside the cloud layer (humid air),
- in the cloud layer, without precipitation (saturated air),
- in the cloud layer, with precipitation (saturated air with increasing liquid water content).

In fact, on the basis of adiabatic theory, a decrease in temperature from -2 to -4°C at approximately 3000M (10 000 ft) would induce a global increase in cloud liquid water content (LWC) of 0,7 g/kg dry air, which corresponds to 0,65 g/m³, without taking into account the extra liquid water due to the precipitation falling from the layers above. In this case, temperature variations must be correlated to the corresponding areas traversed.

1.6.4. ICING CONDITIONS

Calculation of the time spent by the ATR 72 in precipitation leads to a cumulative time of almost 24 minutes out of a total time of more than 30 minutes in such conditions in the holding pattern, with static air temperature varying between -2 and -4 °C (total air temperature between + 1.5 and + 3.5 °C). This duration is based on precipitation echoes detected on the weather radar in the area of the holding pattern of the aircraft, which means, by deduction, drop size diameters detected of about 100 µm or more (see appendix 3).

Between 15:24 and 15:29 and then from 15:33 to 15:35, the aircraft was flying intermittently and briefly in low to moderate precipitation (15-20 dBz). SAT varied between -2.5 and -4 °C (LWC = 0.45 g/m³) and TAT between +1, 5 and +2.8°C. **The crew, who had activated the airframe de-icing at 15:16.32, switched it off at 15:23.22, and although the NP had remained at 86% since take off (during climb, cruise, initiation of the descent phase), they reduced it to 77% at 15:24.13 (DFDR time, steady state). At 15:33.56 a caution alert single chime was recorded on the CVR which was not acknowledged by the crew.**

Between 15:37 and 15:39.30, the plane passed through a light precipitation area (5 to 15 dBz) ; then, from 15:40 to 15:45, precipitation became moderate (15-20 to 25 dBz), and precipitation was also falling from upper layers. Temperatures varied between -2.5 and -4°C (LWC = 0.45 g/m³) and TAT between +1.8 and +2.2°C. **In that interval a caution alert single chime sounded, which can be considered to be the aural warning from the ice accretion detector 15:41.07 ; the crew immediately activated the airframe de-icing and modified RPM, increasing NP from 77% to 86%.**

At 15:48, the aircraft left an area of generally light precipitation (5 to 15 dBz), including precipitation from an upper layer ; SAT varied between -2.3 and -3.2°C (LWC = 0.27 g/m³), TAT by +1.8 and +2.5°C. At 15:48.32, one of the pilots remarked “I’m showing some ice now”.

At 15:55.42, the copilot said “we still got ice”, getting no answer from the Captain. The ATR had been flying under precipitation becoming moderate for more than four minutes (10 to 20 dBz) with SAT between -2.6°C and -3.5°C (LWC = 0.27g/m³) and TAT between + 1.2°C and +2.2°C.

From 15:56 until 15:58, the plane was descending, from 10000 ft. to about 9000 ft, in moderate precipitation (20 to 30 dBz). SAT varied between -1.2 and -3.5°C (LWC = 0.5 g/m³) and TAT between +2.8 and +4.5°C.

1.6.5. ICE ACCRETION

The aim of this paragraph is not to discuss the size of water drops and droplets in clouds or in precipitation. The radar echoes considered are precipitation echoes ; the minimum diameter for drop detection being about 100µm.

Using parameters set out in this study (liquid precipitation, air temperature, liquid water content), it is possible to make a simple ice accretion calculation, using the “Lucas Aerospace” diagram : accretion per minute in relation to liquid water content. The values calculated are provided for information only and are no more than a rough estimate. Ice accretions (rime or glaze) would have reached 1 to 2mm/mn, which overall represents a thickness of between 30 to 65mm during the time spent in the holding pattern for more than 30 minutes, independently of freezing drizzle or freezing rain falling in the layer or from the layer above for about 24 minutes.

As an example, for the different major phases described above, the following rough values were obtained (regardless of drop size or water runoff capacity and liquid precipitation) :

- between 15:24 and 15:35: thickness of 10 to 12mm,
- between 15:37 and 15:45 : 11 to 13mm,
- between 15:46 and 15:48 : 2mm,
- between 15:51 and 15:55: 4mm,
- between 15:55 and 15:58 : 4 to 6mm.

No calculation or information could lead to a conclusion as to the possible shape of ice accreted on the wing, nor regarding an ice ridge behind the de-icing boots. **However, we can assume, considering the size of the drops (100µm or more), the temperature of about -2°C and the aircraft configuration (flaps at 15°, leading to AOA reduction through 0°) that water drop impacts occurred both aft of the upper wing leading edges and that, due to a deficiency in heat transfer, significant water run-back could have occurred aft of the de-icing boots. These observations mainly relate to the time from 15:37 to 15:45 (including the AAS warning time) and between 15:51 and 15:58 (last minutes before the accident).**

1.6.6. AVAILABLE METEOROLOGICAL INFORMATION FOR THE FLIGHT 4184

. Flight release

As specified in the NTSB Report, the available AIRMET, which stated icing in precipitation, was not released to the flightcrew by the Dispatcher. But the flightcrew received all other pertinent information about the weather situation including the disturbance area as well as winds and temperatures in altitude.

. Hazardous in flight Weather Advisory Service (HIWAS)

This AIRMET was also broadcast over VOR frequencies. In the CVR transcription there is no information on a listening of the AIRMET through HIWAS. However there is no evidence that the flightcrew did not select a HIWAS frequency in order to listen an up-to-date weather information before the CVR started (15:27.59).

. Center Weather Service Unit (CWSU)

One out the five operational units of the Air Traffic Control System Command Center (ATCSCC), based in Virginia, is the Central Flow Weather Service Unit (CFWSU) which provides 24 hours service to the ATSCC in particular. This service consists in providing a Meteorological support to the 20 ARTCC (Air Route Traffic Control Center).

Regarding the Chicago Weather Service Unit (CWSU), there was no weather Advisory in effect about freezing precipitation or icing conditions at the time and in the area of the accident.

Several PIREP's on icing were reported to the ATC by flightcrews operating in the Chicago area. But no information regarding the deal with these PIREP's is known, nor the precise actions, of the CWSU as well as of the CFWSU meteorologists, that day.

1.7. FLIGHT RECORDERS

The BEA believes that factual information set forth in sections 1.7.1 and 1.7.2 below is critical to a complete understanding of the data obtained from Flight 4 184's DFDR and CVR.

1.7.1. CVR

Note 2 of the NTSB Exhibit 12A, Cockpit Voice Recorder Transcript, AMR flight 4184, states that “non pertinent conversation, where noted, refers to conversation that does not directly concern the operation, control or condition of the aircraft , the effect of which will be considered, along with other facts during the analysis of flight crew performance”.

The recording started at 1527:59, uninterrupted until 1557:57.1.

The CVR group, consisting of representatives from the parties to the investigation, collectively transcribed the tape in its entirety, directly on a micro-computer, and had the opportunity, to review the end product only by displaying through the computer screen. The NTSB took alone the decision to publish the public CVR transcript (Exhibit 12A) in an incomplete and edited version. The deleted parts were considered by the NTSB as “non-aviation related conversation or non pertinent and flight attendant conversation”. The CVR group members were not consulted upon the reasons for editing in this manner.

The correlation between CVR and DFDR timing was obtained by adding to DFDR a time bias of 4 seconds (i.e Time CVR = time DFDR + 4 seC). However, in this document, all CVR and DFDR events were given in correct sequence but dated without bias such as to avoid any mismatch with source material.

1.7.2. DFDR

The following complementary information has to be added :

Two specific labels on DFDR record represent a discrete signal indicating when the force applied on the Captain or F/O Control Column Rod (pitch) is exceeding 10 daN (22 lbs). This discrete signals have three valid states :

- Neutral = 3
- Down = 2
- UP = 1

Exceeding the a.m threshold triggers a different micro switch closure on either direction up/down. As long as the force is exceeding 10 daN, a ground signal is sent to the acquisition Unit (FDAU).

FDAU function is to scrutinize the a.m signal 16 times per second (i. e each 62,6 ms Cycle) but the output data is proceeded once per second based on the outcome of the three last sampling.

The “exceed signal” is only validated after ground is detected twice over the three last cycles. Therefore, it would mean that an “exceed signal” :

- shorter than 62,5ms is not recorded.
- longer than one (1) second is recorded for sure.

Any signal in between will or will not be recorded depending upon its position in the one second data processing cycle.

Concerning Flight 4184, the parameter has been validated during aircraft rotation at take off, since this particular discrete was active, with an elevator deflection up on the F/O side which correlates with the flying pilot at that time.

1.8. TESTS AND RESEARCH

The NTSB's report omits significant factual information regarding prior ATR 42 incidents as well as the extensive post-Roselawn accident investigation. This information is critical to a complete understanding of this accident because it makes clear that none of the prior ATR 42 incidents disclosed an ice-induced "aileron hinge moment reversal" phenomenon. In this regard, none of the prior incidents exhibited the unique characteristics involved in the Roselawn accident, namely an outer wing flow separation at an AOA well below the icing stall warning threshold, without any prior noticeable drag build-up and without any significant asymmetrical lift loss. This fact becomes even more apparent when the factual record of the extensive post-Roselawn accident investigation is fully examined. The BEA discusses these critical facts in sections 1.8.1 and 1.8.2 below.

In respect to the NTSB's treatment of the Bilateral Airworthiness Agreement (BAA) the certification process between the FAA and DGAC under the BAA, and the exchange of airworthiness information between the FAA and DGAC under the BAA, the BEA believes that the report is highly deficient. Critical factual information is missing regarding the respective roles of the DGAC and FAA during the certification of the ATR aircraft. Further, the report appears to ignore the communications which occurred between the FAA and DGAC in respect to continuing airworthiness.

The BEA discusses these issues in sections 1.8.3, 1.8.4 and 1.8.5 below.

1.8.1. PREVIOUS ATR-42 INCIDENTS

Five prior icing related ATR 42 incidents were considered as being possibly relevant by the NTSB :

.AMR Eagle/Simmons Airlines ATR-42 on approach at Mosinee, Wisconsin, December 22, 1988. (MSN 9 1);

.Air Mauritius ATR-42 in cruise over the Indian Ocean, April 17, 1991 ; (MSN 208);

.Ryan Air ATR-42 in cruise over South Wales , August 11, 1991. (MSN 161);

.Continental Express ATR-42 on approach at Newark, New Jersey, March 4, 1993. (MSN 259); and,

.Continental Express ATR-42 in cruise over the Burlington area, Massachusetts, January 28, 1994. (MSN 153)

1.8.1.1. SUMMARY OF PREVIOUS ATR 42 INCIDENTS

a) AMR/SIMMONS ATR 42 s/n 91 on December 22, 1988 on Approach Mosinee

During approach, in level flight at 6000ft, when flying in conditions later on clearly established as freezing rain, not using the airframe de-icing system, (although ATR was initially advised that the de-icing was “on”) during a right bank turn with 0°flap and autopilot engaged at 157 kt (engine torque 22-23%) and at an AOA of 10.2°, the aircraft progressively rolled out to a 0° bank angle, while aileron and rudder positions were maintained.

When the AOA reached 11.5°, the autopilot disengaged, the ailerons immediately deflected to about 12,5° and the aircraft rolled to the left to an 80° maximum bank angle. The maximum aileron deflection was recorded at 12.5°.

Recovery was achieved by a prompt reaction of the crew, which applied maximum power and brought the wings back to a level position by quickly positioning the ailerons opposite to the initial roll upset. The loss of altitude was 600 feet.

The NTSB conducted the investigation. The BEA participated in this investigation with the NTSB, mostly in meetings in Washington (December 29-30, 1988 and March 2-3, 1989) and Chicago (March 19-20, 1990).

On January 16, 1989, the DGAC disseminated a telex message to all concerned Airworthiness Authorities (including the FAA) which reminded the authorities of the importance of observing the minimum operating speed in icing conditions. In this message, special notes also drew their attention to the purpose of the AAS system ‘that gives a better information for managing” the flight in icing conditions and to the fact that “no aircraft is approved for flight in freezing rain conditions”.

On January 17th, 1989, ATR issued an All Operators Telex providing a detailed briefing about this incident, reporting that it had occurred in freezing rain and referencing the language and the recommendation of the FAA Advisory Circular 20.117 that such conditions be avoided.

On January 24 1989, ATR generated a complete incident analysis based upon DFDR read out that was provided to the DGAC, and to the BEA. Based upon the initial pilots' report, ATR assumed in this analysis that the airframe de-icing had been selected ON prior to the incident". The BEA issued a comprehensive report of this event, based on CVR transcript, DFDR data study and all available environmental information, which was provided to the NTSB by the BEA in Washington on March 2nd and 3rd, 1989 (See attendees list attached next page). During that meeting, the NTSB informed the participants that the pilots had changed their statement and that the airframe de-icing was not selected ON prior to the event. ATR did not re-issue its analysis.

3/2/89 - NTSB Meeting to Discuss ATR-42 Icing Characteristics
and 12/22/86 Incident

Attendees - Please give name, organization
and a telephone contact.

Gene Doub	NTSB - IIC	(312) 377-8177
Jack Drake	NTSB	(202) 382-6825
Xavier CHAMPION	Aerospace	61-93-80-59
ERIC DORMOY	DEAC	(1) 45-52-51-27
GILBERT CATTANEO	Flight Test Center (DGAC)	42 48 30 00
Philippe GOURGURCHON	Pilot Inspector DGAC	(1) 40 43 46 27
J. C. ANTOINE	B.E.A. Investigator	33 (1) 4828 5002
Don ELAM	FAA	(202) 267-9632
BOB McCracken	FAA SEATTLE	206 431 1979
DENNIS GROSSI	NTSB	(202) 382-6692
Steve Corrie	NTSB	382-6537
Clay Salotolo	NTSB	382-6671
CHRISTIAN TYNELSKI	ATR SUPPORT INC	(703) 430 3636
EDMOND BOULLAY	DGAC Rep to FAA	202 944 6054
Gwendolyn Adams	NTSB (NSF)	202 382 6619

ATR proposed to the DGAC, and through the DGAC to foreign Airworthiness Authorities (including the FAA), to amend the manufacturer's AFM and FCOM in order to further emphasize the risk of flying in freezing rain and to provide procedures for inadvertent encounters with such conditions. The FAA did not accept the proposed manual changes, but rather, mandated the development of a design change which aimed at moving the ice-induced type of asymmetrical stall seen in Mosinee beyond the icing stall warning threshold. The DGAC and ATR then proposed to retrofit the entire ATR 42 fleet with the addition of vortex generators derived from the configuration developed for the ATR 72. The retrofit was monitored by the DGAC but no French AD (Airworthiness Directive) was published. However, the FAA issued an AD requiring the installation of the vortex generators on the ATR-42 aircraft *.

* the retrofit of all the North American fleet of ATR 42 with vortex generators allowed the FAA to delete the temporary restriction of use of the autopilot in icing conditions imposed just after the incident.

In its draft Memorandum, dated March 5, 1990 the NTSB's I.I.C proposed the following probable cause for this incident :

“The National Transportation Safety Board determines that the probable cause of this incident is a stall induced by the accretion of moderate to severe clear icing due to freezing rain. Factors contributing to the incident are the lack of a hazardous weather advisory for severe icing being issued by the National Weather Service, lack of recognition of the severe icing condition by the flight crew, and the non-use of the airframe deice system by the flight crew.” (Emphasis added.)

The NTSB did not issue a final report.

In its Brief of Incident data base, the NTSB only issued findings and a simple probable cause :“a stall induced by the accretion of moderate to severe clear icing”.

b) Air Mauritius ATR 42/SN 208 on April 17. 1991 over the Indian Ocean.

While cruising at flight level 160 in clouds with SAT at about -3°C, with autopilot engaged, with anti-icing system ON, with airframe deicing system OFF and at 77% NP (minimum required was 86%), the aircraft experienced a progressive loss of speed from 183 to 160 kt (engine torques 710A) with a 10kt/mn rate. At 160 kt, two roll excursions were controlled by the autopilot.

When the crew disconnected the autopilot, the AOA increased to 11° and the aircraft rolled to the right, achieving a 40° maximum bank angle when the pilot released the effort applied on the control wheel on the roll axis, during the nose down maneuver. Recovery was performed without any controllability difficulty along with applying full power. The DFDR data did not show any tendency of the ailerons to move uncommanded.

Following this incident and the later ATR 42 S/N 161 incident, which also occurred at the improper NP77% setting, the DGAC undertook with the manufacturer a study aiming at determining the airflow disturbance and the loss of speed generated by ice contained propeller blades when NP is set at 77% instead of the required 86% in icing conditions. Moreover, the DGAC required an improvement of the AFM, check-list and operational procedures to re-inforce the requirement of a minimum Propeller RPM (86%) in icing conditions.

ATR incorporated a brief of this incident in their Monthly Report dated April 1991 and sent it to all operators and Airworthiness Authorities (including FAA Washington, Seattle and Brussels).

c) Ryanair ATR 42-S/N 161 on August 11. 1991 over South Wales *

While cruising at flight level 180 with autopilot engaged, with anti-icing system ON, with airframe deicing OFF, and at 77% NP (instead of 86% as required in icing conditions), the speed progressively decreased, starting from 180 kt, at the rate of 8 kt/mn. When reaching 145 kt (engine torques 68%) with an AOA of 10°, a g-break was recorded, then the stall warning and stick shaker were activated and the autopilot disconnected.

The applied elevator input (5° nose-up) led to an AOA varying between 10° and 13°. The aircraft stalled with an initial roll of 12,6° left wing down immediately followed by a right wing down to a 49.9° bank angle. The nose-up elevator input remained for 12 seconds, in a stall condition.

Recovery was performed as soon as the crew pushed on the control column to decrease the AOA and restored the wings level position. Shortly afterward, the flight crew reported to ATC very heavy icing conditions at flight level 180 (the aircraft flew through a cold front with freezing rain). The DFDR data did not show any tendency of the ailerons to move uncommanded at any time during the stall.

*. A similar event occurred in cruise at about 16,000 feet with a British Aerospace ATP flying through the same cold front, in freezing rain conditions,

The investigation was conducted by the DGAC, with the BEA assistance, on behalf and with the Irish Air Navigation Service Office. The actions taken by the DGAC and by ATR were identical to those initiated after the Mauritius incident.

ATR incorporated a Brief of this incident in their Monthly Report dated August 1991 and sent it to all operators and Airworthiness Authorities (including FAA Washington, Seattle and Brussels).

d) Continental Express ATR 42 S/N 259 on March 4, 1993 at Newark.

The aircraft leveled at 3,150 feet to intercept the final approach descent path. It remained at this altitude during about 15 mn, at flaps 0 setting, with TAT varying between 0 degrees C and -2 degrees C.

Severe turbulence and icing conditions prevailed. Anti-icing was ON, the NP setting was set at 77% (minimum required was 86%) and airframe de-icing was ON. The autopilot was ON with noticeable activity to maintain a wings level altitude. The airspeed was fluctuating at about 170-190 kt with peaks between 140-208 kt. After the aircraft initiated final descent, the crew set engine torques at 30%. A banking tendency developed to the right. The autopilot disconnected at an AOA of 7°, at a speed of 170 kt and the ailerons deflected to 7° to the right, then were positioned on the opposite stop (14°). The roll excursion was limited to 52° right.

Recovery was performed while controllability remained difficult, due to the high level of turbulence, until touch down.

The NTSB conducted the investigation and sent a DFDR copy to the ATR Manufacturer.

ATR generated a study based on the DFDR read out and communicated this information to the NTSB, the DGAC and the BEA. However, the analysis of the aircraft performance and controllability from the DFDR data traces was seriously hampered by the extreme levels of turbulence present during the entire period.

The NTSB did not provide the BEA with any information on its investigative results. Meteorological data required for a proper characterization and evaluation of the prevailing atmospheric conditions was requested from the NTSB by the BEA, but was never provided. The existence of freezing rain conditions and its correlation with the flight crew's observations could not therefore be confirmed. The narration of the incident filed in an anonymous manner by the pilots into the NASA ASRS data base, which somewhat differs from their previous report made in 1993 right after the incident and from what the DFDR data traces show, was not communicated to the BEA, DGAC or ATR.

Based upon the available data and since no noticeable aircraft performance degradation could be detected from the DFDR data, the BEA, DGAC and ATR concluded that the incident had been primarily generated by the severe turbulence. The side contribution of unidentified ice contamination was acknowledged as a possible factor only, however, all aircraft responses were consistent with the documented effects of the turbulence.

The NTSB later issued a factual report stating that the Newark incident occurred in "severe turbulence with strong horizontal gusts and icing conditions".

e) Continental Express ATR 42 S/N 153 on January 28.1994 at Burlington

While cruising at flight level 160, with the autopilot engaged, and with the airframe de-icing ON, the aircraft experienced a progressive loss of speed from 200 kt to a speed (144 kt), lower than the minimum speed authorized in icing conditions, at an average rate of 6kt/mn.

Correlatively, the engine torques decreased from 72% to 66% in the same period. When the AOA reached 11.5°, the autopilot automatically disconnected at the stall warning and a g- break was noted. The aircraft stalled. After the stall commenced the ailerons briefly deflected to about 10° left and the aircraft rolled on the left with a maximum bank angle of 54°.

Recovery was performed by the crew by promptly pushing on the control column and by applying full aileron deflection in a direction opposite to the initial roll upset.

The NTSB did not investigate the incident.

ATR received the DFDR directly from the Airline. The DFDR analysis found that the high level of drag and resultant loss of speed were consistent with severe ice accretion conditions. A momentary modification of the aileron hinge moment was noted after the stall commenced, but it had no effect on the incident. The manufacturer communicated all available information to the BEA. It was analyzed by the DGAC as well, which questioned the ATR conclusion regarding the presence of severe icing given that the accurate weather conditions were not known.

The DGAC requested a review of the ice codes which had been applied to the ATR-42, to compare this to the changed industry ice codes used for the ATR-72, as the ATR-72 had no history whatsoever of icing incidents involving roll control. This study was underway at the time of the Roselawn accident.

1.8.1.2. COMPARISON OF FLIGHT 4184 AND PREVIOUS ATR-42 EVENTS CIRCUMSTANCES AND CHARACTERISTICS

The factual data of each previous incident have been compared to identify possible similarities.

a) Configuration Comparison

All of the ATR-42 events reported prior to the Roselawn accident occurred in the flaps 0 configuration. The airplane S/N 401, instead, encountered icing conditions conducive to ice accretions in the flaps 15 configuration and experienced a roll upset when the crew changed the configuration from flaps 15 to flaps 0.

b) Flight Phase Comparison

The aircraft S/N 208, 161 and 153 incidents occurred in cruise phase at high altitude with torque values (between 65 and 71%) corresponding to this phase.

The aircraft S/N 91 and 259 incidents occurred when descending on approach for landing with torque values (between 20 and 30%) corresponding to this phase.

The airplane S/N 401 was performing four successive circuits in the same holding pattern, at 10000ft altitude. The accident initiated at the top of descent with torque set at idle.

c) Compliance with icing procedures at the time of the events

Icing procedures were not respected in all of the prior ATR-42 incidents.

In this regard, Aircraft S/N 91 and 208 accreted ice with airframe de-icing system "OFF". Aircraft S/N 161 showed a late selection (150" before the event) of this system. Aircraft S/N 259, 153 and 401 had the de-icing system "ON".

The published procedures for flight in icing conditions require a minimum propeller setting of NP 86%. Propeller RPM settings were left at NP 77% for aircraft S/N 208, 161 and 259, which did not ensure a proper propeller de-icing and generated a highly turbulent airflow over the wing. The flight crew of S/N 401 left the propeller RPM at NP 77% while operating in icing conditions, as established by their late selection of NP 86%, only after ice had accreted and the ice detection system aural warning was triggered. The NP 86% setting was made simultaneously the Level III activation of the de-icing boots. The proper propeller RPM was observed for Aircraft S/N 91 and 153.

Aircraft S/N 153 and S/N 161 were flying below the minimum airspeeds authorized in icing conditions when the incidents occurred.

d) Comparison of meteorological conditions

Aircraft S/N 91 encountered icing rain conditions for approximately 10 minutes. Similar conditions may have been experienced by aircraft S/N 259, although it could not be established from the available data.

For aircraft S/N 151, 208 and 153, factual meteorological data are very limited but the speed reduction rates (8 to 10 kt/mn) correspond to ice accumulations which cannot be obtained with accretion rates compatible with FAR 25 Appendix C conditions. These conditions were therefore outside Appendix C but were encountered for less than 10 minutes.

Aircraft S/N 401 has encountered established freezing drizzle / freezing rain conditions, the only one for such a duration of about 24 minutes.

The aircraft S/N 259 encountered severe turbulence throughout its incident as shown by the DFDR read outs which include vertical load factor variations of about $\pm 0,3g$. Other events occurred in an atmosphere considered as calm and for aircraft S/N 401 no turbulence was reported and recorded.

e) Comparison of performance degradation

It is possible to make fairly precise aircraft drag assessments, thus allowing a comparison with the predicted drag for an unpolluted aircraft, for all the events, using the same methodology.

The accuracy of such comparison could only be questioned for the S/N 259 (Newark) incident, due to the prevailing severe turbulence.

On this basis, all aircraft evidenced a very high degradation in drag (and/or in propeller traction). The computed drag increase, expressed in drag counts (DC) are to be compared with a figure for an unpolluted aircraft of about 300 to 400 DC. For instance the aircraft S/N 153 exhibited a + 100% drag increase.

Also, a fairly precise assessment of the lift was made using the same methodology in each incident, thus allowing a comparison with the predicted lift for an unpolluted aircraft.

These losses in lift, estimated at the time when the anomaly appeared in the prior incidents, are all of the order of $ACL/CL = 0.2/0.9$, that is greater than 20%.

Based upon the foregoing, Aircraft 401 can be characterized by the absence of significant drag performance degradation, which is at the limit of that discernible by the method used ($+3^\circ A$). This condition, never before observed in any ice-related event, was eventually associated in the further post-Roselawn investigations with the very specific accretion shape found in the Edwards AFB flight tests which related to the unique combination of the meteorological conditions and of the outer wing negative angle of attack, during the phase of accretion, resulting from the flaps configuration and the speed selected by the Flight 4184 crew.

The only recorded degradation of aircraft 401 performance corresponds to a loss of 10 to 15 kt in airspeed during some turns, which is mainly attributed to the turn technique.

f) Comparison of Angles of Attack

The angles of attack indicated here correspond to the disconnection of the autopilot which was at the point of stall on all prior incidents except S/N 259. The figures are those recorded by the DFDR (AOA vane). All prior incidents occurred at an AOA value close to the value (11.2°) corresponding to the stall warning threshold in icing conditions except for two aircraft : S/N 259 and S/N 401.

The dynamic of the aircraft S/N 259 incident, associated to large, almost instantaneous variations of the vertical load factor and the existing rolling moment at the time of the auto pilot disconnection, created a local angle of attack on the (right hand) dropping wing higher than the figure recorded in the DFDR. This value was, however, still lower than the icing stall warning threshold.

In the accident of aircraft S/N 401, the autopilot disconnection occurred after changing Flap configuration from 15 degrees to 0 degrees at an angle attack of approximately 6 degrees and far below figures recorded in any previous incidents.

g) Roll Initiation Mechanisms

All prior incidents occurred at high angles of attack (at or about at the icing stall warning). The initial roll phenomenon was of the pure asymmetrical stall type for aircraft 161 and 208 to which no aileron hinge moment modification could be associated. Aircraft 91 and 153 also involved a sudden asymmetrical stall, but to which some aileron hinge moment modification was associated. The DFDR data from the aircraft S/N 259 incident did not permit, and does not today permit, any further elaboration or analysis of the roll initiation mechanism.

Aircraft S/N 401 is unique in that there was no significant loss of lift and the roll upset was entirely due to the sudden deflection of the left aileron upwards to its stop, at an angle of attack far below stall, and caused by the profound alteration of the hinge moment constituting the “ice-induced aileron hinge moment reversal” phenomenon discovered in the post-Roselawn investigations.

Unique Characteristics Of The Roselawn Accident

The analysis of all significant parameters in the previous ATR-42 events and the aircraft S/N 401 accident highlights the unique characteristics of the latter event :

- This is the only roll control icing event involving an ATR 72.**
- Ice was continuously accreting during the holding duration, and probably intensively in freezing drizzle / freezing rain conditions for almost 24 minutes, in icing conditions beyond Appendix C.**

- **The aircraft was holding in icing conditions in the flaps 15 configuration at a speed close to VFE, resulting in a negative outer wing local AOA during the accretion phase.**

- **The roll upset occurred at an angle of attack (about 6°) which is less than half the stall warning threshold in icing conditions, while torque was at a steady value of 6 % since the initiation of descent toward 8000 feet.**

- **There was very little degradation of the aircraft performance in terms of drag and lift.**

- **The autopilot disconnected due to its internal monitoring system.**

- **An abrupt aileron hinge moment reversal appeared at the autopilot disconnection and was not associated to other characteristics of an aircraft asymmetric stall which was involved in all other events.**

1.8.2. POST FLIGHT 4184 ACCIDENT ACTIONS

Extensive work has been done after the ATR72 A/C401 accident in order to understand and, if possible, reproduce the type of aileron anomaly experienced during Flight 4184 and never experienced before and to find the probable cause of this accident.

€ Dry wind tunnel tests at S5/CEAT (Nov. to Dec. 1994).

These tests were performed to find which type of ice shape might cause an aileron anomaly similar to the one experienced during this accident.

Hypothetical ice shapes resulting from the following, have been tested :

- runback on the aileron horn,
- ice shapes on the vortex generators,
- hoar frost on the aileron and the horn,
- lugs in front of the aileron,
- ramps in front of the aileron,
- specific shapes behind the wing de-icers (pseudo runback shapes).

The findings were that among all the probable tested hypothesis (7 different scenarios), only an arbitrary triangular shape (located downstream of the external de-icers, over the span of both external de-icers and having an approximate thickness of 1") provides a phenomenon similar to the one extracted from the flight 4184 DFDR (low drag and aileron hinge moment anomaly occurring at low AOA).

€ High speed ground test (Dec. 1994) With a quarter round shape (3/4" then 1" in height) over the whole aileron span of the right wing at the upper active limit of the de-icers. These tests correlated with the dry wind tunnel test finding : flow separation then aileron suction at low AOA.

€ High speed ground and flight test (Jan. 1995) with a quarter round shape (3/4" in eight) over 25% of the aileron span of the right wing at the active limit of the de-icers. These tests correlated again with the dry wind tunnel test findings : flow separation then aileron suction at low AOA.

All the previous tests were performed to reproduce the A/C 401 behaviour. The main finding is that this behaviour can be reproduced using a 3/4" to 1" shape located over the aileron span downstream of the active limit of the outer wing de-icers.

The next steps consisted in the search of icing conditions which could have led to such a shape. The weather reports mentioning the possible occurrence of large supercooled droplets in the accident area it has been decided to conduct flight test at Edwards behind a tanker simulating these large droplets and to find an icing wind tunnel capable to produce large droplets.

€ Edwards test phase 1 (December 94). Numerous tests simulating normal operating and system failures under FAR 25 Appendix C (40 to 70 µm) and far beyond FAR25 Appendix C icing conditions (150 to 250 µm). It appears that only a prolonged flight (17 mn) under large supercooled droplet conditions can produce a ridge downstream of the external boot active limit on the wing upper surface.

The ridge chordwise position varies from 8% to 9% and the accretion cross-section varies according to the flap position (respectively 0° to 15°). The main findings of this campaign are :

The ATR72 fully complies with all certification requirements for flight in icing conditions,

For droplet diameter up to 70 µm the aircraft did not experience any anomalies of handling problems and the systems operated as intended,

For 180 µm droplet diameter, far beyond the requirements, the systems efficiently shed the ice on the boots and the aircraft only experienced a roll anomaly before the stall warning, after a prolonged exposure at flap 15 and a stall conducted at flap 0°. Nothing noticeable occurs for the two other tested conditions : prolonged exposure then stall at flap 15° and prolonged exposure then stall at flap 0°.

A clear and obvious visual cue (a granular ice pattern) develops on the unheated part of the side windows within 30 sec. under large supercooled droplets conditions.

Performance (drag) assessment could not and were not performed after these tests.

€ Icing wind tunnel test at Modane/ ONERA (Feb. / Mar. 1995) have been performed on a 1/12 scale and a full scale model. The aim of these tests was to evaluate the ability of the new spraying rig to produce large droplets, to verify the validity of the French scaling law, to study the freezing process at Roselawn conditions and to validate the modified ONERA icing code for large droplets. The main findings are that a ridge could develop at those conditions at the active limit of the de-icers (on the full scale model only) and that the observed impingement limits are in good agreement with the predicted one.

€Flight tests with simulated “Edwards ice shape” (January / February 1995). Further to icing tanker tests and wind tunnel tests, simulated “Edwards ice shapes” have been tested in flight (on ATR42-500 S/N 443 and ATR72-2 10, S/N 441) to assess the effects of the spanwise distribution, of the ridge height and of the chordwise location. During the flight 23 of A/C441 the anomaly of the flight 4184’s has been nearly reproduced. The ice shape configuration were :

- symmetrical on left and right wing,
- ice shape upstream of 75% of both aileron span,
- height : 3/4”,
chordwise location : between 8 and 9%,
cross-section derived from the Edwards Flap 15° accretion pattern.

Test with asymmetrical ice shape (upstream of R.H. wing only) resulted in similar aircraft behaviour.

At this step it appeared that flight with Flap 15 under prolonged operation into freezing conditions could lead to a ridge formation which could induce a flow separation upstream of the aileron and then a roll anomaly appearing at a specific A.O.A.

With this knowledge the following actions were undertaken within 4 months :

€ **define, certify and retrofit the appropriate aircraft modification (external wing boots extension up to 12.5% of the chord),**

€ **Edwards test phase 2 (March 1995) to validate the boots extension,**

€ **provide the crew with means to recognise these conditions,**

€define new procedures within the AFM to cope with, leave and continue safe flight after an inadvertent freezing drizzle encounter (prohibition of holding flap15 under icing condition,...),
€contribute to the ATR operators and flight crew information with the publication of the freezing drizzle brochure,
€implement within the flight simulator a “freezing drizzle simulation” for pilot training.

Moreover, on behalf of the DGAC, most of the French aeronautical partners (Airworthiness Operations and ATC Authorities, National Weather Service, operators, aircraft manufacturers) actively participate in the French National Icing Committee, initiated by the BEA, which addresses several icing topics (atmosphere characterisation, prediction, detection, computing code, simulation, training and information dissemination).

The French Aircraft Manufacturers also participate as task co-ordinator in the European project EURICE dedicated to icing atmosphere characterisation and prediction and to the critical review of both operational and certification requirements.

AILERON HINGE MOMENT

AILERON HINGE MOMENT REVERSAL

(TYPICAL RESULT FROM WIND TUNNEL TESTS WITH EDWARDS TYPE ICE SHAPES)

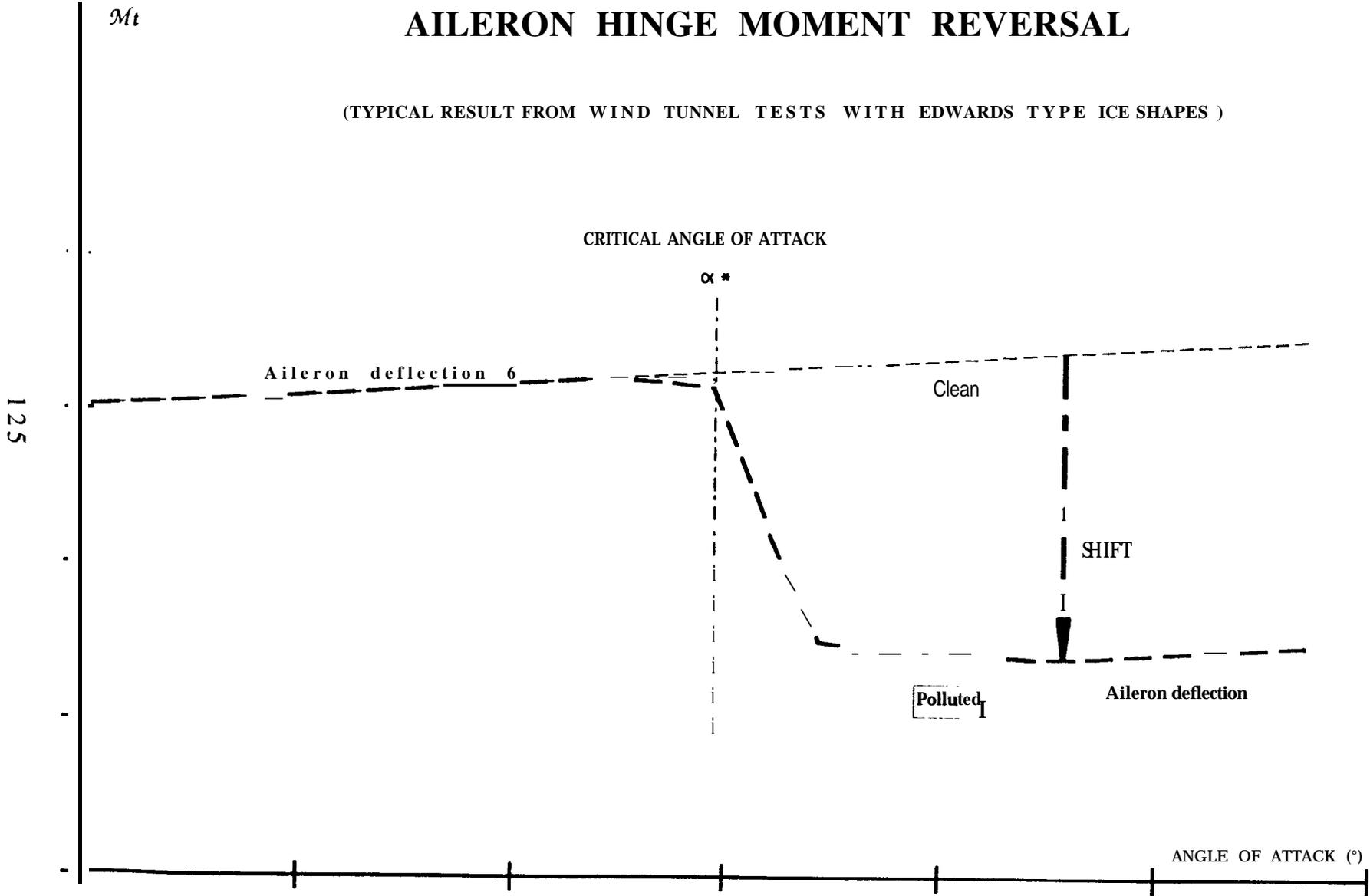


FIGURE 13 : HINGE MOMENT REVERSAL IDENTIFICATION

1.8.3. BILATERAL AIRWORTHINESS AGREEMENT (BAA)

The Bilateral Airworthiness Agreement (BAA) is an “enabling” document developed by two countries when they have competent civil Airworthiness Authorities and their manufacturers produce “Civil Aeronautics Products” which they desire to export to the other country. It is a mutual agreement which facilitates the importation and exportation of aircraft between such countries. This agreement is technically oriented, and is intended to:

1. prevent unnecessary repetitive certification activities by facilitating cooperation and acceptance of findings between the Airworthiness Authorities of the contracting states; and,
2. to ensure that the product certified meets the level of safety required by the contracting states during its service life.

The Bilateral Airworthiness Agreement between France and the United States was effected by an exchange of notes signed on August 29 and September 26, 1973.

1.8.4. CERTIFICATION PROCESS BETWEEN FAA, AND DGAC UNDER THE BAA

The ATR-42 certification was conducted between 1981 and 1985 by the DGAC acting as the primary certification Authority, in other words, the airworthiness authority of the state of manufacture (Exporting State).

The FAA certified the ATR-42 under the Bilateral Airworthiness Agreement (BAA), relying partially on the DGAC's prior certification of the aircraft. During its certification process of the ATR-42, the FAA raised 90 specific technical issues in addition to those which had been raised by the DGAC. The FAA required these issues to be addressed by ATR to the satisfaction of the FAA. The FAA also performed thorough flight testing of the ATR-42 before granting it a U.S. type certificate in October of 1985.

The same procedures were applied during the certification of the ATR-72. The DGAC's certification of the ATR-72 was conducted between 1987 and 1989, with the DGAC acting as the primary certification authority. During its certification of the ATR-72, the FAA raised 19 technical issues and performed thorough flight testing of the ATR-72 before granting a U.S. type certificate in September of 1989.

Under U.S. law the FAA is required to make an independent determination that FAA standards are met before issuing a type certificate under the BAA, regardless of how much the FAA relies on the certification work of the

These BAA certification procedures are still in force between France and the United States to address reciprocal acceptance of airworthiness certification work on their respective aircraft, and to provide a framework for appropriate actions as necessary to work towards common safety objectives.

The Special Certification Review Team jointly appointed by the FAA and DGAC following the Roselawn accident confirmed that the DGAC and FAA acted correctly and properly in their certification of the different ATR model aircraft. The ATR-42 and ATR-72 certifications were confirmed to have complied with all FAA and DGAC certification standards, and the BAA was found to have been properly applied in these certifications.

**1.8.5. CONTINUING AIRWORTHINESS INFORMATION EXCHANGED
BETWEEN FAA AND DGAC UNDER THE BAA, AND KNOWLEDGE OF
THE NTSB REGARDING ICING RELATED INCIDENTS ADDRESSED
IN THE NTSB'S REPORT**

Paragraph 6 of the BAA between the United States of America and France provides in pertinent part :

“[The aeronautical authorities of the exporting State shall assist the aeronautical authorities of the importing State] in analyzing those major incidents occurring on products to which the BAA applies, and which are such as would raise technical questions regarding the airworthiness of such products”.

This BAA provision requires the aeronautical authorities of the Exporting State to assist the aeronautical authorities of the State conducting an investigation in its analysis of a major incident or accident when the incident or accident “raises technical questions regarding the airworthiness of such products”, and when the matter has been duly reported to the Aeronautical Authorities of the Exporting State with all information which is available to the State of Occurrence being provided to the Aeronautical Authorities of the Exporting State.

This obligation in the BAA is based in part on Section 4.2.2 of Annex 8 of the Convention on International Civil Aviation, which provides in pertinent part :

The State of Design of an aircraft shall transmit [to States which have registered the aircraft] any generally applicable information which it has found necessary for the continuing airworthiness of the aircraft and for the safe operation of the aircraft (hereinafter called mandatory continuing airworthiness information). . . .“
(Emphasis added.)

Thus, unless incidents raise questions about the airworthiness of a product or its ability to operate safely, the airworthiness authority of the State of Design has no obligation to report the details of the incident to other Airworthiness Authorities.

To fulfill these BAA and Annex 8 obligations with respect to the ATR products, the DGAC has:

- a) assisted the FAA in analyzing major incidents which involve U.S. registered ATR airplanes and which “raise technical questions regarding the airworthiness of such products” when they are properly reported and documented to the DGAC, and
- b) provided the FAA with information “necessary for the continuing airworthiness of the aircraft and for the safe operation of the [ATR] aircraft” when such information is identified.

It should also be noted that Annex 13 to the Convention on International Civil Aviation provides that the State of Occurrence of an accident or serious incident has the responsibility for investigating the event unless the State of Occurrence formally delegates that responsibility to another State.

Since the NTSB is the primary aviation accident investigation Authority of the United States, the NTSB has the primary responsibility for investigating all such accidents and incidents occurring in the U.S.

It should also be noted that Section 6.14 of Annex 13 provides that if the State of Occurrence conducts an investigation into “an incident which involves matters considered to be of interest to other States, ” then the State of Occurrence “should forward to them the related information as soon as possible. ”

**1.8.5.1 PRIOR TO THE ROSELAWN ACCIDENT, THREE INCIDENTS,
DISCUSSED BY THE NTSB OCCURRED INVOLVING U.S.
REGISTERED AIRCRAFT IN THE U.S.**

Mosinee incident -AC 91- 12/22/88.

After this incident, the DFDR data was properly provided to the BEA by the NTSB. An investigation was conducted by the NTSB which, as the primary investigative authority of the State of Occurrence, was responsible for the investigation. The NTSB also requested and received the assistance of the FAA, BEA, DGAC and ATR. The NTSB provided all these parties with the DFDR readout, pilot reports, and weather information for use in their investigation.

Based on their investigation, the BEA, DGAC, and ATR developed an analysis of the incident. This analysis was fully presented by the BEA, DGAC, and ATR to the NTSB and the FAA, in Washington on 02 and 03 March, 1989. Corrective actions proposed by ATR were subsequently reviewed by both the DGAC and the FAA and jointly discussed in Seattle on 21 April 1989.

Design and system modifications were mandated by the DGAC and implemented on the ATR fleet in 1990 and 1991. In addition, Operating Manual changes were proposed by ATR to the DGAC, which in turn, recommended them to other Airworthiness Authorities, including the FAA for the U.S. The FAA did not adopt the proposed Manual changes, in accordance with its standard policy of preferring design modifications.

Newark incident- AC 259- 03/04/93 .

In this incident, the DFDR traces were forwarded by the NTSB to the BEA which in turn forwarded copies to ATR. The NTSB requested, and was provided by ATR, a copy of ATRs earlier study regarding the effects of a NP 77% setting for the propellers. However, the NTSB did not request further assistance from the BEA, DGAC, or ATR in the investigation of this incident. The NTSB, which was responsible for the investigation by virtue of its being the primary investigative authority of the State of Occurrence, provided to the BEA, DGAC, or ATR none of the further information developed by the NTSB and FAA during its investigation of the incident. Consequently, the ability of the DGAC, BEA and ATR to further conduct their own investigations and to effectively assist the NTSB in its investigation was limited.

Nevertheless, based on the DFDR readout, the BEA, DGAC, and ATR were able to determine that the incident involved a failure by the flight crew to follow the AFM and AOM procedures (NP 77% instead of the required 86%) while the anti-icing systems were activated.

In addition, the DFDR readout indicated that high levels of turbulence were involved which could alone explain the aircraft behavior. Neither the BEA nor the DGAC were ever advised of the final determinations by the NTSB in its investigation, or that any further assistance was desired by the NTSB.

Burlington incident - AC 153- 01/28/94.

After the incident, the DFDR and pilot reports were sent to ATR by the airline, and ATR forwarded the DFDR readout and the pilot reports to the BEA for its analysis. Neither the NTSB, which had the responsibility to conduct the investigation by virtue of its being the primary investigative authority of the State of Occurrence, nor the FAA, requested any assistance from the BEA or the DGAC in respect to the conduct of the investigation. The NTSB never forwarded any weather information or any other information whatsoever on the incident to the BEA or the DGAC.

ATR analyzed this incident based on the information available to it and presented its preliminary conclusions to the BEA and the DGAC on 15 February 1994. A draft report was provided by ATR to the DGAC on 17 March 1994.

The DFDR data established that there was a substantial failure by the flight crew to follow the AFM and AOM procedures for flight operations in icing conditions as the flight crew was flying below the minimum airspeed for such conditions and was losing speed due to ice accretions. The aircraft stalled causing the autopilot to disconnect.

Given the unusual lift loss and drag increase noticed during that incident, and given the fact that the ice-induced stall occurred at 86% NP, the DGAC required ATR to conduct an additional study of the ice codes used for the ATR 42. That additional investigation was in progress at the time of the Roselawn accident.

1.8.5.2 PRIOR TO THE ROSELAWN ACCIDENT, TWO INCIDENTS OCCURRED INVOLVING NON-US REGISTERED AIRCRAFT OUTSIDE THE U.S.

Ryanair incident -AC 161- 08/11/91

The DFDR, pilot reports, and weather conditions, along with information provided by other aircraft operating in the area of the incident, were provided to the BEA and the manufacturer by the airline with the agreement of the Irish Civil Aviation Authority.

The ATR investigation concluded that the cause of the incident was an aerodynamic stall. The stall was the consequence of an ice accretion which resulted from a failure by the flight crew to respect AFM and AOM procedures for flight operations in icing conditions.

The results of the ATR investigation were presented in Toulouse to the BEA and the DGAC on 13 September, 1991. The conclusions were accepted by the BEA and DGAC and presented to the Irish Civil Aviation Authority in Dublin, Ireland on 7 November, 1991. The investigation report was not sent to the FAA since the incident did not “raise technical questions regarding the airworthiness of [the ATR aircraft]”. ATR did, however, report this incident to all ATR operators.

Air Mauritius incident - AC 208- 04/17/91.

In this incident, the DFDR, pilot reports, and weather conditions were provided to the BEA and to the manufacturer by the airline with the agreement of the Civil Aviation Authority of Mauritius. The investigation conducted by ATR concluded that the cause of the incident was an aerodynamic stall which was the consequence of ice accretion resulting from a failure by the flight crew to respect AFM and AOM procedures for flight operations in icing conditions.

ATR's investigation report was presented in Toulouse to the BEA and the DGAC on 12 June, 1991. The conclusions were accepted by the BEA and DGAC and were provided to the Civil Aviation Authority of Mauritius on 17 October, 1991, which raised no further comment on it. The investigation report was not sent to the FAA since the incident did not “raise technical questions regarding the airworthiness of [the ATR aircraft]. ” ATR did, however, report this incident to all ATR operators.

1.9. AIR TRAFFIC CONTROL

In the NTSB's Report some important information is missing in respect to the actions of Air Traffic Control. The BEA provides its comments and additional data below.

The investigative record indicates that on the afternoon of the accident, a weather system was moving through the south area of Chicago Center. The South Area Supervisor, Chicago Air Route Traffic Control Center (ARTCC), testified at the NTSB Public Hearing that "conditions were right for light to moderate icing to occur." In this regard, Chicago ATC controllers were aware that icing conditions were forecast for the area they were in charge of. Further, ATC controllers in charge of the 15:00 to 23:00 shift, had been given a clear briefing upon expected weather conditions by the Supervisor with the explicit warning that "Icing Kills". He testified at the NTSB Public Hearing that he wrote NTSB Exhibit 3G, the "south area weather briefing" which states : (see next page)

Icing Kills - it's your job to know the freezing level in your sector, and the tops & bases. That is the fastest way out of the ice. Pass on the PREPS. Use Depts [departures] off your airports to solicit this critical info." (Emphasis added.)

"ICING KILLS"

SOUTH AREA WX. MONDAY EVENING SHIFT

COMPUTER PROBLEMS TONITE!

RAIN ALL SHIFTS. TOPS 18 TO 20 THOU

T-STORMS DEVELOPING IN THE SOUTH. TOPS

WILL BE FL300. LOTS OF LT CHOP @ 80

FR LVL: 8,000. → EXPECT LI RIME/MIXED.

THE ENTIRE SHIFT WILL BE IMPACTED BY THIS WX. SYSTEM.

PROGRAMS: STL - 'TILL AFTER MIDNIGHT - } WATCH FOR
EWR - LOTS OF SPACE TO 208 } RE ROUTES!
ORD 80-RATE
JFK - GRD STOP.

"ICING KILLS - IT'S YOUR JOB TO KNOW THE FREEZING LEVEL IN YOUR SECTOR, AND THE TOPS & BASES, ... THAT IS THE FASTEST WAY OUT OF THE ICE. PASS ON THE PIREFS. USE DEPTS OFF YOUR AIRPORTS TO SOLICIT THIS CRITICAL INFO."

D. L. W.

He further testified that he “wanted to highlight to the controllers how important it was to stay alert and stay on top of the weather conditions in their particular sectors. ” He also testified that he gave a copy of this weather briefing to each sector, including the Boone Sector, and that he took the original and hung it next to the weather radar scope.

During the NTSB Public Hearing, The Supervisor also testified regarding what ATC’s response would have been had a pilot complained about holding in icing conditions on the day of the accident. He responded by stating:

Very responsive. The first thing the controller would ask is if the pilot wanted an altitude change to get out of the icing conditions. The rest of the scenario would be based upon the pilot’s transmissions and requests. (Emphasis added)

He also testified that Flight 4184 was the only flight holding at LUCIT intersection, and that if the flight crew had complained about icing conditions while holding at LUCIT intersection, there were “four other altitudes” that would have been available, 5,000 feet through 9,000 feet. In addition, he testified that “higher altitudes could have been coordinated and could have been worked out on request. ” The supervisor further testified that “icing conditions [were] a valid reason” to request a different altitude, and that the “aircraft would [have been] allowed to hold at any altitude that it wished. ” Finally, He confirmed that at no time while Flight 4184 was holding at LUCIT intersection did the flight crew make any request for a speed change or an altitude change.

The record also indicates that Flight 4184 was a scheduled flight of only 1 hour and 5 minutes between Indianapolis and Chicago. However, because of delays for low ceilings and visibility at Chicago O'Hare International Airport, Flight 4184 was held on the ground for approximately 42 minutes, and held in the air for approximately 35 minutes prior to the accident.

In respect to the release of Flight 4184, the Chicago Center Traffic Management Coordinator (TMC) released Flight 4184 from a 42 minute ground hold which had been implemented by Air Traffic Control System Command Center (ATCSCC) despite having been informed by the ZAU Traffic Management Coordinator (TMU) that conditions were such that the flight would likely be required hold in the air before reaching its destination. In this regard, FAA Order 7110.65 states that the Control Departure Time (CDT) program is the :

Flow control process whereby aircraft are held on the ground at the departure airport when delays are projected to occur in either the enroute system or the terminal of intended landing. The purpose of these programs is to reduce congestion in the air traffic system or to limit the duration of airborne holding in the arrival center or terminal area (Emphasis added.)

Once Flight 4184 was airborne, the BOONE Sector Controller, who was a trainee, placed the aircraft in a hold at LUCIT intersection to accommodate incoming traffic from the west. Flight 4184's Expected Further Clearance (EFC) time was extended on four separate occasions. However, despite the fact that it was mandatory for the BOONE Sector Controller to report those arrival delays to ATCSCC which are expected to meet or exceed 15 minutes, neither the Central Flow Control Facility (CFCF), nor the Traffic Management Unit (TMU) were advised that Flight 4184's holding time had exceeded 15 minutes.

In respect to the solicitation of PIREPS, FAA Order 7110.65J, Section 6 entitled *Weather Information* provides that ATC controllers are required to "solicit PIREPS when requested or when one of the following conditions exist or are forecast for your area of jurisdiction. " One of the conditions for which ATC controllers are required to solicit PIREPS is "icing of light degree or greater. " (Emphasis added.)

1.10. ADDITIONAL INFORMATION - WORLDWIDE FLEET ICING EVENTS

1.10.1. FOUR DIFFERENT AIRPLANES ICING EVENTS

1. FOKKER 27 G-BMAU accident on January 18, 1987 on final at EAST MIDLAND AIRPORT (UK)

Reference : AAIB report 7/88

It was a British Midlands Airways training flight. The purpose of the flight was an instrument approach with one engine simulated failure. On final approach, the airplane struck the ground. Wings and elevator leading edge were covered with one inch of clear ice.

Weather situation on the airport area was characterized by a stationary warm front with stratus and stratocumulus layers between 900 and 1700 feet. Freezing level was on ground.

The investigation led by the AAIB highlighted a loss of directional control and apparently then a stall. Deicing systems had not been activated and speed fell below the normal approach speed.

2. BRITISH AEROSPACE ATP 6 G6BMYK incident on August 11, 1991 near OXFORD (UK)

Reference : AAIB report 4/92

While the airplane was climbing to FL 160 buffeting then roll oscillations occurred. The left wing stalled without warning and vertical speed increased.

The crew activated the de-icing system and manually recovered the aircraft below the cloud layer. After this recovery, a loss of ailerons efficiency was noted by the crew. The crew did not detect ice accretion.

A cold front prevailed in the area. The freezing level was at FL 110 and an altostratus - altocumulus layer was present between FL 90 and FL 130. At the level where the airplane was flying the SAT was -2° C to - 5°C and moisture was very high.

The investigation underlined that there were falling water drops as big as one millimeter-diameter inside the cloud. The accretion rate was calculated to be about 1/2 inch per minute.

At that time, the industry understanding of freezing precipitation or of supercooled drops precipitation associated the freezing rain phenomenon to a temperature inversion in the atmosphere. The conditions encountered by the ATP aircraft were not considered to be freezing rain.

3. EMBRAER 120 BRASILIA F-GFEP incident on November 22, 1991 on approach to CLERMONT-AULNAT AIRPORT (FRANCE)

Reference : BEA report 7/92

This was an Air-Littoral flight from Lyon-Satolas to Clermont-Aulnat. Due to high traffic on the airport the airplane was flying one circuit in the holding pattern. After the ATC clearance to descend down to 4500 feet was given, the flight crew disconnected the auto-pilot at 4700 feet in order to manually capture the altitude.

The stick shaker abruptly activated and the airplane stalled. After a prompt recovery it stalled again and then once again. While the first officer activated deicing systems, the captain applied full power and executed the final recovery with an altitude loss of 1200 feet.

After landing, accretions of ice (cleared to mixed ice) still covered the leading edge of wing tips and elevator (3 cm X 6 cm thickness) and the upper wings (0.5 cm thickness).

A stratocumulus layer extended over a large part of France. On the area of incident, the base was at 2000 feet (-1.5°C) and the top was at about 5500 feet (-7/-8°C) to 6300 feet (-3/-5°C) limited by a temperature inversion.

The investigation underlined a high rate of liquid water content inside the upper part of the cloud up to 1.0/ 1.2 g/m³ with an increase of droplets size.

The BEA issued a recommendation asking for a review of certification criteria, in terms of icing conditions more severe than those admitted in Appendix C,

4. ANTONOV AN-12 accident on January 31, 1971

Reference : MAK (Interstate Aviation Committee - CEI). ISASI FORUM 9/95.

The following comments concern the data recorded during the accident which occurred on January 31, 1971 on an AN-12 airplane, serial 12996 :

“The command for flap extension was given at the 21 -st second. At the same time air speed decreased and the transition period of flap extension coincided with the aileron oscillations. It had been misunderstood by the captain as non-symmetrical flap extension and the command to bring the flaps up was given at the 25-th second.

At this time the airspeed dropped to 172 KIAS, despite the oil pressure increase in inboard engines torque-meter to 30 kg/cm². The aileron oscillations were due to the hinge moment reversal on the ailerons, and occurred at the $CL = 0,95$ in case of the ice accretion on the wing.

The sudden aileron deflection to the left bank, practically to the limit, was initiated at the 25-th second. This deflection was due to the high forces on the yoke's lateral channel ; the yoke was “breaking out” from the pilot's hands. The pilots were able to bring the yoke back from the extreme left position by applying a great deal of force. However they failed to hold it in the neutral position, since the necessity to counteract the left bank ($f = 15-20^\circ$) made them turn the yoke to the right. That, in turn resulted in repeated snatching the yoke out of the pilot's hands completely to the right due to the hinge moment reversal on the ailerons. ”

1.10.2. WORLDWIDE TURBO PROP ICING EVENTS

From the current BEA accident data base, 23 significant icing events can be identified since 1985 until 1994.

Among them, 11 events could be classified as “loss of control”.

This data base demonstrates that icing incidents / accidents affect virtually all types of turboprop aircraft. However, more events were reported for recently manufactured aircraft than for older aircraft types.

A LIST OF SOME EVENTS OCCURRED SINCE 1985

AIRCRAFT MODEL	LOCATION	DATE	INJURIES/DAMAGE	ICING CONDITIONS EVENT
Short 360	UK	86/01/31	0/Destroyed	Loss of control
Cessna 441	USA	86/03/03	8/Destroyed	stall
Be 99	USA	86/05/16	0/Substantial	Stall
Fokker 27	UK	87/01/18	0/Destroyed	Loss of control
DHC3 otter	Canada	87/01/31	0/Substantial	stall
piper PA 23	USA	87/04/28	0/Destroyed	Loss of control
Be 1900	USA	87/11/23	18/Destroyed	Loss of control
BAe Jetstream 31	USA	87/12/24	0/Destroyed	Loss of control
Mitsubishi Mu 2	USA	88/11/06	1 /Destroyed	Loss of control
Cessna 404	Canada	89/11/08	0/Destroyed	Stall
NA Commander 500	Canada	89/12/04	0/Substantial	Loss of directional control
BAe Jetstream 31	USA	89/12/26	6/Destroyed	Stall

A LIST OF SOME EVENTS OCCURRED SINCE 1985

AIRCRAFT MODEL	LOCATION	DATE	INJURIES/DAMAGE	ICING CONDITIONS EVENT
Cessna 208	USA	90/01/29	2/Destroyed	stall
Cessna 208	USA	90/02/27	1 /Destroyed	stall
BAe Jetstream 31	USA	91/01/30	0/Destroyed	Loss of control
BAe ATP	UK	91/08/11	0/None	Stall with severe uncontrollable roll oscillation
Embraer 120	France	91/11/22	0/None	Stall
Lockheed Neptune	USA	92/02/08	2/Destroyed	Stall
NA Commander 500	USA	92/11/23	0/Substantial	Loss of control
NA Commander 500	USA	93/01/11	0/Substantial	Stall
HS 748	Canada	93/11/11	7/Destroyed	Loss of control on final
BAe Jetstream 41	USA	94/01/10	4/Destroyed	Loss of control on approach
SAAB-F 340	UK	94/03/23	0/None	Loss of control (left wing dropped)

1.11. ADDITIONAL PERTINENT DOCUMENTATION

The following list of additional documents is considered by the BEA as an interesting source of information in the frame of the forthcoming :

1. The *American Eagle's Crew Resource Management* publication, adapted from American Airlines, outlines the training program utilized by American Eagle/ Simmons in respect to training its flight crews for *Techniques for Effective Crew Coordination*. (NTSB Exhibit 2-E). The preface to this publication entitled *CRM Overview* states in part :

The purpose behind American's CRM program is to enhance crew coordination and situation awareness in order to decrease the chances of an aircraft accident attributable to flight crew behavior and to increase crewmembers' ability to deal with mechanical and environmental factors that could easily cause an accident.

The following *Techniques for Effective Crew Coordination* are set forth in the *American Eagle Crew Resource Management* publication and are considered by American Eagle to be the "four critical areas" in respect to techniques for effective crew coordination :

1. *Technical Proficiency :*

Do crew members know their aircraft and procedures?

2. *Situation Awareness and Management :*

How do you recognize a deteriorating situation? Once recognized, how do you deal with the workload?

3. *Communications :*

Did everyone know the plan?

4. *Teamwork :*

Was the crew functioning as a team?

The BEA will discuss the actions of the Flight 4184 flight crew in the context of these “four critical areas” in the *Flight Crew Performance section*.

2. Advisory Circular No. 120-51A (NTSB Exhibit No. 2D) entitled *Crew Resource Management Training* also provides guidance in respect to assessing the Crew Resource Management (CRM) issues involving this accident. Appendix 1 of AC No. 120-51A provides “Crew Performance Marker Clusters” which can be utilized to assess the performance of flight crews. Although the BEA will not provide an exhaustive analysis of the flight crew’s performance in the context of these “marker clusters”, the BEA strongly recommends that the NTSB conduct a thorough review of the actions of Flight 4184’s flight crew in this context.

3. Section 4, para. 90, of American Eagle's Flight Manual entitled *Nonessential duties during critical phases of flight (Sterile Cockpit) (FAR 121. 542)* sets forth procedures for flight crews during such phases of flight. Paragraph 90 states in part:

A. Crewmembers will not perform duties during a critical phase of flight except those duties required for the safe operation of the aircraft.

B. The Captain will permit no activity during a critical phase of flight which could distract any flight crewmember from the performance of his duties or which would interfere in any way with the proper conduct of those duties. Nonessential activities prohibited during critical phases of flight include eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, announcements pointing out sights of interest, non-operational company radio calls such as confirming passenger connections, filling out company logs and reading of any publication not related to the proper conduct of the flight.

Section 4, para. 91 *Sterile Cockpit Definition* further defines “critical phases of flight (sterile cockpit)” in part as follows:

A. Critical phases of flight (sterile cockpit) include all ground operations involving movement of the aircraft under its own power, including takeoff and landing, and all operations below 10,000 feet MSL, except cruise flight. A critical phase of flight may also include any other phase of a particular flight as deemed necessary by the Captain. (Emphasis added.)

4. Federal Aviation Regulation 14 CFR §121. 542 *Flight Crewmember Duties* states in part:

(a) No certificate holder shall require, nor shall any flight crewmember perform, any duties during a critical phase of flight except those duties required for the safe operation of the aircraft. Duties such as company required calls made for such nonsafety related purposes as ordering galley supplies and confirming passenger connections, announcements made to passengers promoting the air carrier or pointing out sights of interest, and filling out company payroll records are not required for safe operation of the aircraft.

(b) No flight crewmember may engage in, nor may any pilot in command permit any activity during a critical phase of flight which would distract any flight crewmember from the performance of his or her duties or which could interfere in any way with the proper conduct of those duties. Activities such as eating meals, engaging in nonessential conversations within the cockpit and nonessential communications between the cabin and cockpit crews, and reading publications not related to the proper conduct of the flight are not required for the safe operation of the aircraft.

(c) For the purposes of this section, critical phases of flight include all ground operations involving taxi, takeoff and landing, and all other flight operations conducted below 10,000 feet, except cruise flight.

5. The National Transportation Safety Board's. Safety Recommendation dated February 3, 1994 sent to the Honorable D. R. Hinson, Administrator FAA and proposing criteria to evaluate flight crew performance and errors made in major accidents, states in part :

"The nine error types are defined below.

Primary Errors *--Eight of the nine descriptive types of errors are considered primary errors ; that is, they are not dependent on making a prior error.*

1. *Aircraft handling* : *Failure to control the airplane to desired parameters.*

2. Communication : Incorrect readback, hearback ; failure to provide accurate information ; providing incorrect information.
3. Navigational : Selecting wrong frequency for the required radio navigation station ; selecting the wrong radial or heading ; misreading charts.
4. Procedural : Failure to make required callouts, making inaccurate callouts ; not conducting or completing required checklists or briefs ; not following prescribed checklist procedures ; failure to consult charts or obtain critical information.
5. Resource management : Failure to assign task responsibilities or distribute tasks among crewmembers ; failure to prioritize task accomplishment ; overloading crewmembers ; failure to transfer / assume control of the aircraft.
6. Situational awareness : Controlling aircraft to wrong parameters.
7. Systems operation : Mishandling of engines or hydraulic, brake, and fuel systems ; misreading and mis-setting instruments ; failure to use ice protection ; disabling warning systems.
8. Tactical decision : Improper decision making ; failure to change course of action in response to signal to do so ; failure to heed warnings or alerts that suggest a change in course of action.

1.12. ADDITIONAL COMMENTS ON NTSB FACTUAL SECTION

The following additional comments refer to portions of the NTSB's draft report as it was delivered to the BEA.

p. 4, line 5.

The Beech Baron's crew asked the ATC for a diversion from 12,000 feet down to 10,000 feet.

p.4, line 23.

Modify as follows : "... the level III airframe deicing, the propeller RPM remaining at 86 percent from the beginning of the flight (climb and cruise)".

p. 6, lines 9-10.

Modify as follows : The airframe deice system was deactivated at 1523: 22 and propellers speed was reduced to 77 percent at 1524 : 13".

p. 8, line 8 to 21.

Delete : " the following exchange " because some exchange is missing.

Add : "...." in intervals where quotations are missing.

p. 8, line 22.

Add a few words on demonstration made by the flightcrew to the stewardess about some systems functioning.

Moreover, the single caution alert chime sounding at 1533 : 56 during the demonstration should be noted as well as the absence of flight crew comment about it.

p. 9, line 19.

After “. . . by an unintelligible word(s) “ add : “pronounced by either the same pilot (or the other one) likely the First Officer.

p. 10, line 2.

The phrase “ During the Captain’s absence both the “ should be modified to read : “ During the duration of the Captain’s absence , for a period of four minutes and 29 seconds, both the“

p. 14, line 11.

The BEA requests that this line be modified to read : “column force momentarily exceeded 22 pounds”,

p. 14 (Graph).

Replace the graph dated “February 25, 1995 with the latest version dated “ January 23rd, 1995”.

p. 17, line 14 to p. 18, line 24.

According to Exhibits 2A and 14A about the Captain, some facts are veiled such :

- he was aware of previous incidents,

information about work time and flight time for previous three days was known.

p. 18, line 3.

After the phrase “ The Captain transitioned to the ATR and . . . “ add the phrase : “ after having failed once on March 10, 1993 to pass his ATR type rating examination ...,”

p. 19, lines 3 to 7.

According to Exhibit 2A and 14A, in the First Officer's background, add aircraft type ratings and especially : "the First Officer was neither ATP nor ATR 42 / 72 type rated".

p. 20, line 25.

Add the shift time of Danville Sector Controller which is missing.

p. 21, line 8.

Add the shift time of Boone Sector Controller which is missing.

p. 21, line 10.

Add another sentence : "His precise functions for this shift were . . . (to be detailed)", because "on-the-job training and instructing" and possible other tasks must be explained.

p. 21, line 19.

Add the shift time of Boone Sector Developmental Controller which is missing.

p. 23, line 7.

Modify as follows : "The EADI also displays red chevrons..."

p. 23, line 15.

The EADI does not display an "eyelid", it is the stand-by horizon which includes an eyelid.

p. 24, lines 3-4.

Modify as follows : "... weather radar and displays 3 levels of detectable precipitation with four separate colors. According to the ATR 72 Flight Crew Operating Manual (FCOM) and the Pilot Handbook PRIMUS 800 Color Digital weather Radar, the colors are used to depict the various densities of the clouds in which precipitation occurs :

Level	Weather Mode	Map Mode	Rainfall rate mm/hr
Level 0	No detectable clouds	Black	< 1
Level 1	Normal clouds	Green	1 to 4
Level 2	Dense clouds	Yellow	4 to 12
Level 3	Severe storm	Red	> 12

(Ref BEA Study of Meteorological information as a Contribution to the NTSB Report, para 1.6).

p. 29, lines 20-22.

This sentence is not factual. This information was not provided by ATR. It looks as an hypothesis and therefore it has to be removed for the Factual section. After the sentence ending "manufacture. " in line 22 , the BEA requests that the NTSB add the following new sentence : " The resulting uncomplicated design provides an inherent safety advantage ."

p. 29, lines 22 to 25.

Replace the phrase beginning "However, ... susceptible to" with the phrase :

"However, during certain extreme flow separations possibly occurring outside the authorized flight envelope, this type of control system, which has been selected on all certificated turboprop aircraft, may be susceptible to...".

p. 30, line 21 to p. 31, line 6.

The BEA considers this paragraph to be wrong, inaccurate, and irrelevant to the Roselawn accident. Therefore, this paragraph should be deleted.

p. 31 (Graph).

The graph shown on page 31 entitled “Right Aileron Hinge Moment” is not understandable by the ordinary reader. It should be either explained or deleted.

p. 32, lines 20-24.

The sentence should be changed to read :

“These SPS AOA values remain constant for operations in any type of icing conditions as defined in 14 CFR Part 25, Appendix C”.

p. 36, line 15.

Modify as follows : “... there is not enough heat transfer to instantaneously freeze the water ...”.

p.36, line 16.

After : “... that contacts the probe” add a foot-note number.

The foot note will be : “This information is provided to the flightcrews in the AOM which states (Ice and Rain Chapter, P. 42- issue 23 June 93) :

“... ice which is building slowly and sublimating at approximately the same rate may cause considerable delay in triggering the detector or fail to trigger it at all. Also, freezing precipitation which tends to flow prior to freezing may flow off the detector prior to freezing, failing to trigger the detector ...”

“Crew vigilance must be used to detect the formation of airframe ice as early as possible”.

p.36, line 18.

Add after line 18 the following new sentence : “In fact, freezing drizzle conditions simulated during the Edwards Air Force Base Tanker Tests were always detected by the Rosemont ice detector probe within 30 seconds after the immersion into the tanker plume”.

p. 37, line 15-16

Modify as follows : “ . . horizontal and vertical stabilizer leading edge boots (if that one installed) ... ”,

p. 37, line 17.

Modify as follows : “... Ice accretion, the AAS alert being only an ultimate adviser”. The present statement of the NTSB is not coherent with the other NTSB statement p. 145, line 6-7.

p. 38, line 18.

After “... the chord of the upper wing surface”, add the following phrase : “Thus, in the specific case of ATR 42 / 72 aircraft, the design of de-icers is such that their use is required as soon as ice accretion begins, even if has not yet accreted”.

p.40, line 6 or new p.42, line 15.

Foot note 33 : Different definitions of freezing drizzle and freezing rain are provided in this Report, certainly by several writers without any final check. Currently, only one definition of these phenomena is internationally agreed : drizzle drop sizes are between 50 and 500 μm and rain drop sizes above 500 μm .

p. 40, line 18.

Add : “However this Special Condition B6 was included in JAR 25 as NPA 25D219 in 1991”.

p. 44, lines 4-5.

This sentence as written makes no sense. The BEA requests that this sentence be deleted and replaced with the following sentence extracted from the NTSB Performance Group memorandum dated December 2, 1994, which is more accurate :

“The coverage of the certification envelope was, however, described by the NASA / FAA group members as typical to above-average for a turboprop certification effort given the apparent difficulty in finding natural icing conditions in certain areas of the certification envelope”.

p. 47, line 9.

“... Unacceptable . . .” is a term suggesting an analysis and must be deleted. In the factual section “control anomalies” is sufficient in itself.

p. 47, line 17.

It is wrong to write “weather observed in the area”. There were only later limited testimonies on the ground (Lowell airfield, car driver at Demotte) and from aircraft (B727 KIWI 17 and 24...).

p. 47, lines 18-19.

Regarding droplets and drops “in the size range of about 40 to 400 μm ”. there is neither factual information nor objective study which allows determination of such sizes. It is an assumption that must be deleted in the factual section, to be reported in the analysis section.

p. 49, lines 7 to 10

This paragraph is badly and insidiously elaborated (factual section!). [t should be modified as follows : “The original certification test program did not include an evaluation of airplane characteristics with asymmetrical ice shapes since such an evaluation is not standard practice”,

p.57, line 2

1.7 Meteorological Information,

The BEA Contributive Study to the NTSB Report attached to the BEA Extended Comments is based on the all available weather and pertinent factual information. It is more detailed and accurate in terms of concrete arguments than the NTSB “Meteorological information” chapter hereafter elaborated. (Ref. BEA Extended Comments, para., 1.6.).

p.69, line 6 or new p.73, line 3

After “... KLOT radar site” add : “. . but it is only reliable for this area located in the cold air mass to the west of the cold front”.

(Ref. BEA Study of Meteorological information as a Contribution to the NTSB Report, para. 1.6).

p.71, line 5

In fact this altitude of 17,000 feet is the lower value determined by both the NTSB and the BEA using the Mc Idas computer. This determination included some uncertainty about cloud top temperature between - 13°C and - 16°C which corresponded to an altitude of 17,000 feet to 19,000 feet (Ref. BEA Study of Meteorological Information as a Contribution to the NTSB Report, paragraph, p.).

p.71, line 6

After “. . . generated by windshear”, add this phrase : “These Kelvin - Helmholtz waves did not correspond to the 10,000 feet layer, therefore did not have any influence on the water drops coalescence process in the area which the N401AM was flying “.

(Ref. BEA Study of Meteorological Information as a Contribution to the NTSB Report, paragraph, 1.6)

p.78, line 6 or new p.82, lines 8-9.

After “... 0.3 to 0.7 grams per cubic meter” add : “adding that this content did not include freezing precipitation falling from the cloud layer above the level the N401AM was flying at”. (Ref. BEA Study of Meteorological, information, para., 1.6).

p.78, lines 15 to 18 or new p.82, lines 17 to 20

Contradiction with the footnote 33 p 40 (on new p.42). In fact this one corresponds to the International Definition.

p.79, line 1.

After “... aft of the protected surfaces”, add “and everywhere on the aircraft”.

p.86, lines 12 to 14.

The BEA reiterates its requirement for an accurate description of how CVR transcription was performed by modifying the text as follows, in order to provide an accurate record :

“The CVR group, consisting of representatives from the parties to the investigation, collectively transcribed the tape in its entirety, directly on a micro-computer, and had the opportunity to review the end product only by displaying through the computer screen. The NTSB took alone the decision to publish the public CVR transcript (Exhibit 12A) in an edited version, after editing sections which the NTSB considered as “non-aviation related conversation or non pertinent conversation”. CVR group members were not consulted upon the reasons for editing in this manner.

p.87, line 13

From the January 23, 1996 version of DFDR analysis, it seems that the *last seconds of operational data were recovered*.

P.100, line 13.

The BEA recommends the following modification to the wording to provide a more factual information : replace “at low AOAs” by “at lower AOAs than expected”.

p.102, line 21

The BEA strongly believes that the last NTSB statement will be misinterpreted unless it is presented in the proper historical context and that the NTSB should incorporate the following statement which accurately reflects the state of icing knowledge prior to, and after, the Edwards Flight Tests :

“However, prior to full scale icing tanker flight tests conducted at Edwards Air Force Base, there was no theoretical or experimental evidence available to ATR or to the aviation community, to suggest that an increase in the severity of the ice accretion contamination on a airfoil could tend to lower the AOA at which the aileron hinge moment shift occurs so far below the certified icing SPS AOA thresholds. It was only after the Edwards Flight Tests that experimental evidence became available which demonstrated that this was possible”.

p.103, line 2.

1.16.2 Previous ATR 42 and 72 Icing Events.

In this section, the Aviation Safety Division of the NTSB :

- veiled some essential facts about investigations led by the NTSB with the participation of French Authorities or conducted by the French Authorities in case of incidents that occurred abroad outside the USA,
- suspected the FAA, the DGAC and the BEA of laxism,
- omitted to admit that the Aviation Safety Division did not investigate an incident and failed to provide some resulting information of other incidents to the French Authorities.

The BEA firmly requires that the truth be re-established.

p.103, line 9

The NTSB's statement is not fully supported by factual meteorological evidence. The following text should be modified since it represents a more factual description of the weather conditions :

"... following 5 occurred in weather conditions well outside of Appendix C conditions and in 2 occasions at least consistent with freezing rain conditions, and . . .".

p.104, lines 10 to 12.

The BEA does not that this summary does not convey complete information of the effect of propellers being operated at 77 percent rather than the required 86 percent. The Engineering Division possessed this complete information and should have provided it in the final NTSB Report.

p. 104, lines 24-25 and p.105, line 1

The BEA considers the NTSB statement to be outrageous and absolutely wrong. The NTSB veiled and hid the active participation of the FAA, the BEA, the DGAC and ATR in the investigation between December 1988 and March 1990, and especially meetings held on behalf of the NTSB in Chicago in February 1989 and in Washington (final meeting) in March 1990.

p.107, lines 22 to 25.

Immediately after the incident, the Simmons Airlines Systems Manager reported the event to ATR in a fax dated 12.22.88 indicating that Anti-icing (Level 3) de-icing and all systems functioning normal by at the time of the incident. However it is now confirmed that the level 3 (de-icing) system was OFF.

It is worth indicating that the ATR analysis, based upon the earlier info, assumed that level 3 was on hence the proposed mechanism with a ridge of ice accreting aft of the boots. The ATR analysis should be reconstructed with the latest information which significantly changed the ice accretion pattern and therefore its impact on air flow separation.

This further differentiates A/C 91 from A/C 401 flight in freezing rain with de-icing system off is a combination of rare occurrence.

p. 109, line 1 and following.

To present a balanced report, the BEA recommends that extract from another ALPA letter dated 30 Nov 89 be inserted since it indicates quite an opposite judgment on the ATR attitude towards operation in icing conditions.

The BEA would also like to draw the attention of the Board Members that both in Scandinavia, over the North Sea and adjacent Countries and in Canada, no ATR aircraft icing related incidents were reported and that serious incidents only occurred in the USA.

p.109, lines 24-25.

As in page 104 - 105, the BEA is extremely disappointed that the NTSB does not mention the investigation led by the BEA and the DGAC for the Mauritius Authorities.

p.111, lines 14-15.

The BEA is outraged by the NTSB 's refusal to take into account this other investigation led by both the BEA and the DGAC on behalf and with the Irish Authorities.

(Ref. BEA Extended Comments, para. 1.8.1).

p.114, line 23 to 25.

The NTSB states that the investigation “was commenced on March 5, 1993”, but omits to mention that it did not provide any information to be BEA before October 1995. Moreover, the NTSB only mentions the ASRS report, unknown at that date the BEA, the DGAC and ATR. Thus the BEA requires that the following more accurate information be inserted :

“The pilots of the Continental Express flight provided an early pilot report which was corrected later by the following ASRS, report dated 16.3.94 regarding the events.

p.115, line 2.

The BEA requests that the first full pilot statement be reproduced in order not to eliminate a relevant information ;

Add after “area” :

“... area and complicated by the cruise prop RPM setting rather than icing prop RPM setting. A combination of workload and fatigue probably caused me to miss properly setting the correct icing RPM when we entered icing conditions”.

p.116, line 2

The following more accurate information should be inserted :

“concluded in its “Preliminary Report” dated March 25, 1993 and based upon the early pilot report that”.

p.116, line 3

Moreover, foot note 56 refers to “the only report produced by ATR”.

The Aviation Safety Division ignores the fact that it provided no information, not even factual information, about this Newark Incident.

Therefore, the BEA respectfully asks the Board Members whether the Aviation Safety Division usually waits for a preliminary analysis by the Manufacturer (even though the NTSB does not provide any information) before the NTSB conducts its own investigation without concluding on a probable cause, as of May 1996.

(Ref. BEA Extended Comments, para., p).

p.117, line 2 to 4

Exactly ! But this wording, according to its meaning, is very simplistic and poorly presented and unsubtle.

The BEA can only make the same comment as on page 116.

p.119, line 17-23.

The BEA considers that the NTSB statement is contradictory with the factual evidence : information known by the NTSB about some incidents was hidden or veiled from the French Authorities and ATR.

Regarding the last phrase : “The DGAC and FAA did not recommend or require ATR or its operators . . .”, the BEA can only question the behaviour of the NTSB in this matter : what did the NTSB recommend ?

p.120, line 10 to 12

The BAA, fully in line with ICAO Annex 8, § 4.2.3, specifies that the collaboration between the Exporting State (State of Manufacture) and the Importing State (here, the State of Occurrence) is conducted under the authority of the State of Occurrence. The BEA recommend that the NTSB clarify the processus of exchange of information between the different Aeronautical Authorities (NTSB, BEA, FAA, DGAC), the airlines, and the aircraft manufacturer under the BAA,

p.121, lines 18 to 25 and p. 122, lines 1 to 22.

This specific A320 event is irrelevant in the frame of this accident investigation. There are numerous examples of incorrect information and poor communication between NTSB/FAA/US Airlines, and their foreign equivalent to support the proposed finding.

p.124, line 2.

The BEA request that the ATR analysis be properly reported by adding “with airframe de-icing on” after “freezing rain”.

p.126, lines 19-25.

The BEA considers that this statement results from a general knowledge of control surfaces behavior in presence of flow separation and cannot be derived from the a.m. icing tests, as it could be inferred from the current wording, which should be amended.

p.129, lines 13 to 17.

This statement is in contradiction with the official ATR report and should be rewritten as follows :

“In the 104 to 140 MVD tests (outside FAR 25 Appendix C envelope) during which accretion occurred at flaps 15, the subsequent stall maneuver resulted in hinge moment reversals prior to shaker AOA, only when the maneuver was performed at flaps 0”.

p. 129, line 19.

The momentary peak of 77 lbs mentioned is misleading since it resulted from a combination of exaggerated lift asymmetry resulting from the partial wing pollution behind the tanker, and from the large 20 lbs initial out of trim clearly revealed by the DFDR traces. Hence BEA request that this clarification is added to the original wording.

p.144, lines 9-10.

The BEA requests this wording be modified in order that the NTSB takes into account that :

In complement to ATR generated “All Operators Telexes” specifically covering incidents, ATR incorporated Briefs concerning all other incidents in their Monthly Reports addressed to all operators and Airworthiness Authorities. These briefs report all of the significant technical incidents that have occurred during the corresponding period.

p.145, lines 2 to 5.

The BEA's investigation of the ATR training center simulator software packages revealed that a more representative icing encounter simulation is available to compensate for the lack of external environmental representations. Refer to section 1.5.1 of this document for more details. This ultimate refinement is available for installation on all simulators. The NTSB's statement is unduly critical and does not take into account the associated instructor comments. Furthermore, this NTSB statement is not coherent with the NTSB's statement on page 37 line 17.

p. 145, lines 9-20

This factual information is very attractive but it is surprising that it is not used in the Analysis Section of the NTSB Report.

p. 147, lines 16-17

The BEA strongly disagrees with this NTSB statement :

Holding at 10,000 feet in icing condition and even more so when these conditions refer to moderate to severe icing condition constitutes a critical phase of flight during which the sterile cockpit rule applies. The BEA position is strongly supported by the further NTSB own recommendation to AMR to encourage the pilot to observe the sterile cockpit rule in icing conditions, and to the FAA to enforce this application.

p.153, line 2

The BEA checked the content of this brochure edited in 1992 and the word "freezing drizzle" does not appear.

p.159, lines 7 - 8.

The BEA considers this NTSB statement unfair, particularly since ATR specifically pointed out during the Technical Review Meeting that data or algorithms for training simulators were continuously updated on the basis of acquired knowledge resulting from analysis of in-service reported incidents. The corresponding training software is incorporated in the Toulouse ATR simulator and is made available to other training centers. The BEA independently checkoff that the roll anomaly upset detected in the Mosinee incident was properly incorporated into ATR's simulator software by mid June 1990, and that Flight Safety International's (FSI) Houston Center Simulator had been updated with this information in 1990 as well.

Refer to section 1.5 of this document. It is very likely that the accident crew was trained using this updated software which included the following two flight characteristics of the Mosinee incident i.e., a marked asymmetrical stall and roll control heaviness.

p. 159, lines 13 to 15.

The BEA absolutely insists that this section be deleted in its entirety, as agreed in NTSB TRM. During the Technical Review Meeting, Gilbert Defer specifically informed the NTSB that this testimony in the Hearing had been taken out of context and that the NTSB was not accurately reporting his testimony.

2. ANALYSIS

The BEA generally does not disagree with the Recommendations proposed in this Report. However, it sees little connection between those Recommendations and the Report's Probable cause,

This Probable Cause is developed through an highly selective analysis of the ATR aircraft characteristics, and of the relationship between the DGAC, the FAA and ATR.

This results in very different perceptions of this accident leading to discordant conclusions.

The BEA did undertake a conscientious effort to study the current draft Analysis section and to list all the necessary observations, corrections, and detailed commentaries required to address its many deficiencies. Under such circumstances, considering that the result would be an unusable document, it is more appropriate for the BEA to submit its Annex 13 Comments on the Analysis of this accident in the form of a revised and corrected Analysis which is presented in the following sections.

2.1. METEOROLOGICAL FACTORS

The icing conditions in which the flight 4184 was operating do not appear to be exceptional in terms of meteorological conditions, considering the results highlighted by the present study. The conditions were light to moderate icing, since the flight was taking place in a stable cloud layer at negative temperatures, close to 0°C. **These moderate icing conditions, conducive to ice accretion, were seriously aggravated by liquid precipitation (supercooled drops of rain or drizzle) generated in this layer or originating in an upper layer,** This explanation can be considered to be typical of a meteorological forecast lacking in detail, such as the AIRMET broadcast's summary concern with icing conditions. **The excessive duration of the flight in such conditions, with no recorded comments (as shown by the CVR transcript) on the severity of the icing, nor any upon the procedures to be applied in the conditions, seems incomprehensible on the part of the flightcrew.**

Another major element is the domain of aircraft certification in icing conditions. The reference is appendix C of JAR - JAR 25 regulation, which sets the certification limits. This regulation does not consider the existence of supercooled droplets or drops having a diameter over 40µm (continuous maximum atmospheric icing conditions) with a liquid water content over 0.8 g/m³ in the cloud layer nor the case of freezing drizzle or freezing rain.

Thus the BEA's study points up the following five findings :

1. According to the content of the flight release, the crew was aware of the existence of light to moderate icing on the Indianapolis - Chicago route at the levels at which they were flying.
2. In an available AIRMET, valid before and for the flight, rainfall was forecast at the altitude of Flight 4184 with negative air temperatures.
3. Precipitation was detectable on the airborne radar on WX position.
4. The flight in the holding pattern lasted over 30 minutes in a cloudy atmosphere with liquid precipitation and at a SAT varying between -2 and -4°C. This was in complete contradiction with the limits specified in the certification and operational procedures.
5. Procedures relative to flights in icing conditions, specifically those related to the surveillance of environment, static temperature, ice indicators, and detectors, as well as some visual cues, were not respected by the flightcrew. In addition, standard procedures relating to propellor speed adjustment and anti-icing and de-icing system activation in icing conditions were not properly applied.

In conclusion, overall crew vigilance and awareness did not correspond to the basic rules to be applied on such a flight, occurring in icing conditions conducive to ice accretion.

2.2. HISTORY OF FLIGHT

2.2.1. HOLDING TECHNIQUE

The holding pattern is flown with Auto-Pilot in the Altitude-Hold Mode. Under these conditions, the airspeed must be maintained by manual adjustment of the engine torque. It is observed that throughout the entire holding patterns the number of these adjustments is very limited. As a consequence, airspeed variations of more than 10 knots are noticed during each holding turn, leading the airspeed to decay marginally below the minimum authorized speed (V_m HBO-icing) which was computed at 165 Kt for this holding.

Utilization of higher holding speeds, which could have been authorized by the Air Traffic Controller, would have minimized the crew's feeling related to the aircraft "wallowing in the air", even during the phases where airspeed was reduced as the result of their limited power adjustments. This higher holding speed would have precluded the flight crew's ad hoc decision to use a different flap setting than the one provided for in the aircraft manuals and which was initially selected by the crew. This would have increased the safety margin with the minimum authorized speed while eliminating the risk of inadvertently reaching the maximum authorized speed limit.

The flight path of the aircraft is controlled laterally by modification of the bank angle, through selection of either of the High Bank or Low Bank options of the Auto-Pilot. Analysis of the resulting trajectory indicates that pilot selection was adequate.

2.2.2 ANALYSIS OF HOLDING PATTERN SEQUENCES

• Meteorological Conditions

During the hold, Flight 4184 was operated in and out of clouds with liquid water content (LWC), between 0,3/ 0,7 g/m³, in temperatures close to freezing, with freezing precipitation (with a high content of large supercooled droplet MVD > 100 µm) conducive to what is now referred to as “freezing drizzle” resulting in moderate to severe icing conditions.

. Description of Holding Conditions

The holding conditions imposed by the ATC and accepted by the crew were characterized by :

- a repeatedly extended period of holding, which progressed from a “bit of holding” to 15 minutes, then 30 minutes then 45 minutes.
- Flight level at 10000 ft, close to freezing level (SAT) and speed of 175 kt.

Four successive holding patterns of approximately 9 minutes each, were conducted in an isolated stack.

- The ATC monitoring of the Flight 4184 holding conditions was characterized by a lack of attentiveness.

• Holding Technique

The first holding pattern was conducted at 175 kt at Flap 0°, Propeller NP set at 77%, airframe de-icing (Level III) OFF. The resulting AOA was approximately 6°.

•The subsequent holding patterns were conducted at 175 kt, with 10 to 15 kt speed decay during each turn due to limited torque corrections, at Flap 15, propeller NP at 77%. The NP setting was changed to 86% when the second AAS single chime was triggered and after airframe de-icing system(Level III) was selected. During the Flaps 15 phase the resulting AOA was slightly negative.

This phase ends at 15.57.33 during the descent to 8000 ft, with the sounding of the V_{FE} overspeed signal.

€ Accretion mechanism

These events resulted in a two phase ice accretion mechanism during the hold :

- a first phase of approximately 10 minutes, with Flap 0, where ice accreted with a positive AOA, airframe de-icing system OFF, propeller NP at 77% (the required 86% was not used although in icing conditions).

- a second phase, with Flap 15 (negative AOA), with 8 minutes with Level III OFF, NP 77%, 86% still not respected in icing conditions, followed by 16 minutes with Level III activated, NP at 86%.

€ Due to the nature of the icing conditions (SCLD, freezing drizzle), the resulting intermittent ice accretion covered the leading edge, as well as aft of the de-icing boots on the lower surface of the wing during the Flap 0° phase (positive AOA) and the upper surface of the wing during the Flap 15° phase (negative AOA).

€ At 15:41, the airframe Level III de-icing eliminated the leading edge accretion, but some residual accretions were present on both upper and lower surfaces of the wing aft of the de-icing boots.

During the subsequent phase of accretion at Flap 15° (negative AOA) this residual ice accretion beyond the boot active area probably became a good collector of incoming water drops, resulting in the formation of a unique ice ridge aft of the boot on the upper surface of the wing.

• The Roll Upset

At the V_{FE} overspeed signal, the crew retracted the flaps which resulted in a progressive increase of AOA.

At the critical value (4,8°) a flow separation initiated aft of the ridge and at the trailing edge of the outer wings and progressively developed. This resulted in a right wing down tendency, initially controlled by the Auto Pilot until it disconnected when the full development of the flow separation triggered the hinge moment reversal and the subsequent aileron deflection up to its stop.

2.2.3. FLIGHT CREW PERFORMANCE

The BEA strongly believes that the NTSB's highly edited CVR transcript contains significant information regarding crew performance issues which could provide important safety lessons to all flight crews so that the chain of events involved in this accident can be avoided thus preventing the recurrence of other accidents in the future. The BEA believes that the NTSB should take this opportunity to squarely address these issues with the goal of improving aviation safety.

The NTSB's lack to timely address these issues following this accident is particularly disturbing. The poor cockpit discipline, lack of cockpit resource management, and lack of situational awareness involved in this accident created an obligation on the part of the NTSB to address such safety issues to prevent their reoccurrence. The BEA's concern in this regard has been confirmed by the recent announcement by the FAA that it has initiated an in-depth review and analysis of flight crew training programs.

The cockpit atmosphere lacked the conservative and attentive nature to detail which is required when operating a commercial aircraft. Indeed, the CVR transcript is replete with "non-essential communications" and activities which denote a lack of professionalism and crew coordination by the crew. Such conduct is particularly unacceptable when the aircraft is being operated in an acknowledged icing environment. Complacency replaced vigilance and social discourse replaced proactive safety awareness and sound operational procedures which could have, prevented this accident.

Flight Crew task allocation between Captain and First Officer as defined by the Airplane Operating Manual is mandatory :

- the Flying Pilot, flies the Airplane,
- the Non-Flying Pilot, is in charge of Communication and Navigations,

The BEA provides its additional Annex 13 comments regarding the performance of Flight 4184's flight crew below.

2.2.3.1. COCKPIT RESOURCE MANAGEMENT

As a preliminary matter, the BEA notes that the *American Eagle's Crew Resource Management* publication, adapted from American Airlines, outlines the training program utilized by American Eagle/Simmons in respect to training its flight crews for *Techniques for Effective Crew Coordination*. (NTSB Exhibit 2-E). The BEA has provided some text of this publication in Section 1.11 *Additional Pertinent Documentation*. The BEA has also mentioned Advisory Circular No. 120-51A (NTSB Exhibit No. 2D) entitled *Crew Resource Management Training* which also provides guidance in respect to assessing the Crew Resource Management (CRM) issues involving this accident. Appendix 1 of AC No. 120-51A provides "Crew Performance Marker Clusters" which can be utilized to assess the performance of flight crews.

The BEA recommends that the NTSB conduct a thorough review of the actions of Flight 4184's flight crew in the context of these "marker clusters".

As discussed in the comments below, the BEA believes that the actions of Flight 4184's flight crew violated American Eagle/Simmons' policies regarding cockpit resource management because the flight crew did not exhibit proper and effective crew coordination procedures or cockpit resource management techniques.

2.2.3.2. THE FLIGHT CREW'S USE OF FLAPS 15 WAS NOT PROVIDED FOR BY THE ATR AIRPLANE OPERATING MANUAL

American Eagle/Simmons Operating Manual (AOM), ATR's Flight Crew Operating Manual (FCOM), and the applicable performance charts for holding do not provide for the use of a Flap 15 degree configuration in holding. The flight crew's use of a Flap 15 configuration inducing an AOA of approximately 0 degrees while holding in icing conditions created the critical ice ridge beyond the de-icing boots which ultimately led to the roll upset when the Flaps were retracted from 15 to 0 degrees with an AOA increasing to 5.6 degrees and thereby directly contributed to the accident.

2.2.3.3. THE STERILE COCKPIT RULE WAS APPLICABLE TO FLIGHT 4184 WHILE HOLDING AT LUCIT INTERSECTION

Section 4, para. 90 and 91 of American Eagle's Flight Manual entitled *Nonessential duties during critical phases of flight (Sterile Cockpit] (FAR 121. 542)* and *Sterile Cockpit Definition*, respectively, set forth the policy of American Eagle/Simmons in respect to the Sterile Cockpit Rule. The BEA has provided text of these critical documents in Section 1.11 *Additional Pertinent Documentation*. The BEA has also set forth in this Section the complete text of Federal Aviation Regulation 14 CFR § 121.542 *Flight Crewmember Duties*.

The FAA's original NPRM (Notice of Proposed Rulemaking) confirms that the intent of the sterile cockpit rule was to specifically address situations such as those which occurred in this accident. In this regard, the NPRM published in the Federal Register on 28 August 1980 makes clear that the Sterile Cockpit Rule was proposed by the FAA with the intent of eliminating "distractions caused by flight crewmember performance of duties and activities unnecessary for the safe operation of aircraft ."

The FAA's review of data from NASA and the ASRS (Aviation Safety Reporting System) revealed numerous examples of this problem. Significantly, the FAA identified a "third major category of distractions" which involved "unnecessary communications between the flight crew and cabin crew. "

To the extent that the NTSB relies upon the testimony of the FAA during the NTSB Public Hearing to suggest that Flight 4184 was not operating in a “critical phase of flight”, the BEA strongly disagrees. The BEA questions the relevance of the FAA witness whether he was authorized by the FAA, to make a determination as to whether Flight 4184 was operating in a “critical phase of flight” within the meaning of CFR Section 121.542. Based upon an analysis of all available information regarding this accident, the last thirty (30) minutes of Flight 4184 was clearly a “critical phase of flight” within the meaning of American Eagle’s Flight Manual as well as FAR 121.542. The factors which clearly demonstrate that Flight 4184 was operating in a “critical phase of flight” are as follows :

1. Flight 4184 was a FAR Part 121 air carrier flight.
2. Although the “critical phase of flight” as defined in FAR 121.542 “includes . . . all other flight operations conducted below 10,000 feet, except cruise flight”, the regulation does **not** exclude flight operations conducted at 10,000 feet or above. Indeed, it would be irrational and counter to safety of flight to suggest that a “critical phase of flight” could not occur at or above 10,000. Depending upon the circumstances, a “critical phase of flight” can occur at **any** altitude. This was confirmed by American Airlines recent policy change which now requires that American’s flight crews observe “sterile cockpit” procedures i.e., no extraneous conversation, below 25,000 feet when operating in Latin America, rather than 10,000 feet.

3. Flight 4184 was **not** operating in cruise flight. Rather, Flight 4184 was operating in a holding pattern which is significantly different than cruise flight. In this regard, air speeds are reduced, fuel consumption is of prime importance, the aircraft is operating at lower altitudes and, there are typically more aircraft operating in the immediate vicinity. In addition, when an aircraft is operating in a holding pattern, the flight crew experiences an increased workload which requires more crew coordination, crew communication, and situational awareness, particularly when operating in known icing conditions. In this regard, the flight crew must be more attentive to ice accumulation, ATC clearances and traffic alerts, navigational demands are increased, the crew is required to perform more flight planning and, the crew is required to operate the aircraft more.

4. Flight 4184 was operating in icing conditions conducive to ice accretion in precipitation, It is significant that flight 4184 was **not** transiting an area of icing. Rather, Flight 4184 was operating in known icing conditions and was lingering in that environment for a significant period of time. American Eagle/Simmons' policies mandate that flight crews exercise vigilance when operating in icing conditions and that flight crews avoid icing conditions when possible. Further, such crew vigilance was also critical to assure timely detection of potentially hazardous ice accretions and to request ATC for an alternate holding altitude.

5. Flight 4184 was holding in one of the busiest air traffic control areas in the country, if not the world, in preparation for a clearance to perform an instrument approach into Chicago's O'Hare International Airport, which is one of the busiest airports in the world. Constant and careful monitoring of ATC communications is not only mandatory by regulations and company procedures, but is also dictated by basic airmanship when operating in such a high density traffic area.

6. Flight 4184 was waiting for a clearance from Chicago ARTCC to descend below 10,000 feet. Irrespective of the EFC (expect further clearance) time provided by ATC, the clearance to descend below 10,000 feet could have come at any time.

7. American Eagle's AOM states that a critical phase of flight may also include "any other phase of a particular flight as deemed necessary by the Captain."

Based upon these factors, an operational environment existed which established that Flight 4184 was operating in a "critical phase of flight" while holding at LUCIT Intersection. In this case, both the Captain and the First Officer failed to exercise their joint authority and responsibility in not declaring, complying with, and enforcing a sterile cockpit condition. Under the Sterile Cockpit Rule, it is the Captain and/or the First Officer's responsibility to declare a sterile cockpit. In this case, the Captain and the First Officer should have declared that Flight 4184 was entering a "critical phase of flight" and prohibited all activity which could have distracted or interfered with the safe operation of the aircraft.

The edited CVR transcript clearly indicates that Flight 4184's crew violated applicable Federal Aviation Regulations and American Eagle /Simmons' policies and procedures by not mandating and enforcing a sterile cockpit environment while operating in moderate to severe icing conditions in the holding pattern. Instead of exercising proper crew vigilance, cockpit/crew resource management, and situational awareness, the crew was engaged in almost constant non-essential activities and conversations which had no bearing upon the safe and proper operation of the aircraft. The BEA discusses these issues in more detail below.

**2.2.3.4. AMERICAN EAGLE/SIMMONS' POLICIES MANDATE THAT
FLIGHT CREWS EXERCISE CREW VIGILANCE WHEN OPERATING
IN ICING CONDITIONS AND THAT FLIGHT CREWS AVOID ICING
CONDITIONS WHEN POSSIBLE.**

The BEA analysis of Flight 4184 crew proper decision making is made in reference to the criteria established by the NTSB, presented in section 1.11 of this Document, as Primary Error NO 8.

Numerous documents make it clear that American Eagle/Simmons' policies mandated that flight crews exercise vigilance when operating in icing conditions, and that flight crews avoid icing conditions when possible. In this regard, the BEA refers specifically to the following documents :

- (1) the *Simmons Flight Operations News Letter* dated December 1993 (NTSB Exhibit 2T-1, p. 3-4) entitled *Aircraft Ice* ;
- (2) the American Eagle Flight Manual - Part 1, Section 6, Page 8, issued 17 November 1992 (NTSB Exhibit 2-A, p. 48 - attachment "O") which defines various icing conditions, their effect on airplane performance, and the diversion actions to be taken under various icing conditions ;
- (3) the Flight Manual, Part 1 para. 43 *Use of anti- ice/deicing* which provides instructions for flight crews in respect to the use of anti-ice /deicing equipment as an aid in descending or ascending through icing conditions ;
- and 4) the American Eagle Flight Manual [NTSB Exhibit 2-A, p. 79] which specifically states :

... Also, freezing precipitation which tends to flow prior to freezing may flow off the detector prior to freezing, falling to trigger the detector. Yet this same precipitation will flow aft on the wing and freeze creating a potentially dangerous situation. Crew vigilance must be used to detect the formation of ice as soon as possible.

The BEA has provided text of these critical documents in Section 1.4.1 and 1.4.2.

Based upon these documents it is clear that American Eagle/Simmons' policy mandated that flight crews exercise vigilance when operating in icing conditions and that flight crews avoid icing conditions when possible.

There is a little doubt that the icing conditions encountered by Flight 4184 were at least "moderate" and possibly "severe". In this regard, the Edwards flight tests demonstrated that operations in freezing drizzle conditions for a prolonged period of time, as was the case for Flight 4184, causes significant ice accretions to form on the frame of the aircraft's windscreen, cockpit side windows, wiper blades, spinners, and ice detector probe.

In this regard, Captain Jack Walters testified at the NTSB Public Hearing that Simmons' flight crews are trained by American Eagle to look for these specific visual indicators to determine if the airplane is collecting ice.

Proper monitoring of the outside air temperature, precipitation, and the ice accumulating on the aircraft should have informed the crew that they were operating in a freezing precipitation environment. These conditions were likely encountered by Flight 4184 and the flight crew should have requested a different altitude or holding pattern to avoid these icing conditions.

The BEA considers that the crew did not observe the 14 CFR121.561 requirements relative to Pireps.

Finally, it is significant to note that the Airman's Information Manual (AIM) specifically mandates that the crew of Flight 4184 "report icing conditions to ATC/FSS, and if operating IFR, request new routing or altitude if icing will be a hazard. "

Moreover had the crew of Flight 4184 provided ATC with a PIREP of their known icing conditions, it is reasonable to assume that on their request they would have promptly been issued a clearance and would have immediately exited the area, thus avoiding the accident.

2.2.3.5. THE DFDR AND CVR DATA SHOW THAT THE FLIGHT CREW WAS DISTRACTED WHILE MANAGING THE AIRCRAFT'S DE-ICING AND ANTI-ICING EQUIPMENT IN ICING CONDITIONS

The BEA analysis of Flight 4184 crew operation of aircraft Systems is made in reference to criteria established by the NTSB, presented in section 1.11 of this Document, as Primary Error No 7.

There is no issue about the definition of icing conditions.

ATR's AFM provides specific procedures in respect to operation of the ATR-72's anti-icing system (Level II) and de-icing system (Level III). ATR's AFM, Section 3.04 *Procedure for operation in atmospheric icing conditions*, provides that Level II anti-icing systems, which consist of Propeller 1 and 2, Horn 1 and 2, Engine 1 and 2, Side Window and NP 86% minimum, are to be activated when icing conditions exist. These systems must be activated prior to the activation of the Level III De-icing System which consists of the airframe de-icing system (boots) and which are used only when ice starts to actually accrete on the aircraft.

The DFDR data indicates that at 1516:32, the airframe de-icing system was activated. This means that Flight 4184 was probably accreting ice. At 1524:30, the airframe de-icing system was turned off. At 1524:50, twenty seconds later, the flight crew selected NP 77% whilst they still were in icing conditions. According to ATR's AFM and AOM procedures, NP 77% is not to be selected in icing conditions. NP 86% at least, on the other hand, must be utilized when the Level II anti-icing systems are activated. Based upon this information, the BEA suggests that two separate hypotheses are possible in respect to the crew's actions: (1) the remaining components of the Level 11 anti-icing system were de-activated (Engine 1 and 2, Propeller 1 and 2, Horn 1 and 2, and Side Window) at or about the same time the crew selected NP 77%; or (2) the flight crew left the remaining components of the anti-icing system ON.

The BEA has investigated and analyzed prior icing incidents and has found that this had occurred in the past.

At 1528:00, the CVR transcript starts. At 1533:56, the CVR recorded a "single tone similar to a caution alert chime. " The DFDR data and the meteorological conditions, information set forth in the BEA's meteorological study show that between 1523 and 1534, Flight 4184 was intermittently operating in liquid precipitation with a SAT between -2.5 and -4,0 degrees C. During this time period, the flight crew maintained NP 77% and the airframe de-icing was deactivated. This lack of action by the flight crew was in violation of the ATR-72 AFM/AOM. In this regard, the Simmons Airlines Winter Operations Handout also specifically provides :

FLIGHT 4184 - CVR TIME ANALYSIS

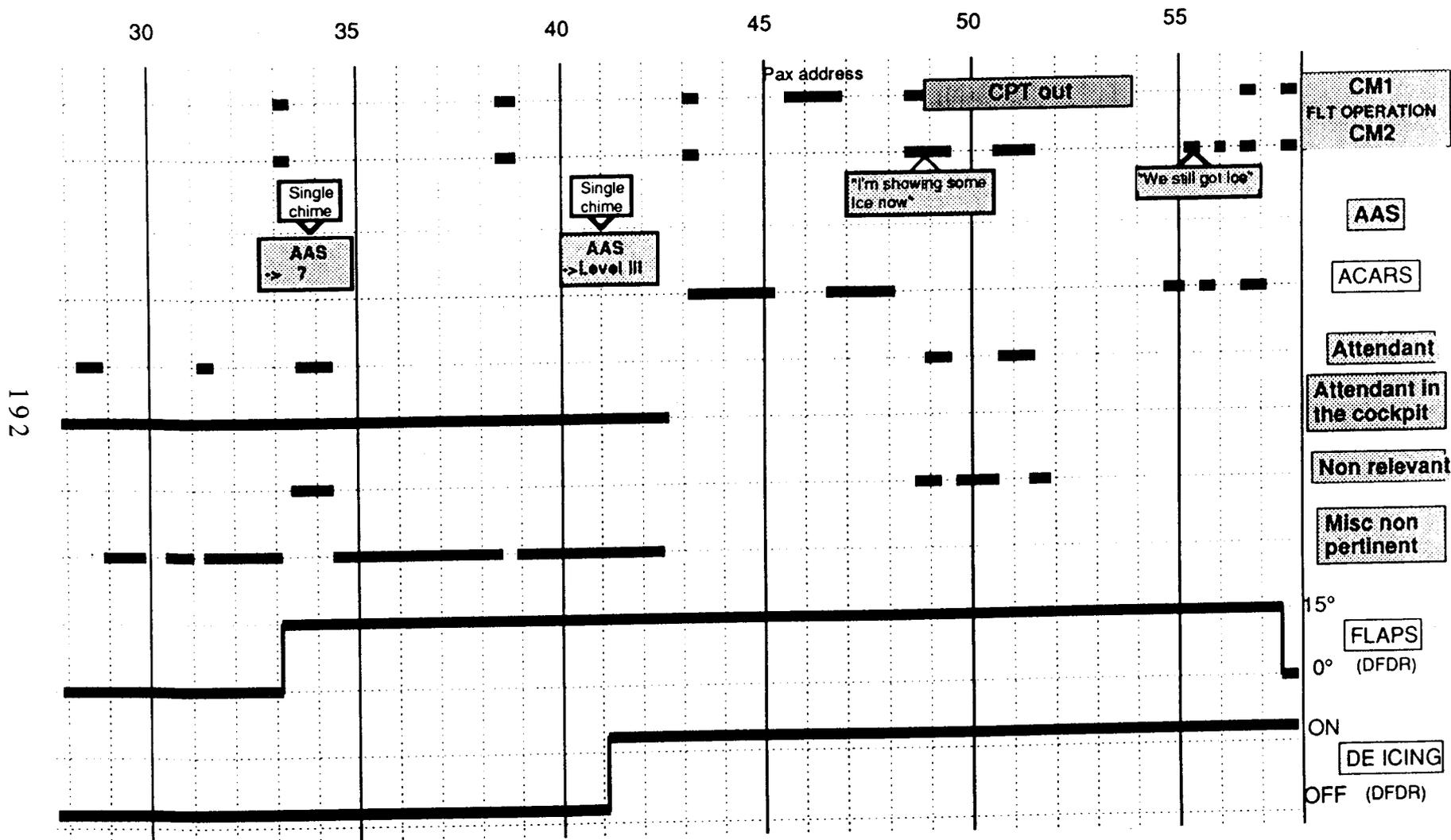


FIGURE 14 : FLIGHT 4184 CVR TIME ANALYSIS

More than 15 mn of Non Relevant & Non Pertinent conversations

Crews are cautioned to remain alert to these conditions and frequently check Static Air Temperature (SAT) indications during cruise and descent. If SAT indications reach a value of 5 degrees C or less, good operating practice would dictate that icing equipment be operated accordingly.

Further, while the aircraft was flying the second northern right turn in the hold, from 1532:30 to 1534:30, a large decrease of 14 kts was recorded on the DFDR. The analysis of this speed reduction indicates that it was caused by the following : turn technique initially conducted at constant torque with a high bank angle representing a large contribution to the speed decay; fluctuating winds with a magnitude of up to 40 kts from the south southwest (210 degrees); ice accretion resulting from icing conditions with freezing precipitation confirmed by the BEA study.

Although it was impossible to accurately evaluate the different individual contributions to the large speed decrease, there is no question that part of this speed decrease was attributable to the ice accretion. The NTSB's own analysis indicates a first small drag increase 24 minutes before the roll upset, at 15.33. Thus, the 1533:56 caution alert chime might have corresponded to the aircraft's ice detector system (AAS), which would have responded within 30 seconds after the first ice accretion began. This view is supported by the fact that during the Edwards AFB flight tests, the AAS system activated the aural icing warning within 30 seconds of encountering the artificial freezing precipitation conditions. Significantly, the 1533:56 caution alert chime was never acknowledged by the flight crew according to both the CVR and the DFDR data.

At 1541:07, a “single tone similar to caution alert chime” sounds. The DFDR data indicates that the flight crew then activated the airframe de-icing system, Two seconds later at 1541:09, the flight crew increased NP from NP 77% to NP 86%. This DFDR data is confirmed by the increased noise which can be heard on the CVR tape.

AT 1542:02, the CVR transcript records “8 clicks” which could have corresponded with the activation of the following anti-icing systems: pushbuttons for Engine 1 and 2, Propeller 1 and 2, Horn 1 and 2, Side Window, and the engine continuous relight knob. However, during the BEA’s investigation, the BEA had the opportunity to participate in two test flights during which the BEA listened and recorded on the CVRs various sounds generated in the cockpit. No clicks were audible on the CVR. Moreover the activation of two push-buttons of the airframe de-icing system is not audible on Flight 4184’s CVR. This suggests that Level II was operating prior to activation of Level III on Flight 4184,

Finally, it is very significant to note that between 1524 and 1541, when the aircraft was not properly configured for flight in icing conditions, the extensive “non-pertinent conversations” between the flight crew and the 1st Female Flight Attendant were occurring in the cockpit. Contrary to the NTSB’s view that these conversations are “non-pertinent”, the fact that these conversations occurred during this critical time period makes them highly pertinent. This is also the same point in time when the NTSB believes that Flight 4184 was experiencing an increase in drag attributable to ice accretion.

2.2.3.6 THE EXTENSIVE “NON-PERTINENT CONVERSATION” BETWEEN THE FLIGHT CREW RAISES SIGNIFICANT SAFETY ISSUES REGARDING CREW INTERACTION AND HOW SUCH INTERACTION CAN IMPACT SAFETY OF FLIGHT.

When the NTSB extensively edited the CVR transcript to delete the “non-pertinent conversations” between the Flight Crew and the Junior Female Flight Attendant, the NTSB deprived itself of an important and unique opportunity to analyze and comment upon male-female crew interactions and how such interactions can interfere with crew vigilance, cockpit procedures and aviation safety. In this regard, the unedited CVR transcript contains significant information which mandates that the NTSB conduct a thorough review and analysis of these issues.

The CVR transcript indicates that when the recording began the sound of “loud music” was being recorded by the Cockpit Area Microphone (CAM), and the Junior Flight Attendant was on the flight deck and remained in the cockpit for the following approximately 14 minutes. Although the CVR transcript is highly edited, both the edited and the transcribed conversations make it clear that the Junior Flight Attendant was involved in an extensive conversation with the Flight Crew. This discussion involved comments by the Flight Attendant as to how easy the flight crew’s job was, how much she liked dealing with the passengers and, the length of the delay in arriving in Chicago. During this same period, the extensive conversations between the Captain, First Officer, and the Flight Attendant consisted of irrelevant and gratuitous demonstrations for the Flight Attendant regarding the functioning of various airplane systems such as the glide slope “pull-up” aural warning and the Ground Proximity aural “terrain” warning.

It is highly significant that during this 14 minute period (1528:00 - 1542:38), 11:14 minutes of conversation between the 1st Female Flight Attendant and the flight crew were not transcribed but simply characterized by the NTSB as “non-pertinent pilot and flight attendant conversation continues”. Again, **the fact that these extensive conversations are considered by the NTSB to be “non-pertinent” conversations which do “not directly concern the operation, control or condition of the aircraft” makes them highly pertinent.**

As discussed above, Part 1 of American Eagle’s Flight Manual prohibits “non-essential conversations within the cockpit and non-essential communications between the cabin and cockpit crews” during a “critical phase of flight”. Similarly, FAR 121. 542(b) prohibits this kind of conduct because “non-essential communications between the cabin and cockpit crews” are “not required for the safe operation of the aircraft, ” These “non-essential conversations” directly contributed to the flight crews lack of vigilance in respect to monitoring and deviating from the known icing conditions the aircraft was holding in. A prudent flight crew, devoting their full attention to the operation of the aircraft instead of carrying on long non-pertinent, non-safety related discussions with flight attendants and other irrelevant conversations, would have carefully monitored the known icing conditions, monitored existing weather information, and analyzed the changing atmospheric conditions which had been deteriorating to assess its potential impact upon the safety of their flight.

2.2.3.7. THE CREW DID NOT EXERCISE PROPER COCKPIT RESOURCE MANAGEMENT TECHNIQUES OR CREW DISCIPLINE IN RESPECT TO MANAGING THE WORKLOAD OF THE FLIGHT

The BEA analysis of Flight 4184 Crew Resource Management refers to criteria established by the NTSB, presented in Section 1.11 of this Document, as Primary Error No 5.

The NTSB's CVR transcript, even in its edited form, clearly demonstrates that the flight crew did not exercise proper resource management techniques in respect to sharing the workload of the flight particularly in known icing condition. In addition to the extensive "non-pertinent conversations" between the Captain and the Junior Female Flight Attendant which are discussed above, it is very important to note that between 1549:05, (when the CVR recorded the "sound of ding along similar to flight attendant call bell"), and 1552:00, the First Officer was completely preoccupied with at least two, and possibly three separate intercom conversations with the Junior Female Flight Attendant, the Senior Female Flight Attendant, and the Captain, which had no bearing on the operation of the aircraft.

The First Officer was alone in the cockpit throughout this entire period of time with complete responsibility for handling the entire workload of the flight. In addition to his extensive conversations on the intercom, the First Officer was also attempting to fly the aircraft, stay within the holding pattern, adjust the bank angle on the autopilot, monitor ATC, receive ACARS messages, etc. This situation increased the First Officer's workload dramatically and clearly represents substandard crew resource management and task sharing techniques. Finally, and most importantly, the First Officer's increased workload severely diminished his ability to carefully monitor the known icing conditions the aircraft was holding in.

2.2.3.8. THE CAPTAIN LEFT THE COCKPIT AFTER ICING WAS OBSERVED, AND THE FLIGHT CREW FAILED TO EXERCISE PROPER SITUATIONAL AWARENESS AND COCKPIT RESOURCE MANAGEMENT TECHNIQUES IN RESPECT TO RESPONDING TO THE ICING CONDITIONS

Without ignoring the physiological needs, it was not appropriate for the Captain to leave the cockpit. As discussed above, there were numerous factors which clearly indicated that Flight 4184 was operating in a "critical phase of flight" which mandated that the Captain declare a sterile cockpit condition. These same factors also mandated that the Captain remain in the cockpit. By leaving the cockpit, the Captain increased the First Officer's work load dramatically. This was particularly inappropriate given the fact that the aircraft was operating in moderate to severe icing conditions.

As discussed above, the DFDR data indicates that at 1516:32, the airframe de-icing system was activated for the first time by the flight crew. Thus, it is clear that Flight 4184 had been operating in icing conditions intermittently for at least 32 minutes when the Captain left the cockpit at 1549:07. The Captain was subsequently absent from flight deck for 5:25 minutes. During this time he engaged in a “non-essential conversation” which had no bearing on the safe operation of the aircraft.

The Captain returned to the cockpit at 1554:13, approximately two minutes later. Approximately one and one half minutes after the Captain returned to the flight deck, the Co- Pilot stated “we still got ice” at 15:42. The Captain did not acknowledge this comment. Based upon the foregoing, it is clear that the Captain was not exercising proper situational awareness or proper vigilance in respect to monitoring the icing conditions.

By leaving the cockpit, the Captain also deprived himself of any opportunity to monitor and request a clearance to deviate from the icing conditions. At no time while the Captain was at the back of the aircraft on the intercom with the Co-Pilot or, when he returned to the cockpit, did the Captain inquire about the icing conditions.

Further, there is no indication that the Captain observed the aircraft’s propeller spinners or any other visible part of the airframe for ice accretion while he was walking back and forth through the aircraft cabin. The Captain’s lack of vigilance in this regard was directly contrary to American Eagle/Simmons’ policies discussed above.

It is very significant that there is no evidence on the CVR transcript that the flight crew discussed the operation of the aircraft's deicing and anti-icing equipment or, that they monitored or discussed the type of ice accumulation or ice accretion rate. Further, there is no evidence that the crew notified ATC that they had encountered icing conditions or, considered giving ATC the Pirep required by Simmons's policies or that they discussed any alternative altitude, holding pattern or route to exit the icing conditions.

In this regard, the FAA Principle Operations Inspector (POI) for Simmons Airlines testified at the NTSB Public Hearing and responded to questions regarding various flight related functions perform by the crew of Flight 4184. The POI stated that given the environment in which Flight 4184 was operating in, “. . . I think I would expected more exchange [verbal communication] between the First Officer and the Captain about the amount - that the ice was there . . .”

Finally, by leaving the cockpit, the Captain completely lost what little situational awareness he had regarding the operation of the flight. In this regard, it is significant to note that at 1557:16.3, approximately 4 minutes after he returned to the cockpit, and 12 seconds before the autopilot disconnected, the Captain asked the First Officer: “are we out of the hold ?“

In sum, the flight crew's actions were directly contrary to American Eagle/Simmons' policies, as well as basic professional airmanship, which mandate that flight crews exercise crew vigilance when operating in icing conditions, and that flight crews avoid icing conditions when possible.

2.2.3.8.1. Flight Planning

The flight crew did not discuss nor revise the flight planning when the weather conditions and the holding situation should have caused him to do so.

2.2.3.8.2. The Flight Crew Was Preoccupied With The ACARS System

The flight crew spent a considerable amount of time attempting to operate the ACARS system, which is a non-essential task.

Moreover, operation of the ACARS system, particularly by the First Officer who was flying the aircraft, prevented any proper scanning of the instruments and hampered other essential flight related activities.

This is supported by the FAA Principle Operations Inspector (POI) for Simmons Airlines testimony at the NTSB Public Hearing. The POI, after having reviewed the transcript of the CVR, stated that it was his perception that the crew “probably was” distracted from flight related duties while attempting to send ACARS information during the period, 1548 to 1555. It was also during this period that two references to icing conditions were recorded on the CVR.

2.2.3.8.3. Listening To “Loud” Broadcast Music While In The Holding Pattern Was Not Appropriate

The CVR transcript begins at 1527:59 with “music similar to [a] standard broadcast radio station” emanating from ADF-2 and continues until 1545:48. Of the 31 minutes transcribed in the CVR transcript, broadcast music was playing in the cockpit for over 18 minutes. Further, the CVR transcript indicates at 1528:21, that the music was “loud’.

The flight crew’s use of the ADF radio to listen to “loud” music while in the holding pattern is not promoting vigilance and situational awareness.

2.2.3.8.4. The Flight Crew Did Not Respond To A Traffic Alert and Avoidance System (TCAS) Advisory

The CVR transcript indicates that there was a TCAS alert “traffic, traffic” at 1556:24. However, there is no evidence in the CVR transcript that the crew responded to the TCAS warning. In this regard, there is no discussion between the Captain and Co-Pilot about the warning, what caused the warning or, how they would resolve the conflict. Further, there is no evidence that the crew attempted to contact ATC to determine whether there were any aircraft in the vicinity which could have generated the warning. The flight crew’s lack of acknowledgment of the TCAS alert raises several significant questions in respect to the crew’s resource management, as it refers to the non flying Pilot (the Captain) primary tasks.

2.2.3.9. THE DFDR DATA INDICATE A LACK OF APPROPRIATE CONTROL INPUTS TO RECOVER THE AIRCRAFT AFTER THE ROLL UPSET OCCURRED.

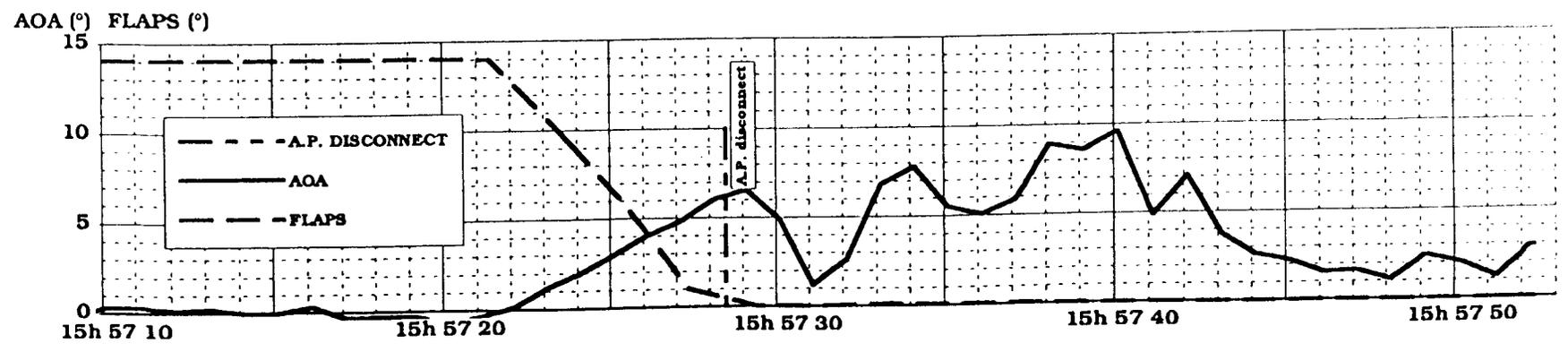
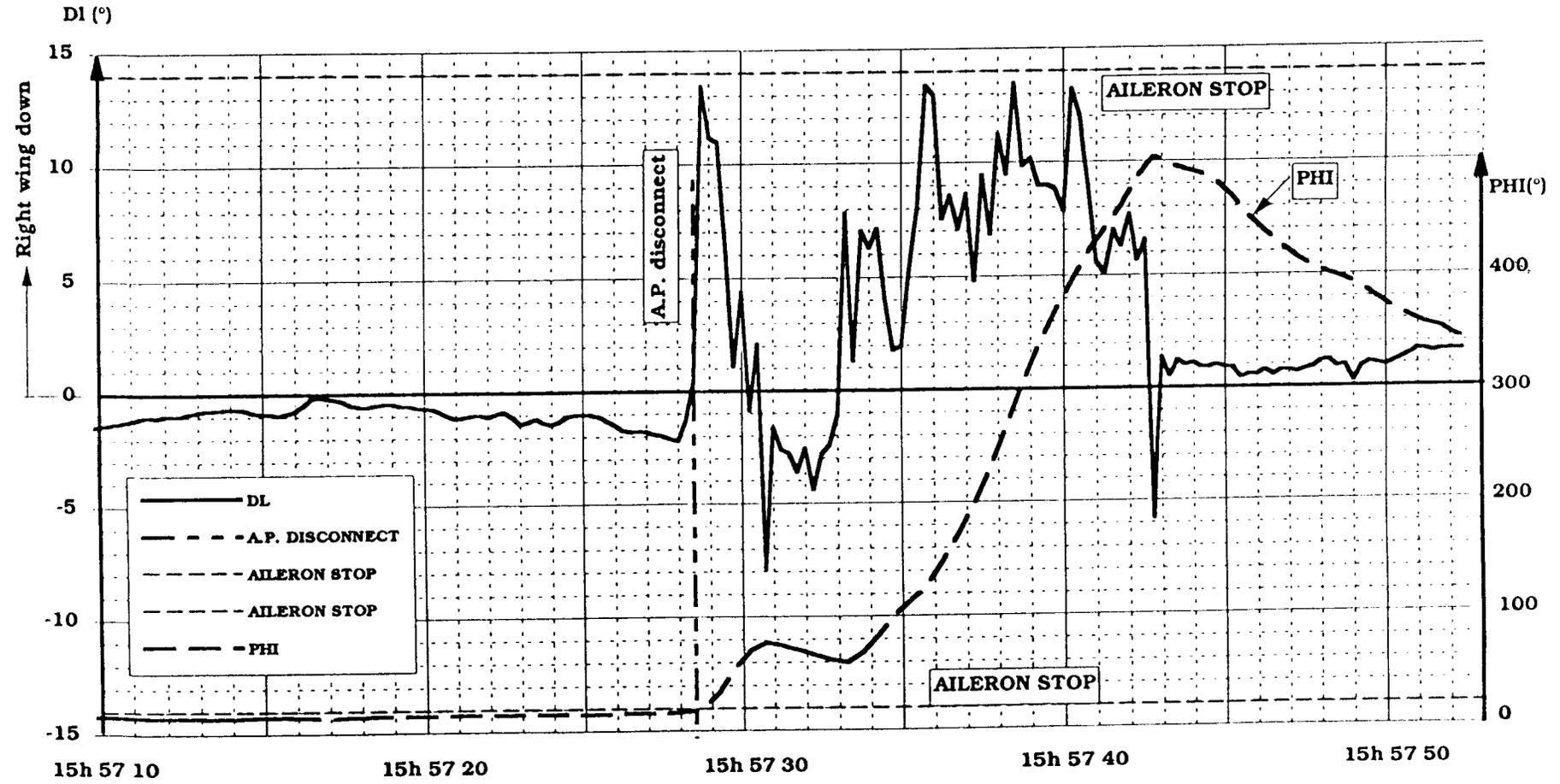
Flight 4184's DFDR data indicates that from the point in time when the autopilot disconnected until the end of the reliable DFDR data there is no obvious indication of the continuous coordinated control inputs which would have been appropriate to counter the roll upset.

From the time of the autopilot disconnection, the DFDR data indicates nine momentary spikes on the pitch axis corresponding to either the Captain's or the First Officer's inputs in excess of 10 daN (22 lbs). However, the elevator deflection momentarily spiked to 8 degrees "nose up" with a mean value of approximately 3 degrees "nose up". During the entire time from the roll initiation, the rudder deflection was erratic and never exceeded 2 degrees. The maximum available rudder deflection was 3.5 degrees. During the same time period, the aileron deflected erratically fluctuating between an 8 degree "left wing down" position and the "right wing down" stop, and returning to the 0 degree position for 6 seconds at 1557:43. During this entire time, the Power Level Angle (PLA) was left at the Flight Idle position.

The last seconds of DFDR data indicate a rapid, large input on the elevator.

FIGURE 15 : ROLL CONTROL INPUTS / ACTIVITY AFTER ROLL UPSET

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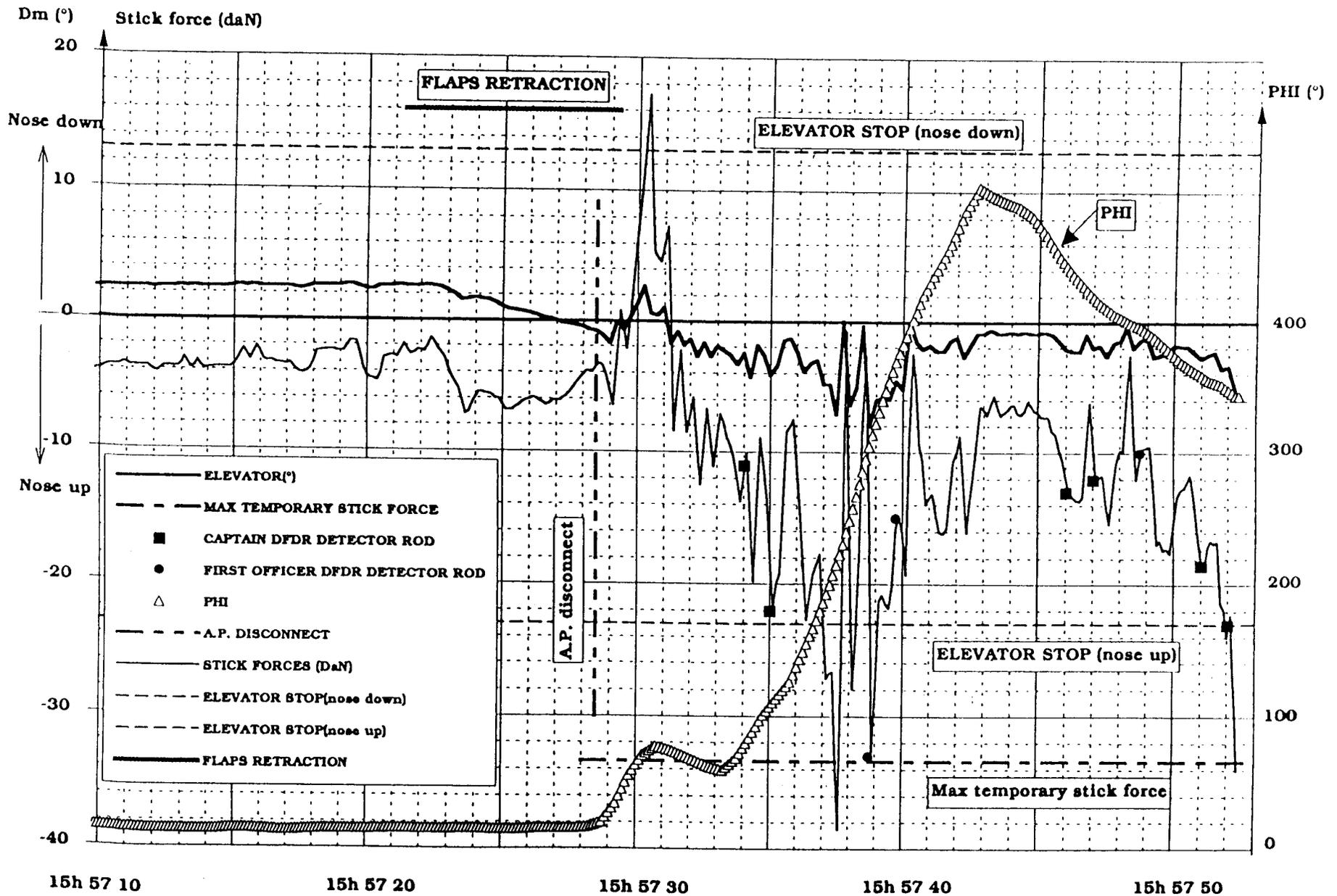
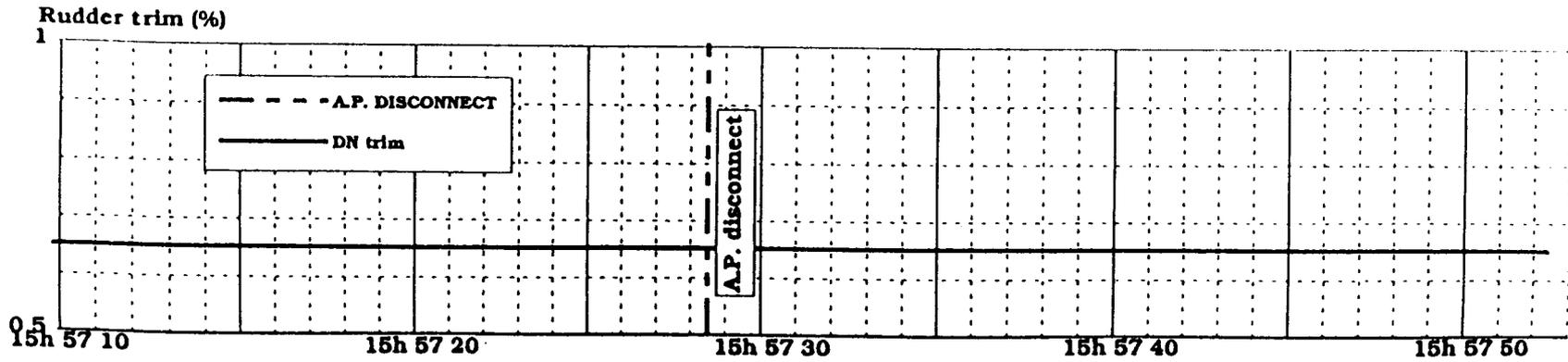
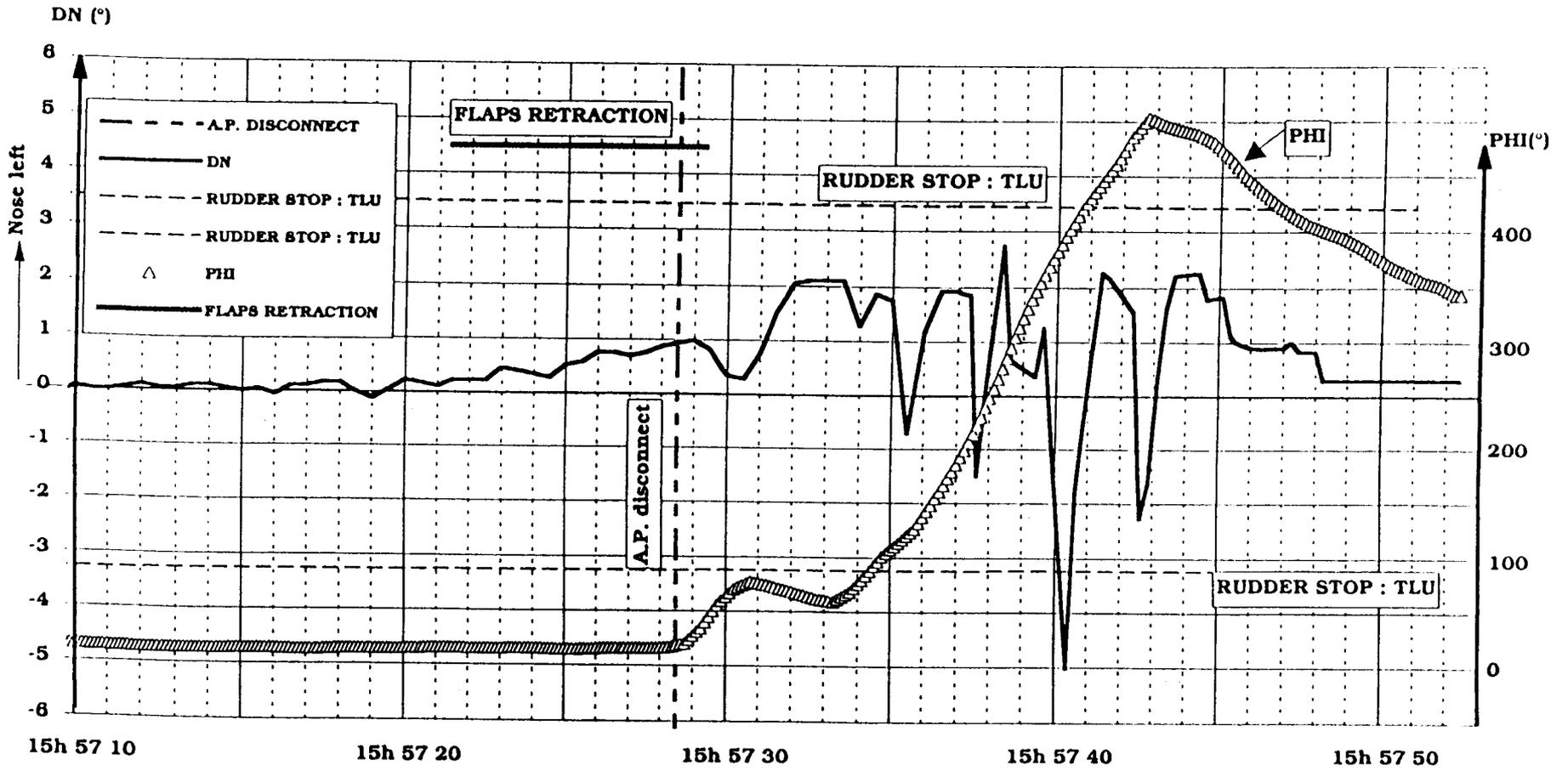


FIGURE 16 : PITCH CONTROL INPUTS / ACTIVITY AFTER ROLL UPSET

A limited control activity mainly during inverted flight

FIGURE 17 : YAW CONTROL INPUTS / ACTIVITY AFTER ROLL UPSET



In addition, the CVR transcript shows that there was almost no discussion between the flight crew in respect to how to respond to the roll upset. Following the initiation of the roll, there was no discussion between the flight crew members regarding the aircraft's attitude or airspeed, nor was there any conversation between them in respect to how to respond to the aircraft's attitude. Further, the First Officer never asked for any help in controlling the aircraft or in responding to the event, nor is there any indication that the Captain exercised his command authority to take over the controls, nor to identify the unusual attitude of the aircraft or to appropriately comment the First Officer's inputs. This shows that the flight crew, probably disoriented, did not identify the unusual attitude nor understood the fast moving evolutions of the aircraft.

The flight crew's lack of appropriate control inputs and lack of communication was due in large part to the fact that they were preoccupied with multiple distractions prior to the roll upset which affected their situational awareness to such an extent that they were precluded from effectively responding after the roll upset which took them by surprise.

The BEA notes with regard to these multiple distractions affecting situational awareness that, in light of the other more recent accidents involving cockpit failures by flight crews, the FAA recently undertook an in-depth review of Airline flight crew training program, which is still pending.

2.2.4. CAPACITY OF AIRCRAFT RECOVERY

Based upon the following investigation, the BEA concludes that Aircraft S/N 401 was fully recoverable.

1. STRUCTURAL INTEGRITY

The analysis of the wreckage, made difficult by the extensive fragmentation of the aircraft, revealed no damage existing before the impact. Also, the spectral analyses of the CVR recordings show no abnormal noises that can be associated with the break of structural elements or equipment.

In addition, the review of the maintenance actions carried out on the aircraft and discussions with the mechanics in charge of this maintenance reveal no signs of abnormal removal, replacement or repair of structural elements or equipment in the wing area. Finally the scenario based on the hypothesis of box structure trailing edge deformation in the flap area has been eliminated, the wind tunnel tests show that such a deformation, not detected by analyzing the wreckage, would not affect the hinge moments.

Based upon the foregoing, the BEA concludes that the aircraft was perfectly in conformity with its definition and that its structural integrity was perfect up to the last seconds before impact.

2. SYSTEM INTEGRITY

The same analysis on the equipment revealed no damage existing before the impact.

The analysis of the 115 DFDR parameters which allowed the operation of the main equipment and the CVR to be monitored, in particular the comments made by the two pilots, showed no evidence of anomalies.

All recordings confirm normal and coherent operation of the various items of equipment, in particular those associated with the deicing systems and the primary and secondary flight controls.

Also, the specific scenario calling the systems - spoiler runaway - into play and which can explain the roll dynamics, cannot explain the aileron suction and must therefore be eliminated.

Other secondary scenarios have also been eliminated as their execution leads to incoherence with the DFDR recordings and require additional failure hypotheses with probabilities too low to be retained.

The BEA can therefore conclude that the aircraft was perfectly in conformity with its definition and that the various systems were operating normally in particular those related to deicing and flight controls until the last seconds before impact.

3. EFFICIENCY OF THE AILERONS IN PRESENCE OF AIRFLOW SEPARATION

The probable accident scenario involves three phases :

- a two phase ice accretion mechanism, in conditions outside appendix C with a second phase, performed at a very low angle of attack corresponding to flap 15 configuration and at a high speed near to the VFE of this configuration. This accretion is characterized by a unique ice ridge downstream of the boots,
- an upper wing surface flow separation phase initiating at the ridge and at the trailing edge and appearing at a critical angle of attack reached during the increase in the angle of attack related to flap retraction,
- a roll initiation phase, resulting both from the local asymmetrical lift loss and the roll moment created by aileron suction, both directly due to the flow separation.

The possibility of counteracting this roll initiation is directly related to the capacity to develop an opposing roll moment using the aileron and spoiler control surfaces. This implies :

- that these control surfaces retain their efficiency (capacity to create a roll speed for a given deflection),
- that the loads required to obtain this deflection remain compatible with those that a pilot can develop (maximum temporary force).

The conservation of the efficiency of the aileron-spoiler pair in the presence of a separated flow has been demonstrated by the following :

- it is at the origin of the rapid roll initiation subsequent to aileron suction,
- the many wind tunnel tests conducted with various types of accretion which confirm that this efficiency is maintained at the level of the one obtained with undisturbed flow,
- tests on ATR 42 and ATR 72 with artificial shapes downstream of the boots confirm that this efficiency is maintained,
- the analysis of the behavior of the ailerons and the associated roll moments during previous incidents demonstrates that efficiency is maintained,
- the theoretical approach is difficult. The bidimensional studies reveal a separation initiating on the trailing edge and propagating upstream. Changes in the lower surface and upper surface pressures allow the changes in the hinge moments and local lift to be qualitatively explained but the effect of an aileron deflection, which could confirm that efficiency was maintained, has not yet been studied.

In conclusion, the experimental data obtained from the wind tunnel tests and the post-Edwards flight tests conducted with natural and artificial pollution confirm that efficiency was maintained in spite of the presence of airflow separation upstream of the control surfaces.

4. ANALYSIS OF FORCES REQUIRED TO DEFLECT THE AILERONS

Several approaches can be used to assess the forces to be applied on the control wheel in order to maintain the position of the ailerons, in the presence of a flow separation at the time of AP disconnection :

- by directly measuring these forces, during flights with natural accretions made at Edwards (asymmetrical pollution limited spanwise),
- by directly measuring these forces, during flights with artificial accretions intended to reproduce the aircraft 401 roll upset at AP disconnection,
- by directly measuring these forces, during high-speed ground runs with random shapes causing massive separation forward of the ailerons,
- by laboratory tests on an AP servomotor simulating the dynamics of the roll control channel and leading to AP disconnection,
- by theoretical studies simulating the dynamics of the roll control channel using aerodynamic coefficients measured in wind tunnel in separated flow and calibrated to reproduce the flight test results.

All these analyses, in particular, the many flights made with artificial shapes show a load level controllable by one pilot, close to the maximum temporary force given in FAR PART 25.143. Without invoking the assistance that could be given by the second pilot on request.

All these elements confirm that the force level required to control the ailerons in separated flow conditions, at the origin of the roll anomaly, were near to the maximum temporary force level.

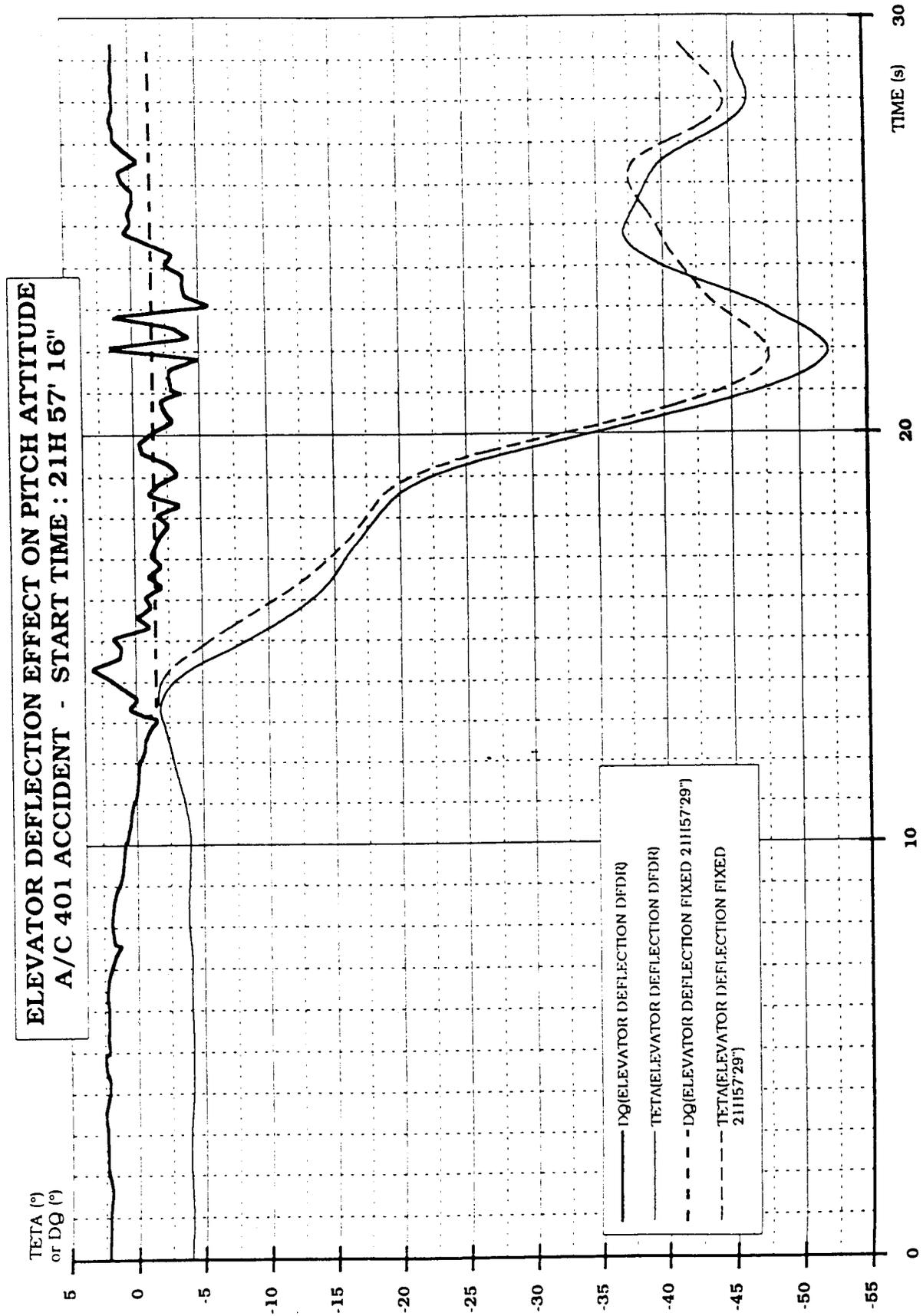
5. CAPACITY OF CONTROLLING ROLL INITIATION AND FLIGHT PATH

The simulation software used with 6 degrees of freedom and incorporating the effect of the accretions on the various aerodynamic coefficients allows to accurately reconstruct the Flight path of aircraft S/N 401, after AP disconnection, using as inputs to be model, the control surface deflections recorded on the DFDR.

It also allows to predict the Flight path resulting from different control surface deflections. It is thus possible to determine (fig. 18) that the deflection of the elevators contributes only marginally to the longitudinal movement whose amplitude is mainly due to roll initiation.

Moreover, assuming a counteracting steady deflection limited to 6° on the ailerons and applied after the maximum conventional crew reaction time used in cruise (3 seconds) after disconnection, the Flight path is rapidly controlled (fig. 19). The lateral attitude is kept close to wings level and the longitudinal attitude does not exceed 22° before returning to 0° .

FIGURE 18 : EFFECT OF A CONSTANT PITCH INPUT ON RECOVERY



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AILERON DEFLECTION EFFECT ON ROLL AND PITCH ATTITUDE A/C 401 ACCIDENT , START TIME : 21H 57' 16"

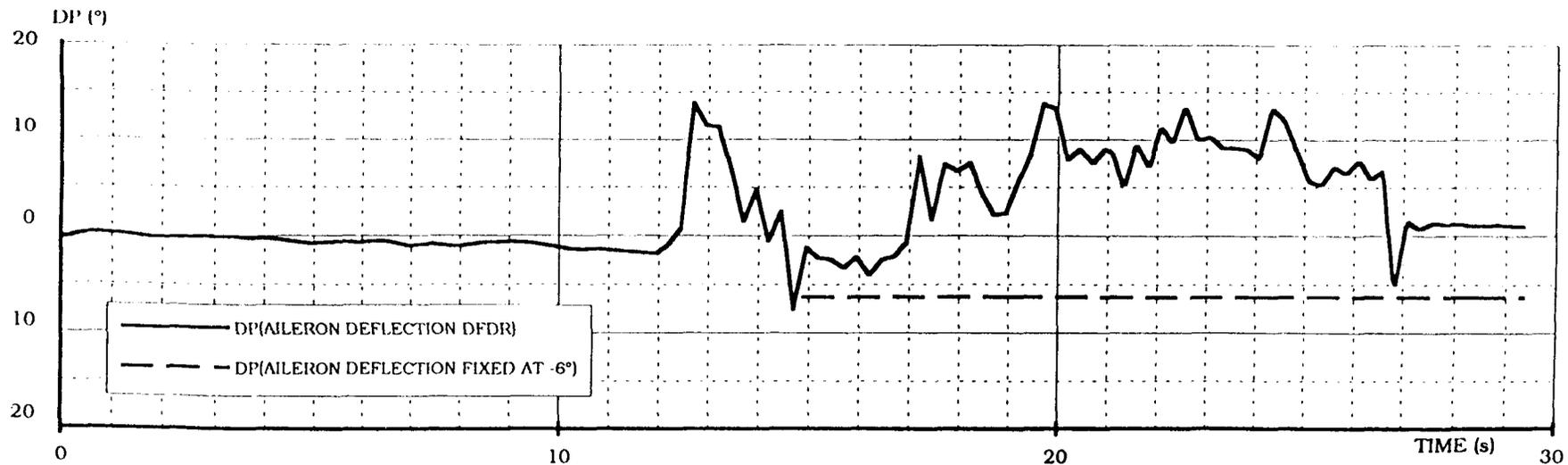
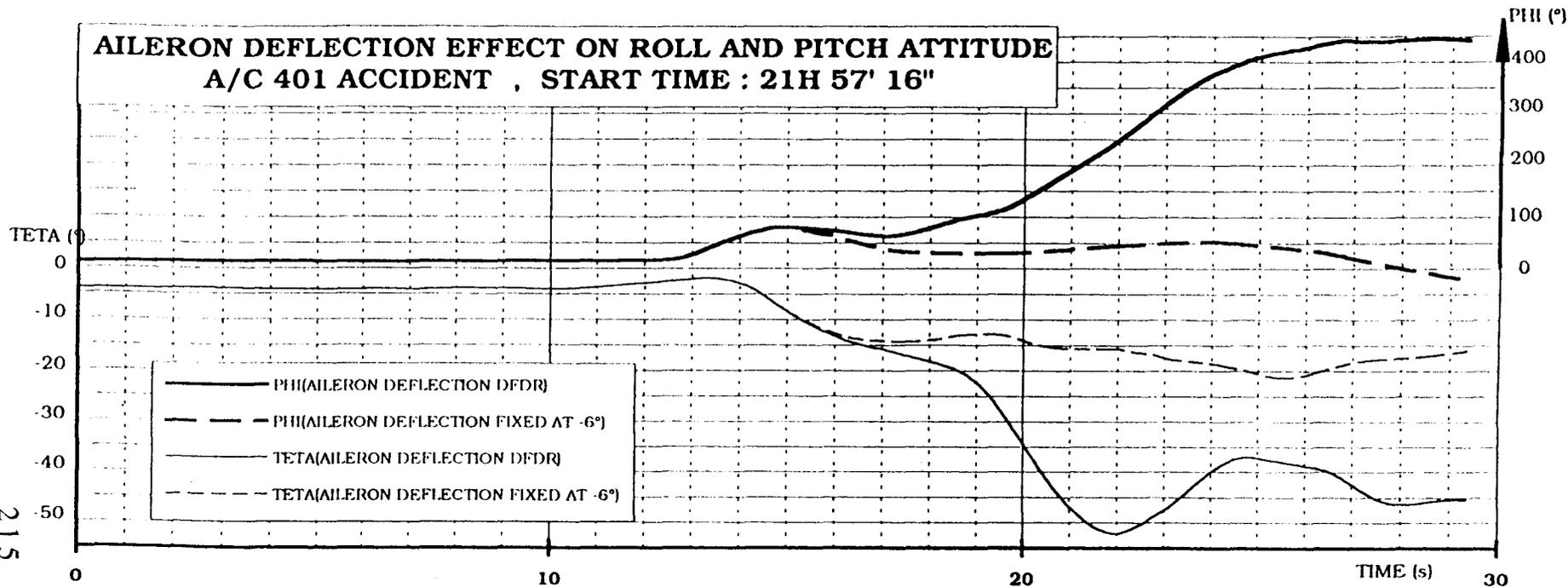


FIGURE 19 : RECOVERY CAPABILITY THROUGH CONSTANT ROLL INPUT

A constant 6° roll input after 3 sec would allow for recovery

This theoretical analysis, based upon a model which was accurately calibrated by flight tests with artificial shapes, confirms the capacity to control roll initiation by a 6° aileron deflection well below the aileron stop (14°) and with forces consistent with those mentioned in the previous paragraph.

The results of this theoretical analysis of the recovery capacity are also supported by the many flight simulations of the scenario of S/N 401 with an ATR 72 equipped with artificial shapes.

6. CONCLUSIONS

The many investigations conducted subsequent to the accident, the results of which were forwarded to the NTSB, permits the following conclusions :

- during flight 4184, aircraft S/N 401 was in conformity with its type definition and the integrity of the structure and the good operation of the systems was maintained until the last seconds before the impact,
- the efficiency of the ailerons was maintained in spite of the presence of a flow separation upstream of these control surfaces,
- the forces required to control the ailerons remained within the capacity of one pilot (let alone two pilots) in spite of the presence of the flow separation,
- an aileron deflection of around 6° maintained in the direction opposite to the roll initiation would have been sufficient to stop the roll departure and the nose-down tendency of the aircraft.

Based upon the foregoing, the BEA concludes that aircraft S/N 401 was fully recoverable.

2.2.5. CREW RESPONSE TO ROLL UPSET

Aircraft recovery following SLD induced roll upsets have been flight tested with the Edwards testing simulated ice shapes glued on the wings : aircraft recovery was repeatedly shown to be physically possible, with one pilot alone using his yoke only. Such a recovery requires a firm pilot's action to overcome the jerky forces which otherwise would drive the roll control wheel in the direction of the upset. Time reaction is also critical, as the roll upset, if not counteracted in the first few seconds, could develop a high rate of roll which would aggravate the pilot disorientation.

2.3. PREVIOUS ATR ICING INCIDENTS AND ADEQUACY OF DGAC/ATR ACTIONS

The following analyses of previous ATR-42/72 incidents incorporates the results of all tests and research conducted after the Roselawn accident. Therefore, these analyses may also review some of the assumptions formulated during the previous analyses of these events.

2.3.1. MOSINEE INCIDENT

The Mosinee incident was the first of five events analyzed by the NTSB, experienced by an ATR-42 aircraft in icing conditions outside the icing certification envelope. These conditions were clearly shown to be freezing rain, associated with a temperature inversion phenomenon. This incident involved an auto-pilot disconnection, at an angle of attack very close to the icing stall warning threshold, with evidence from the DFDR data traces of a rolling moment induced by an asymmetrical lift loss and with evidence of an aileron self deflection. The recovery was readily accomplished by the flight crew. The investigation later revealed that the flight crew had not activated the airframe de-icing equipment prior to the incident, while the aircraft was accreting ice.

ATR's initial response to this first incident was to immediately re-emphasize to all operators the hazards associated with flight operations in freezing rain using the FAA's Advisory Circular 20.117 material. ATR subsequently proposed a design modification to the ATR 42 (Vortex Generators) and also and to proposed changes to the AFM/FCOM to incorporate procedures applicable to inadvertent encounters with such conditions.

These proposed changes were submitted to the DGAC, which in turn submitted the proposed manual changes to other Airworthiness Authorities, including the FAA. The FAA, as stated in its subsequent NPRM (Notice of Proposed Rulemaking) regarding the introduction of the vortex generators modification, declared that as a matter of policy, hardware changes were preferred to procedural changes. Based upon its ATR-72 development activities, ATR demonstrated the benefit of the addition of VG'S (vortex generators) for maintaining to a higher angle of attack the lateral control and stability of the aircraft in the presence of asymmetrical ice build-up on the wing. This design change was an appropriate response to the Mosinee incident, because it had the potential to prevent autopilot self-disconnections prior to the stall warning, as observed during this incident. The effect of VG'S in presence of freezing rain induced accretions could not be checked, since the nature and definition of such accretions were (and are still) unknown. However the manufacturer did demonstrate, by using asymmetrical artificial ice shapes, located on the wing leading edge, the VG'S ability to postpone, at increasing angles of attack, a flow separation over the outer wing airfoil.

The changes to the AFM/FCOM, as originally proposed, were incorporated by ATR, when accepted by Airworthiness Authorities. In accordance with its preference for design changes over special operating procedures for long term operational safety, the FAA adopted and imposed the vortex generator modification, but did not adopt the proposed AFM manual changes. "Considering that this(ese) procedure(s) addressed a condition outside the certification requirements, the DGAC did not request its (their) insertion in the manuals".

Consequently, the corresponding FCOM changes were also not incorporated in the U.S or France. However, the German and Canadian Airworthiness Authorities did incorporate this information in their operation manuals. The same information was, however, repeated to all operators and their pilots in ATRs *All Weather Operations* brochure published in 1991.

In its *All Operator Message* issued immediately after the incident, ATR also disseminated to all of its operators, the information regarding the characteristics of the incident and drew its operators' attention to the hazards of freezing rain, quoting the FAA Advisory Circular stating that such conditions should be avoided.

ATR's analysis of the Mosinee incident was reviewed and accepted by the BEA. The BEA used the results in its own analysis which was presented to the NTSB. At that time the conclusion was that unusual ice accretion patterns may have been caused by the speculated aircraft's sustained flight in freezing rain conditions, and it was concluded that such conditions could have been the origin of an aileron hinge moment modification which occurred about at the stall threshold when the autopilot disconnected. However, the absence of documented freezing rain ice shapes and of any industry standards for such ice accretions gave no basis to support or test such speculation. Several other factors limited any further analysis of this matter by ATR, or by any other party involved in the investigation, including the NTSB.

a) The worldwide industry belief that freezing rain conditions, which are beyond the certification envelope of all aircraft, were rare occurrences, and that it would be impractical to protect aircraft against their effects. Further, it was believed that such conditions were generally “predictable, recognizable and avoidable” [AC 20.117].

b) The absence of certification criteria to cover the consequences of inadvertent encounters and the absence of documented effects in terms of ice accretion patterns.

c) The fact that the event occurred at about the stall threshold, which was further addressed by the vortex generators modification.

d) The fact that the crew had failed to activate the airframe de-icing equipment at the time, which fact was revealed by the NTSB to the other investigating parties after the manufacturer’s analysis was published, was an aggravating factor in the incident. Application of the normal and required de-icing procedures for flight in icing conditions may well have prevented the incident.

e) The fact that the crew had not reported abnormal or excessive wheel efforts during the recovery and that the aileron effectiveness had apparently remained unaffected.

In the frame of the post-Roselawn accident investigation, the BEA made further inquiries about potential similarities between the ATR 42 Mosinee incident and the ATR 72 Roselawn accident and considered whether additional efforts might have allowed the investigating parties at that time to anticipate the Roselawn icing scenario.

Several factors made the ice accretion patterns involved in the Mosinee incident, significantly different from those that most probably developed in the Roselawn case, the first of which being the fact that aircraft S/N 91 accreted ice with the airframe de-icing boots OFF. Also, aircraft S/N 91 accreted ice in the flaps 0° configuration ; droplets sizes associated with the prevailing freezing rain conditions were probably higher than those involved in Roselawn ; the exposure time was not longer than 10 minutes. These differences resulted in ice accretion patterns with both large spanwise and chordwise extents on the wing airfoil and with limited protruding ridge height. Although such shapes cannot be accurately characterized, the BEA believes that their nature may not be very different from one of the Edwards tanker test cases, with the wing de-icer boots inoperative (test n°23) exhibited. In this respect :

a) both the Edwards tanker test (N°23, Flap 15 degrees) and the subsequent corresponding flight test in Toulouse with artificial ice shapes directly derived from the observations made at Edwards, show handling qualities effects consistent with the Mosinee DFDR data, in that the roll control is not affected prior to an AOA very close to the icing stall warning threshold,

b) all available wind tunnel and flight tests data indicate that unusual ice accretion patterns with a large spanwise coverage would noticeably increase the drag, prior to any lateral control alteration.

Such was the case in the Mosinee incident.

c) all available wind tunnel and flight tests data indicate that unusual ice accretion patterns of that same type would generate high lift losses, of a genuine asymmetrical nature. Such was the initiating factor of the roll departure in the ATR 42 Mosinee incident.

d) both the Edwards tanker test (n°23) and the subsequent flight test in Toulouse with artificial ice shapes directly derived from the observations made at Edwards, show some degree of aileron hinge moment shift after the initiation of the roll motion due to the asymmetrical lift loss. Such was the case in the Mosinee incident.

The BEA therefore concludes that the ice accretions patterns, that the mechanism of the airflow disturbance generated by these ice shapes, that the resulting handling effects, involved in the ATR 42 Mosinee incident were different from the ice shapes, airflow separation and hinge moment reversal revealed by the post-Roselawn investigation.

As the consequence, should the investigating parties in the Mosinee incident have decided to conduct further testing and should have testing means been available - which was not and is still not the case - the BEA believes that the simulation of the Mosinee incident - flaps 0° configuration, de-icer boots OFF, freezing rain droplets - might have reproduced the characteristics of this incident but would not have allowed the anticipation of the Roselawn icing scenario.

2.3.2. AIR MAURITIUS AND RYAN AIR INCIDENTS

The analysis of the next two ATR-42 incidents showed that the roll excursions were primarily caused by asymmetrical lift loss. No alteration of the aileron hinge moment was evident from the DFDR data traces, nor can such evidence be seen today in re-visiting the analyses of these traces. In both incidents, the following signs of the impending stall clearly existed :

- a) Continuous drag increase and correlative speed loss at constant engine power,
- b) Abnormal autopilot activity in roll prior to the disconnection,
- c) G-break,
- d) Stall warning.

In both incidents, the flight crews readily recovered from the stall. None of them reported either abnormal or excessive aileron wheel forces during the recovery. The existence of icing conditions outside the JAR/FAR icing envelope was indirectly shown by computing the drag build-up from the DFDR data traces and by comparing it with the certification criteria envelope. The effects of the ice pollution were clearly shown to be beyond what had been taken into account in certification. Still, the stalls occurred at angles of attack consistent with the icing stall warning threshold.

The “ice-induced aileron hinge moment reversal” phenomenon, which was discovered in the post-Roselawn accident investigation and testing, was not involved in the Air Mauritius and in the Ryanair incidents.

Based upon the foregoing neither of these incidents suggested to ATR an icing scenario of the type of that was discovered during the post-Roselawn accident investigation

Since the failure of the flight crew to observe the minimum Np setting (86 %) in icing conditions was a common fact in both cases, at DGAC request, ATR rightly investigated the effects of the lower than required Np setting (77 %) associated with severe icing conditions. ATR's tests and research involved both theoretical studies and flight testing. The results were presented to the DGAC and to the BEA. ATR showed that the combined effects of Np setting at 77% and of severe icing conditions were likely to cause unusual ice accretions on the propeller blades, which in turn could generate an highly turbulent airflow over the wing airfoil. Since an increased level of turbulence is known to cause the deposit of a rough, thin layer of ice over the entire airfoil, especially in severe icing environments, this mechanism was believed to be the origin of the abnormal drag build-up observed prior to the Air Mauritius and RyanAir incidents and of the stall at or about the icing stall warning threshold.

As a consequence, ATR took actions to re-emphasize the already existing limitations regarding the minimum Np setting in icing conditions. The aircraft check list was in particular amended for that purpose.

The BEA, the DGAC, and ATR still believe that the mechanism described above could contribute to the alteration of aircraft performance in severe icing environments. This mechanism was clearly not a factor in the Roselawn accident.

2.3.3. NEWARK INCIDENT

The prevailing icing atmospheric conditions were found by the investigating parties (NTSB, BEA, DGAC, and ATR) to be probably outside the scope of the JAR/FAR 25 Appendix C. This conclusion was based upon the general meteorological data available, the observations by the flight crews of unusual ice accretions, as well as ground reports of freezing precipitation in the area of the incident. These conditions, however, could not be precisely analyzed by the BEA because BEA requests for further information from the NTSB were not responded to.

The analysis of the aircraft's performance and controllability from the DFDR data traces was seriously hampered by the extreme level of turbulence which was present during the entire approach and landing phase of the flight and throughout the incident. Vertical and lateral accelerations and instantaneous speed variations of respectively $\pm 0,3$; $+0,15$; ± 10 kts were noted on the DFDR, preventing accurate computation of aerodynamic coefficients, as well as the alteration of aircraft performance. Sharp roll oscillations and pilot's inputs were also present along the entire flight path.

The interpretation of the autopilot disconnection, the roll excursions, and the aileron deflections was, and is still, extremely difficult. All such aircraft responses, however, are consistent with the documented effects of the turbulence itself. Although today, in the light of the post-Roselawn tests and research, possible correlation between some transitory aileron deflections and the increase of the aircraft AOA beyond 7° may be seen, the existence of any transient aileron hinge moment modification remains questionable.

Both wind gusts and roll motion could have created local wing tip angles of attack much higher than the recorded fuselage angle of attack and could have triggered unsteady airflow separations responsible for asymmetrical lift loss and rolling moments. Abrupt pilot inputs and induced roll oscillations cannot be rejected, either.

The interpretation of the DFDR data traces was, extremely difficult for a number of reasons. 1) the characteristics of the icing conditions could not be determined by lack of pertinent data ; 2) the flight crew observations did not correlate with any previous observations noted by, or reported to, ATR ; and, 3) the flight crew failed to respect the minimum Np setting in a severe icing environment which was again a contributing factor. Accordingly, none of the investigating parties, including the NTSB, BEA, DGAC and ATR, could identify the exact contribution, if any, of an ice-induced pollution of the airframe in the Newark incident. None of the same parties which investigated this event had any indication that an aileron hinge moment modification could be a significant factor as it was in the Roselawn accident.

Following the Roselawn accident, the BEA and NTSB reviewed the Newark DFDR. Because the DFDR readout disclosed that a high level of turbulence was involved throughout the incident, and would by itself explain the aircraft behavior, it cannot be determined whether the "ice-induced aileron hinge moment reversal" phenomenon which was discovered for the first time in the post-Roselawn accident investigation and testing was involved at all in the Newark incident.

2.3.4. BURLINGTON INCIDENT

This incident occurred early 1994 and its DFDR data was reviewed by ATR and the BEA. The aircraft experienced, prior to the autopilot disconnection, a continuous speed decrease of about 45 kts, without any pilot corrective action. The airspeed reached prior to the upset was below the minimum prescribed speed for icing conditions. In addition:

- a) a g-break was apparent before the A/P disconnection,
- b) the autopilot was disconnected by the stall warning,
- c) the aileron briefly self-deflected after the stall commenced. ATR identified in its analysis a momentary aileron hinge moment modification. However, the predominant factor was clearly the asymmetrical lift loss in the stall which induced the roll motion. The momentary modification in the aileron hinge moment which occurred after the stall commenced had no effect on this incident.
- d) The Np setting was 86%, in accordance with the published procedures. but the airspeed was below the specified minimums.

This incident was considered by the BEA, DGAC, and by ATR as an indication that unidentified ice accretion patterns, other than that caused by a turbulent airflow behind an improperly de-iced propeller might alter the aircraft performance and controllability. However, the stall nevertheless occurred at the icing stall warning threshold and a massive drag build up and the correlative airspeed loss should have triggered the crew's attention. Such severe drag increases were felt to be always associated with these unusual ice accretions. as all incidents had indicated, including this one. Also, recovery actions were readily accomplished by the flight crew, and aileron effectiveness and control wheel forces were not reported to be abnormal.

Nevertheless, because the ATR-72 had no in-service history of any such roll control icing related events and was certified using different and modified icing codes from those used for the certification of the ATR-42, the DGAC required that ATR re-visit the determination of ice accretions within the Appendix C envelope, under the modified codes, for the ATR-42. This research was on-going at the time of the Roselawn accident.

2.3.5. CONCLUSION

Until the post-Roselawn tests and research, the freezing drizzle/freezing rain conditions were not perceived by the worldwide industry as a major threat to the safe operation of regional airline aircraft. These conditions were, and still are, omitted from the certification criteria. Although such conditions were generally understood to be hazardous and to be avoided, there was no absolute prohibition to fly into such conditions, based upon the assumptions that they were rare occurrences which could be recognized and avoided and that properly certificated aircraft would safely cope with short inadvertent encounters.

Neither regulatory environment nor the available means of experimental research did encourage the Western manufacturers and Airworthiness Authorities to focus on the characteristics of such conditions and on their potential effects on the aircraft performance and controllability, but rather, to re-emphasize good operational practices to avoid such conditions as ATR has emphasized, and in particular, re-emphasized following the Mosinee incident.

The BEA notes that among of the ATR 42 incidents, which **all** occurred in the clean, flaps 0°, configuration, and which **all** involved failure to follow icing conditions procedures none, exhibited the unique characteristics involved in the Roselawn accident, namely an outer wing airfoil flow separation at an AOA well below the icing stall warning threshold, without any prior noticeable drag build-up and without any significant asymmetrical lift loss.

Aileron hinge moment modifications could only be noted in two of these incidents - it is still doubtful that they existed in the Newark incident - and their contribution was perceived by all investigating parties as a marginal characteristic of what was substantially concluded as an asymmetrical stall in severe icing conditions. There was no evidence that such modifications of the aileron hinge moment could become a predominant factor in different circumstances, since they had not initiated roll excursions or interfered with crew recovery actions in any of the incidents.

It is furthermore today understood that the prior ATR 42 incidents and the ATR 72 Roselawn accident involved different mechanisms and amplitudes of airflow separations. Prior incidents are attributed to extended airflow stalls over the wing, progressing from the airfoil trailing edge towards its leading edge at increasing angle of attack, until the asymmetrical nature of that stall results in a rolling moment and, in some instances only, deeper in the phenomenon, in some degree of aileron hinge moment shift. The mechanism revealed by the post-Roselawn investigation, involves in a very different manner, complex local airflow separation patterns, behind the ice ridge and at the aileron trailing edge which, at a critical angle of attack, could abruptly merge and drive an aileron hinge moment reversal.

ATR and the DGAC took appropriate actions to address the risk of asymmetrical stalls in severe icing conditions by restating warnings to operators to avoid such conditions and including several hardware changes and training actions. These actions were intended to :

a) provide early warnings to flight crews of an impending stall by enhancement of the autopilot roll servo monitoring and associated procedures, and by airspeed monitoring through procedures and through the implementation of the AAS system,

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It is furthermore today understood that the prior ATR 42 incidents and the ATR 72 Roselawn accident involved different mechanisms and amplitudes of airflow separations. Prior incidents are attributed to extended airflow stalls over the wing, progressing from the airfoil trailing edge towards its leading edge at increasing angle of attack, until the asymmetrical nature of that stall results in a rolling moment and, in some instances only, deeper in the phenomenon, in some degree of aileron hinge moment shift. The mechanism revealed by the post-Roselawn investigation. involves in a very different manner. complex local airflow separation patterns behind the ice ridge and at the aileron trailing edge which, at a critical angle of attack. could abruptly merge and drive an aileron hinge moment reversal.

ATR and the DGAC took appropriate actions to address the risk of asymmetrical stalls in severe icing conditions by restating warnings to operators to avoid such conditions and including several hardware changes and training actions. These actions were intended to :

a) provide early warnings to flight crews of an impending stall by enhancement of the autopilot roll servo monitoring and associated procedures, and by airspeed monitoring through procedures and through the implementation of the AAS system,

2.4. AIR TRAFFIC CONTROL

Based upon the information contained in the NTSB'S report, the Chicago Center Traffic Management Coordinator (TMC) improperly released Flight 4184 from a 42 minute ground hold when it had been informed by the ZAU Traffic Management Coordinator (TMU) that conditions were such that the flight would likely be required hold in the air before reaching its destination. The release of Flight 4184 under these conditions appears to be contrary to the policy set forth in FAA Order 7110.65, *Air Traffic Control Handbook*, to reduce congestion in the air traffic system and to limit the duration of airborne holding. Had Flight 4184 not been released prematurely, the flight would not have been required to hold at LUCIT intersection as long as it did, and the accident may not have occurred.

After Flight 4184 entered the hold at LUCIT intersection, Flight 4184's Expected Further Clearance (EFC) time was extended on four separate occasions. Further, despite the fact that it was mandatory for BOONE Sector Controller to report those arrival delays to the Air Traffic Control System Command Center (ATCSCC) which are expected to meet or exceed 15 minutes, neither the Central Flow Control Facility (CFCF), nor the Traffic Management Unit (TMU) were advised, that Flight 4184's holding time had exceeded 15 minutes.

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In this regard, it is significant to note that an altitude diversion could have been easily accommodated since Flight 4184 was the only aircraft holding at LUCIT intersection and multiple altitudes were available for diverting. The flight crew's failure to provide a PIREP of the known icing conditions they were operating in contributed to this accident.

Finally, the BOONE Sector Controller was required to solicit a PIREP from Flight 4184. In this regard, FAA Order 7110.65J, Section 6, entitled *Weather Information*, provides that ATC controllers are required to "solicit PIREPS when requested or when one of the following conditions exist or are forecast for your area of jurisdiction. " One of the conditions for which ATC controllers are required to solicit PIREPS is icing of light degree or greater (Emphasis added.) Had the BOONE Sector Controller solicited a PIREP from Flight 4184 and learned that they were holding in icing conditions, immediate precautionary action would have been taken by ATC to communicate with the crew regarding exiting the icing area, thus avoiding the accident. ATC'S failure to solicit a PIREP from Flight 4184 contributed to this accident.

2.5. THE DGAC'S CONTINUING AIRWORTHINESS MONITORING UNDER THE BILATERAL AIRWORTHINESS AGREEMENT

Pursuant to Paragraph 6 of the U.S.-France Bilateral Airworthiness Agreement and Annex 8 to the Convention on International Civil Aviation, the DGAC is required to:

- a) assist the FAA in analyzing accidents and major incidents which involve U.S. - registered ATR aircraft and which "raise technical questions regarding the airworthiness of such products" when they are properly reported and documented to the DGAC, and
- b) provide the FAA with information "necessary for the continuing airworthiness of the aircraft and for the safe operation of the aircraft" when such information is identified.

This BAA and Annex 8, however, in no way remove the responsibility of the primary investigative authority of the State of Occurrence to conduct a proper investigation of the accident or incident as the lead investigative authority under Annex 13 to the Convention on International Civil Aviation. The BAA and Annex 8 do not delegate to the Exporting State, or otherwise change in any way, the investigative responsibilities of the State of Occurrence. One of the most important of these responsibilities is the obligation of the State of Occurrence to forward to other States information on the investigation of "an incident which involves matters considered to be of interest to other States. "

The DGAC has consistently fulfilled its obligations as the primary certification authority for the ATR-42 and ATR-72 aircraft. The joint FAA/DGAC Special Certification Review Report confirmed that the DGAC acted correctly and properly in its certifications of the different ATR model aircraft, that the certifications complied with all applicable certification standards, and that the DGAC and FAA properly applied the BAA in their certifications of the aircraft.

The NTSB's probable cause finding (and the associated analyses and findings) that the DGAC provided inadequate oversight of the continuing airworthiness of the ATR aircraft and inadequate corrective action to assure their continued airworthiness in icing conditions is not supported by the NTSB'S record of investigation and is wrong. This record demonstrates that the DGAC was actively involved in investigating ATR icing events, considered whether these events warranted any corrective actions, and required that ATR take decisive corrective action whenever this was appropriate.

This NTSB probable cause finding, and the associated analyses and findings, that the DGAC's failed to require ATR to take additional corrective actions and that this "led directly to this accident" appears to be based on the erroneous assumption that the DGAC had identified, from earlier ATR icing incidents the "aileron hinge moment reversal" which was involved in the Roselawn accident. This presumption, as well as the analyses and findings which appear to be based thereon, are not supported by the NTSB's record of investigation and are wrong.

Neither the DGAC nor the NTSB, FAA, BEA, or ATR identified from their investigation of these earlier incidents the “aileron hinge moment reversal” phenomenon which was involved in the Roselawn accident. This phenomenon was not identified until after the Roselawn accident. In suggesting that the DGAC should have required ATR to take additional corrective actions regarding a phenomenon that neither the DGAC nor the NTSB, FAA, BEA, or ATR had yet identified, the NTSB is clearly wrong. Thus, the BEA entirely disagrees with the NTSB’s statement that the DGAC’s failure to require ATR to take additional corrective action “led directly to this accident. ”

The NTSB’s probable cause finding (and the associated analyses and findings) that the DGAC failed to provide the FAA “with timely airworthiness information developed from previous ATR incidents and accidents in icing conditions, as specified under the BAA and ICAO Annex 8” appears to be based on an NTSB misunderstanding of the BAA and Annex 8, is not supported by the NTSB’S record of investigation, and is wrong. As noted above, the pertinent sections of the BAA (section 6) and of Annex 8 (Section 4.2.2), require the Exporting State to provide to other Airworthiness Authorities information obtained during the investigation of major incidents or accidents only where those incidents or accidents” raise technical questions regarding the airworthiness of [the aircraft]” or otherwise identify information which is “necessary for the continuing airworthiness of the aircraft and for the safe operation of the aircraft. ”

There is no factual basis whatever in the NTSB's record of investigation to support the suggestion that the DGAC failed to provide the FAA on a timely basis with critical airworthiness information "developed from previous ATR incidents and accidents. " Prior to the Roselawn accident there had never been an ATR-72 accident of any type, nor had there been any ATR-72 icing incident involving roll control.

With regard to the ATR-42 icing related incidents reviewed by the NTSB, and which occurred prior to the Roselawn accident, the facts demonstrate that the DGAC also fully complied with its obligations under the BAA and Annex 8, as noted below. In the one incident which did disclose an airworthiness issue, the DGAC worked hand in glove with the FAA to identify corrective actions, passing on adequate information to the FAA and other Airworthiness Authorities. In the other incidents, neither the BEA nor the NTSB determined that any aircraft airworthiness or safe operation issue was involved.

To the extent that the NTSB is suggesting that the DGAC failed to disclose to the FAA information indicating that the ATR was susceptible to an aileron hinge moment reversal of the type which caused the Roselawn accident, this suggestion simply ignores the fact that none of the parties which had investigated any of the prior incidents, including the NTSB, had identified this phenomenon before the Roselawn accident.

The following is a discussion of the DGAC's compliance with its BAA and Annex 8 obligations in each of the prior ATR-42 icing related incidents.

Mosinee incident -AC 91- 2/22/88.

In respect to the Mosinee incident, a final investigation report, incorporating ATR's analysis and report, was provided by the BEA to the NTSB in direct meetings with the NTSB. The DGAC subsequently distributed to the Airworthiness Authorities in all countries where ATR aircraft were registered (including the FAA) appropriate information covering the corrective actions mandated on the ATR-42 fleet, and recommended manual changes to address the potential hazard resulting from flight in freezing rain.

Newark incident - AC 259- 03/04/93

In respect to the Newark incident, the DGAC investigated this incident along with the BEA and ATR. The BEA, DGAC, and ATR concluded from the DFDR readout that the incident involved high levels of turbulence and a failure by the flight crew to follow the AFM and AOM procedures while the anti-icing systems were activated.

Since these conclusions did not "raise technical questions regarding the airworthiness of [the ATR]" or otherwise identify information which was "necessary for the continuing airworthiness of the aircraft and for the safe operation of the aircraft, " the conclusions were not sent to the NTSB, FAA, or other Airworthiness Authorities,

The DGAC was hampered in its efforts to investigate this incident because the NTSB, which was the lead investigative authority by virtue of its being the primary investigative authority of the State of Occurrence, provided to the BEA and the DGAC only a limited portion of the information developed by the NTSB and FAA during their investigations.

At the time of the Roselawn accident, over a year and a half after the Newark incident, the NTSB still had not issued a Probable Cause finding on this incident. A Probable Cause finding has not been issued to this day, three years after the incident. A Factual Report regarding the incident was provided to the BEA only in October, 1995, two years after the incident. This Factual Report appears to conclude that the incident occurred while the flight was operating in severe turbulence, and in icing conditions.

Burlington incident - AC 153- 01/28/94.

The DGAC investigated this incident along with the BEA and ATR. ATR performed an analysis of the incident and provided its preliminary conclusions to the DGAC and the BEA. Those conclusions were that the incident involved a substantial failure by the flight crew to follow the AFM and AOM procedures for flight operations in icing conditions. The DGAC reviewed these conclusions, but questioned the conclusion regarding the present of severe icing because accurate weather conditions were not known. The DGAC required that ATR perform a study of the industry icing codes applied to the ATR 42 as the ATR 72 had no history of similar icing incidents which was in progress at the time of the Roselawn accident. Since the preliminary ATR conclusions were that the incident was caused by a failure of the flight crew to follow required procedures, rather than an aircraft airworthiness or safe operation issue, and since the DGAC had no evidence to indicate such an airworthiness or safe operation issue was involved, the DGAC did not send the conclusions to the NTSB, FAA, or other Airworthiness Authorities.

The DGAC was again hampered in its efforts to investigate this matter because the NTSB, which had the responsibility to conduct the investigation by virtue of its being the primary investigative authority of the State of Occurrence, failed to carry out that responsibility, apparently because the operator did not advise the NTSB of the incident. As a result, the NTSB failed to provide the BEA with any information at all related to this incident. The FAA also failed to provide the DGAC with any information on this incident.

Ryanair incident (A/C 161- 8/11/91) and Air Mauritius incidents (A/C 208 - 4/17/9 1) which occurred on non-US registered ATR-42 aircraft outside the U.S.

Both incidents were fully documented by the aeronautical authorities of the State of Occurrence, which provided the full documentation to the DGAC and the BEA. These incidents were then investigated by the DGAC at the request of, and on behalf of, these authorities. The BEA and ATR assisted the DGAC in this investigation.

ATR analyzed these incidents and provided its conclusions to the DGAC and the BEA. The DGAC and BEA reviewed these conclusions and found them to be accurate. The DGAC then sent these conclusions to the Civil Aviation Authority of Mauritius and the Irish Civil Aviation Authority, the State(s) of Occurrence. These conclusions raised no technical question whatsoever about the airworthiness or safe operation of the aircraft, as both matters involved stalls resulting from a failure by the flight crew to follow required operating procedures in icing conditions.

Since these conclusions did not “raise technical questions regarding the airworthiness of [the ATR] ,” or otherwise identify information “necessary for the continuing airworthiness of the aircraft and the safe operation of the aircraft, ” the conclusions were not sent to the NTSB, FAA, or other Airworthiness Authorities.

In conclusion, the only failures to disseminate information in the above-referenced four incidents were the failure of both the NTSB and/or FAA to disseminate to the BEA, DGAC, and ATR important information on the NTSB’s and FAA’s investigations of the Newark incident, and the failure of the NTSB to carry out its responsibilities as the primary investigation authority of the State of Occurrence with respect to the Burlington incident. The foregoing facts simply do not support the NTSB’s finding that the DGAC failed to provide the FAA with timely airworthiness information developed from these incidents “as specified under the BAA and Annex 8,” or the NTSB’S finding that this alleged failure to disseminate airworthiness information “raises concerns about the scope and effectiveness of the bilateral. ”

The DGAC notes that since October 1994, U.S. operators have reported two icing related incidents involving ATR aircraft. Although the BEA has, on several different occasions, requested that the NTSB provide the BEA and DGAC with the relevant DFDR readouts, these data were not provided to the French BEA or DGAC until April 1996, more than six months after the incidents. This unfortunate situation has prevented the DGAC from conducting its own investigation and from providing timely assistance to the FAA and the NTSB in their investigation of these incidents.

2.6. ATR OPERATIONS IN ICING CONDITIONS

2.6.1. CERTIFICATION

The Certification program for the ATR 72 was conducted in a manner consistent with other FAA icing certification programs and demonstrated the adequacy of the anti-ice and de-icing systems to protect the airplane against adverse effects of ice accretion in compliance with the FAR/JAR 25.1419.

The handling qualities flight test programs addressed by the Special Condition B6 (refer to parag. 1,3. 1) for ATR 72-200 and ATR 72-210 included tests with both artificial ice shapes and natural icing conditions. As stated in the FAA “Special Certification Review” final report (page 14), “the scope of these (Ice-contaminated Configuration tests) programs generally exceeded normal certification and industry practices (without SC B6)”.

The NTSB Memorandum (Trip Report & Status of airplane Performance Group Investigation on the AMR Eagle/Simmons ATR 72 accident at Roselawn, IN, DCA-95-MA-001) from Ch. Pereira, AE/DFDR, RE60 (dec 2,94) - refer to page 4 also confirmed that :

“The coverage of the certification envelopes was, however, described by the NASA/FAA group members as typical to above-average for a turbo-prop certification effort given the apparent difficulty in finding natural icing conditions in certain areas of the certification envelopes. ”

. As part of the SCR team work, the data shown parag. 1.3.1 relative to stall characteristics tests- with and without ice shapes and with natural ice - were extensively reviewed, (quote from SCR report page 37)"to determine if there were any lateral control anomalies. That was a specific request from NTSB to a member of the accident investigation team from NASA'.

The conclusion extracted from SCR report was :

Some minor uncommanded aileron activity was noted on several stalls, but under the criteria of FAR/JAR 25.203, this activity was (and is) considered acceptable. All of these small uncommanded aileron movements occurred just at or after activation of the stick pusher. Additionally, for these tests conducted with ice shapes on the ATR-72-100/200, the stall stick pusher on the test airplane was set at the AOA threshold of the no-ice configuration (i.e.,approximately 5° more than the AOA threshold for the ice configuration). These aileron force anomalies are indicative of some aileron snatch tendencies following asymmetric left and right wing airflow separation as the stall progresses. All airplanes with aerodynamically balanced control surfaces can be affected in a similar manner. Therefore, these characteristics were not considered unusual at wing stall AOA, and were fully acceptable from a certification criteria point of view. The airplane was always controllable with normal use of controls.

In conclusion, the final SCR team conclusions confirm:

. ATR-42 and ATR-72 series airplanes were certificated properly in accordance with the FAA and DGAC certification bases, as defined in 14 CFR parts 21 and 25 and JAR 25, including the icing requirements contained in Appendix C of FAR/JAR 25, under the provisions of the BAA between the United States and France.

. The Roselawn accident conditions included SCDD outside the requirements of 14 CFR part 25 and JAR 25. Investigations prompted by this accident suggest that these conditions may not be as infrequent as commonly believed and that accurate forecasts of SCDD conditions does not have as high a level of certitude as other precipitation. Further, there are limited means for the pilot to determine when the airplane has entered conditions more severe than those specified in the present certification requirements.

2.6.2. FLIGHT CHARACTERISTICS

2.6.2.1. INSIDE APPENDIX “C”

During the ATR-72 icing certification process, the aircraft exhibited normal behavior, free of any sort of roll anomaly, within the normal flight envelope, up to maximal angle of attack, even in the case of wing covered with ice shapes on unprotected surfaces, and even with ice shapes simulating the de-icer failure case. That result was confirmed by the EDWARDS tests performed with liquid water droplets within Appendix “C” envelope, i.e. below 40 μm .

2.6.1.2. OUTSIDE APPENDIX “C”.

Certification rules do not request the execution of natural icing tests under SLD conditions, as those are not specified nor part of the certification envelope and are considered as excessively difficult to execute on purpose in nature. Nevertheless, during ATR 72 development they were met once. Data analysis of flight 418, development A/C MSN 98 [ATR 72-210) revealed that droplets above 47 μm had been encountered. Normal assessment of handling qualities by the test crew performed in all configurations did not reveal any particular anomaly.

In that context, Roselawn is a very specific case, the study of which revealed a unique chain of events leading to the roll upset :

- Icing conditions far beyond Appendix “C” limits.
- Prolonged holding, leading to ice accumulation.
- Aircraft set at high speed with flap 15°, leading to negative AOA.
- Flap retraction leading to positive AOA.

After Roselawn, EDWARDS tests revealed the particular and very specific type of ice accretion resulting from prolonged exposure to SLD with 15° flap.

These holding conditions, never provided for in the Aircraft Operating Manuals led to a negative AOA which generated quite unusual ice shapes, in that the accretion concentrates on the upper wing aft of the deicing boots and with limited coverage of the wing lower surface.

- The severe anomaly in roll which was discovered at EDWARDS results from the following unique sequence : prolonged ice accretion phase in SLD conditions with Flap 15° configuration and stall demonstration performed at the Flap 0° configuration.

- Given the technology of unpowered flight control systems, all Commuter-class turboprop are affected by the same type of roll control problem, when submitted to the same SLD environment and same configuration changes.

- After full understanding of such a complex icing process, the ATR de-icing system was modified with extended overwing boots which were tested successfully at EDWARDS in SLD environment.
- Associated with AFM procedural changes (visual cues, flaps utilization), they provide the ATR fleet with a demonstrated level of safety in case of inadvertent encounter with SLD conditions, which is beyond the current icing certification standard.

This physical modification associated with these procedural changes have been recognized as an acceptable means of compliance, and therefore a terminating action to the ADs respectively issued by DGAC and FAA.

Recent industry tests and research conducted after, and as a result of the Roselawn accident, have provided valuable information on the potential effects of unusual ice accretions in the SLD environment. In light of this new information, the BEA understands that certification criteria will be changed to better address these conditions in line with the recommendations of the FAA/DGAC Special Certification Review (SCR) report. Changes in the regulatory standards are therefore being prepared in both France and the US to :

- identify the physical characteristics associated with large supercooled droplets outside of Appendix C conditions.
- establish criteria for acceptable aircraft behaviour in the presence of accretions resulting from these extreme conditions, as well as the same associated means of compliance.

2.7. ATR DISSEMINATION OF ICE RELATED INFORMATION

2.7.1. THE NTSB REPORT MISREPRESENTS FACTS AND ATR KNOWLEDGE

The Report's probable cause finding (and the associated analysis and findings) that ATR failed to completely disclose to operators "adequate information concerning previously known effects of freezing drizzle and freezing rain conditions on the stability and control characteristics, autopilot and related operational procedures when the ATR 72 is operated in such conditions" is not supported by the NTSB'S record of investigation and is wrong.

As described more fully in Section 2.7.2, in addition to making design changes to the ATR-42 and ATR-72, after the Mosinee incident (AC 91 - 22 December 1988), ATR also disseminated to its operators and flight crews extensive information and warnings reminding them that prolonged exposure to freezing rain conditions are to be avoided. ATR also provided to operators and flight crews additional information designed to facilitate the recognition and avoidance of such conditions which exceed the certification limits of all turboprop aircraft. ATR very specifically advised operators that such conditions could affect roll control forces leading to an auto pilot disconnect and resulting in a roll to a large bank angle until the crew took over the controls. ATR described appropriate recovery procedures and introduced them into ATR training programs. ATR also modified simulator packages for icing operations to simulate such roll departures.

Thus, contrary to the report, ATR did provide to operators “information that specifically alerted flight crews that encounters with freezing rain could result in sudden autopilot disconnects, rapid roll excursions, [and] guidance on how to cope with these events. ”

In addition to stating that ATR did not provide to operators the above-referenced information, the NTSB also states that an “aileron hinge moment reversal” mechanism was disclosed in the icing related incidents it reviews, and criticizes ATR for failing to issue warnings to specifically describe such an event. The NTSB’S “facts” are wrong and its assertion is untrue.

The basis for the NTSB’S assertion is it’s claim that an “aileron hinge moment reversal” was involved in the incidents of Mosinee, Ryanair, Air Mauritius, Burlington, and Newark and was therefore known to ATR. On the contrary, the DFDR data from Mosinee, Ryanair, Air Mauritius and Burlington incidents confirm that they were all stall departures following ice accumulations which resulted from flight crew failures to follow the basic procedures for operation in icing conditions by failing to select airframe de-icing, to maintain minimum airspeeds or proper propeller speed settings. No “aileron hinge moment reversal” was involved in Ryanair or Air Mauritius. The momentary modification of the aileron hinge moment in Mosinee and in Burlington which occurred after the asymmetrical stall commenced had no direct effect on these incidents. Both the NTSB and ATR determined that the Newark incident involved severe turbulence. From a review of the Newark DFDR data after Roselawn, because of the high level or turbulence, it cannot be determined whether or not any aileron hinge moment modification was involved in the incident.

The incorrect assertion by the NTSB of prior ATR knowledge is all the more surprising because the NTSB was the primary investigation authority for the Mosinee incident with full access to the facts and data involved. It had full access to the BEA's report, which incorporated fully ATR's own investigation report, and was involved in several meetings with the DGAC, the BEA and the FAA. The NTSB'S level of participation and knowledge of the Mosinee incident was as great as any other entity investigating the incident. The NTSB had absolutely no recommendations or suggestions for any other corrective action, warnings, or any other response based on the Mosinee incident.

The NTSB's assertion is also surprising because the NTSB not only received the full and open cooperation of the manufacturer following the Roselawn accident, but also encouraged and participated in the manufacturer's extensive efforts after the accident that led to the discovery of the ice-induced "aileron hinge moment reversal" phenomenon. The NTSB knows of the extensive wind tunnel testing, high speed taxi tests, flight testing, and millions of dollars spent by ATR after Roselawn for the first-ever USAF tanker freezing drizzle/rain testing program for civil or military aircraft at Edwards AFB. The NTSB knows from its own involvement in the testing that the phenomenon of an ice-induced "aileron hinge moment reversal" was discovered for the very first time as a result of this exhaustive post-Roselawn investigation by ATR.

The BEA also would like to note that even if the phenomenon of an ice-induced "aileron hinge moment reversal" had been previously identified, there would have been no need to include this type of technical information in further a warning to flight crews.

The warnings which were previously provided by ATR to all operators, including Simmons, and which in turn were provided by Simmons to all its flight crews, identified that the weather environment of concern could result in an increase in roll control force which might cause a autopilot disconnect and a roll to a large bank angle until the controls were taken over by the crew. The fact that such a change in aileron control force might or might not be caused by an “aileron hinge moment reversal” is not a piece of information which would have added to the warning provided by Simmons to its flight crews. So long as the flight crews have been informed as to what they might experience in terms of their control of the airplane i.e., a ice-induced change in roll control forces an autopilot disconnect, a roll to a large bank angle, and the need to employ a firm manual control to recover, it is nonsensical to suggest that they need to know the scientific cause of the roll departure in order to deal safely with it.

The BEA respectfully submits that the NTSB does not promote aviation safety by ignoring its own role in the investigation of these prior incidents and by misrepresenting facts in order to advocate a position of prior knowledge by a manufacturer. The NTSB was the lead investigative authority for the most significant of the prior ATR icing incidents. It is quite odd now for the NTSB to assert that these same prior incidents disclosed an ice-induced “aileron hinge moment reversal” phenomenon to ATR and not to itself. It is doubly odd for the NTSB to make this assertion when it encouraged and participated in the Edwards AFB test program whose stated goal was to discover for the first time whether “freezing drizzle conditions could produce an aileron hinge moment divergence” (as the NTSB so-called the phenomenon in its comments on the Edwards AFB flight test plan).

What is most disturbing about the report's position on this point is that it obscures the safety concern disclosed in this accident that this flight crew was so oblivious to the icing conditions they encountered that they ignored the multiple warnings, instructions, and regulations they already had received regarding proper operations in such conditions. To suggest that a more specific warning about an "aileron hinge moment reversal phenomenon would have had any impact on this flight crew is not supportable by the NTSB's record of investigation.

2.7.2. ATR DISSEMINATION OF ICING INFORMATION

The BEA strongly disagrees with paragraph 1 of the report's Probable Cause Statement regarding ATR's alleged failure to "completely disclose to operators and incorporate in the ATR- 72 AFM and FCOM and training programs, adequate information concerning previously known effects of freezing drizzle and freezing rain conditions on the stability and control characteristics, autopilot and related operational procedures when the ATR-72 is operated in such conditions. " The NTSB's position in this regard completely ignores the critical factual information discussed in Sections 1.4.1 and 1.4.2, above which shows that ATR did provide specific warnings in respect to these issues. The BEA discusses its further comments regarding this issue below.

Despite the lack of identification by the NTSB, BEA, ATR, FAA, and DGAC, prior to the Roselawn accident of the freezing drizzle induced "aileron hinge moment reversal" phenomenon, the documents discussed in Sections 1.4.1 and 1,4.2 above clearly show that American Eagle/Simmons passed on to its flight crews these ATR warnings that, under icing conditions outside those specified in 14 CFR Part 25, Appendix C, the ATR-42/72 aircraft performance and control forces may be affected in such a way that autopilot self-disconnect and subsequent roll excursions could occur; that roll efficiency would nevertheless be maintained; and that recovery could be readily achieved by making firm aileron inputs to counter the roll excursions, and by applying basic stall recovery techniques.

Simmons own “restatement of company operations policies”

(ref. Appendix 2) further provided :

- a) “Large droplets of freezing rain impact much larger areas of aircraft components and will in time exceed the capability of most ice protection equipment”;
- b) “Flight in freezing rain should be avoided where practical”;
- c) “If icing or adverse weather is experienced, make a PIREP . . .”;
- d) “Freezing rain may form ice on an aircraft that is near the freezing level”;
- e) “If freezing rain is encountered, you should exit the condition immediately. This diversion should consist of a turn towards better conditions and/or climb to a warmer altitude”;
- f) “Freezing rain and clear ice can be very difficult to recognize on an aircraft, therefore it is strongly recommended when operating in conditions favorable to this type of icing that an extra vigilance be maintained;”
- g) “However, our aircraft are not to be operated in known freezing rain or severe ice. If these conditions are experienced, the procedure is to exit these conditions immediately. ”

Flight 4184’s flight crew violated these “company operations policies” by not avoiding freezing precipitation conditions; by not making a PIREP; by not exiting the freezing precipitation conditions immediately, and most importantly, by not exercising crew vigilance in such conditions. To suggest that a more specific warning about a freezing drizzle induced “aileron hinge moment reversal” phenomenon, which was not known until after the Roselawn accident, would have had any impact at all on this flight crew, is not supported by the record.

Finally, when the Simmons “company operations policies” discussed above are combined with the multiple warnings, instructions, and regulations this flight crew had already been provided, as discussed by the BEA in Section 1.4.1 and 1.4.2 above, it is clear that ATR and the Operator Simmons had provided numerous warnings of the type the NTSB describes as missing, regarding the hazards of flight operations in icing conditions, including freezing precipitation conditions. Had these warnings not been ignored by the crew of Flight 4184, this accident would not have occurred.

2.7.3. ATR TRAINING FOR UNUSUAL ATTITUDES

ATR developed a Flight Simulator Data Package to enable simulation of aircraft behaviour cases of unusual attitudes.

This Data Package was contained in the Flight Safety International Simulators, in particular in Houston since early 1989.

The normal training syllabus includes demonstrations of recovery from unusual attitudes as early as the second training session. This demonstration consists of large longitudinal and lateral excursions approaching 60° bank angle without reaching the stall.

The BEA is concerned by the AMR Eagle’s decision not to have taken advantage of this simulator capability until after this accident.

3. CONCLUSION

3.1. BEA FINDINGS

The BEA strongly believes that the following Findings are mandated by the facts of this accident. These Findings are fully supported by the previously cited factual references and analysis of the accident.

1. This accident occurred as a result of a prolonged operation of the aircraft in freezing drizzle/rain conditions well beyond the certification envelope for all aircraft.
2. Airworthiness Authorities and the aviation industry worldwide did not sufficiently recognize, prior to the Flight 4184 accident, freezing drizzle characteristics and their potential effect on aircraft performance and controllability.
3. Despite investigation of prior incidents involving icing conditions outside 14 CFR Part 25, Appendix C, by the NTSB, BEA, ATR, FAA and DGAC, these parties did not anticipate the mechanism of the ice-induced aileron hinge moment reversal that was involved in this accident and that was not discovered until the post-accident Edwards AFB testing program.

4. ATR properly analyzed and took appropriate and adequate measures in response to such prior icing related incidents.
5. The DGAC acted correctly and properly in its certifications of the different ATR model aircraft as the primary certification authority, and the FAA properly applied the Bilateral Airworthiness Agreement in its certifications of the aircraft.
6. The DGAC provided appropriate oversight of the continued airworthiness of the ATR-42 and ATR-72 aircraft and took all appropriate actions to assure the continued airworthiness of the aircraft in response to such prior icing related incidents.
7. The DGAC provided the FAA on a timely basis with all relevant airworthiness or safety of operation information developed from previous ATR icing incidents, including those in freezing rain, in full compliance with the BAA and ICAO Annex 8.
8. The FAA Indianapolis Ground Controller released Flight 4184 from a 42-minute ground hold despite having been informed by the Traffic Management Coordinator that conditions were such that the flight would likely be required to hold in the air before reaching its destination. The release of Flight 4184 under these conditions was contrary to the policy established in FAA Order 7110.65, Air Traffic Control, to reduce congestion in the air traffic system and to limit the duration of airborne holding.

9. American Eagle/Simmons' policy precluded the distribution of AIRMET Zulu Update 3 for icing and freezing level in the Flight Release for Flight 4184. This AIRMET was applicable to Flight 4184's route of flight from Indianapolis to Chicago, and stated that "light occasional moderate rime icing in cloud and in precipitation" could be expected. This AIRMET also provided information regarding the freezing level along Flight 4184's route of flight.

10. AMR Eagle/Simmons was adequately warned by ATR prior to the accident about the dangers of operating in freezing precipitation and understood the need to avoid such conditions.

11. AMR Eagle/Simmons, in turn, warned its flight crews prior to the accident about the dangers of operating in icing conditions, including freezing precipitation, and instructed its flight crews to avoid such conditions.

12. The flight crew of Flight 4184 had been expressly warned about the dangers of freezing precipitation and the necessity of crew vigilance.

13. Flight 4184's flight crew knew they were operating in icing conditions.

14. Proper monitoring of the outside air temperature, clouds, precipitation, and the ice accumulating on the aircraft by the crew of Flight 4184 would have informed them that they might be operating in a freezing precipitation environment.

15. Despite these warnings and instructions, and having entered known icing conditions, the flight crew of Flight 4184 had absolutely no discussions regarding: the nature and extent of the icing conditions they were encountering; the outside meteorological conditions; the need to request a clearance to an alternative altitude or route to remain clear of the known icing conditions; the operation of the aircraft's de-icing and anti-icing equipment.

16. Flight 4184's flight crew had ample opportunity to ask the ATC for a clearance to exit the icing conditions.

17. AMR Eagle/Simmons' company policies require that flight crews stay out of icing conditions when possible.

18. After the Mosinee incidents, ATR proposed to the FAA, through the DGAC, a revision to the ATR-42 FCOM and AFM which contained information on the effects of freezing rain conditions on aircraft stability and control characteristics and on the autopilot and set forth related operational procedures to be used when an aircraft inadvertently encounters such prohibited conditions. This proposal was not accepted by the FAA.

19. ATR provided Simmons and other operators with the identical information, applied to both the ATR-42 and ATR-72 aircraft, concerning the effects of freezing rain (understood by Simmons to include "freezing precipitation" in the AOM).

20. ATR provided specific warnings to Simmons and other operators, for their pilots, about the adverse characteristics of freezing rain and about roll events which could occur in such conditions and gave specific guidance for recovery from such events and, in addition, developed aircraft modifications seeking to reduce the possibility of such events occurring.

21. Simmons company policy had already provided ample instructions to the Flight Crews regarding the icing threat and the basic rules of behaviour to face such a situation.

22. The failure of Flight 4184's flight crew to follow these company policies and manual provisions and exit the known icing conditions led directly to this accident.

23. Despite the lack of anticipation by the NTSB, BEA, ATR, FAA and DGAC, prior to the accident, of the mechanism of the ice-induced aileron hinge moment reversal, Simmons/AMR Eagle and its flight crews had been warned that, under icing conditions outside those specified in 14 CFR Part 25. Appendix C the ATR 42/72 aircraft performance and controllability might be affected in such a way that auto-pilot self-disconnect and subsequent roll excursions could occur; that roll efficiency would nevertheless be maintained; that recovery could be achieved by making firm aileron inputs to counter the roll excursions and by applying basic stall recovery techniques. These were appropriate and adequate instructions to flight crews based on what was known from prior incidents.

24. ATR adopted appropriate and adequate changes to its flight crew training program and simulator data training package based on what was known from prior icing incidents.

25. Chicago ARTCC controllers were aware that light to moderate icing conditions were forecast for the area of LUCIT intersection at the time Flight 4184 was released from its ground hold.

26. Chicago ARTCC controllers had received PIREPs reporting icing conditions on the day of the accident and had been specifically briefed by their supervisor at the beginning of their shift that they must be aware of icing conditions and because "Icing Kills".

27. Chicago ARTCC controllers were aware that the weather conditions were deteriorating throughout the Chicago area before and during the time Flight 4184 was enroute from Indianapolis to Chicago. Therefore they could not have ignored the specific weather conditions at the Lucit holding pattern, at Flight Level 100.

28. If the Controller at Chicago ARTCC had received an icing PIREP from Flight 4184, immediate precautionary communication would have been made by ATC with the crew regarding exiting the icing area.

29. Flight 4184 was the only aircraft holding at LUCIT intersection, and multiple altitudes were available for diversion from the known icing conditions.

30. AMR Eagle/Simmons' company policy, Federal Aviation Regulations, and the Airman's Information Manual require that flight crews provide ATC with a PIREP of known icing conditions. However the crew of Flight 4184 did not to provide such a report of their known icing conditions.

31. Had the crew of Flight 4184 provided to ATC the mandatory PIREP of their known icing conditions, ATC would have provided them with a diversionary clearance so that they could have immediately exited the icing conditions. The flight crew's failure to provide a PIREP of their known icing conditions contributed to this accident.

32. FAA Order 711 0.65J, *Air Traffic Control*, requires ATC controllers to solicit PIREPS of "icing of light degree or greater" when such conditions exist or are forecast to exist in their area of jurisdiction. ATC did not solicit an icing PIREP from Flight 4184, that contributed to this accident.

33. ARTCC failed to report to the Air Traffic Control System Command Center (ATCSCC) and the Traffic Management Coordinator of the excessive holding time experienced by Flight 4184 as required.

34. The Sterile Cockpit Rule (as imposed by FAR 121.542 and Simmons/AMR Eagle's Flight Manual) requires the captain to impose the rule during any phase of a particular flight as deemed necessary. This rule should have been applied by the Captain of Flight 4184.

35. Flight 4184's holding in known icing conditions at 10,000 feet, in instrument conditions, awaiting momentary clearance to descend below 10,000 feet to commence an instrument approach into one of the world's busiest airports constituted a "critical phase of flight" within the meaning and intent of FAR Section 121.542.

36. The flight crew of Flight 4184 demonstrated a lack of involvement in primary duties and failed to exercise proper situational awareness as well as proper Cockpit Resource Management. This directly contributed to the accident.

37. The Captain's lack of assertiveness and complete failure to integrate himself into the required flight activities left the entire operation of the aircraft to the First Officer.

38. AMR Eagle/Simmons' ATR42/72 Airplane Operating Manual (AOM) provides only for holding with the aircraft configured in the flap zero degree configuration. Flight 4184's flight crew's unauthorized use of the flap 15 configuration while holding at 175 knots in icing conditions created the critical ice ridge beyond the de-icing boots which ultimately led to the roll upset, and thereby directly contributed to the accident.

39. Post-accident flight tests at Edwards Air Force Base and in France confirmed that Flight 4184 was recoverable after the initial roll upset.

3.2. PROBABLE CAUSE

This accident was caused by a combination of factors, as reflected in the following BEA-proposed Probable Cause Statement :

The Probable Cause of this accident is the loss of control of the aircraft by the flight crew, caused by the accretion of a ridge of ice aft of the de-icing boots, upstream of the ailerons, due to a prolonged operation of Flight 4184 in a freezing drizzle environment, well beyond the aircraft's certification envelope, close to VFE, and utilizing a 15 degree flap holding configuration not provided for by the Aircraft Operating Manuals, which led to a sudden roll upset following an unexpected Aileron Hinge Moment Reversal when the crew retracted the flaps during the descent.

The contributing factors to this highly unusual chain of events are :

1. The failure of the flight crew to comply with basic procedures, to exercise proper situational awareness, cockpit resource management, and sterile cockpit procedures, in a known icing environment, which prevented them from exiting these conditions prior to the ice-induced roll event, and their lack of appropriate control inputs to recover the aircraft when the event occurred ;

2. The insufficient recognition, by Airworthiness Authorities and the aviation industry worldwide, of freezing drizzle characteristics and their potential effect on aircraft performance and controllability ;

3. The failure of Western Airworthiness Authorities to ensure that aircraft icing certification conditions adequately account for the hazards that can result from flight in conditions outside 14 CFR Part 25, Appendix C, and to adequately account for such hazards in their published aircraft icing information;

4. The lack of anticipation by the Manufacturer as well as by Airworthiness and Investigative Authorities in Europe and in the USA, prior to the post accident Edwards AFB testing program, that the ice-induced Aileron Hinge moment reversal phenomenon could occur.

5. The ATC's improper release, control, and monitoring of Flight 4184.

4. RECOMMENDATIONS

The BEA notes with interest the disparity between the broad scope of the recommendations which the NTSB makes as a result of this accident and the selective focus of the NTSB's statements of its findings and proposed Probable Cause of this accident. Except as noted below, the BEA agrees with the NTSB recommendations.

4.1. FLIGHT CREW PERFORMANCE -STERILE COCKPIT

It is significant that the Report recommends that the FAA evaluate the need to make observance of the sterile cockpit rule mandatory for air carriers when their aircraft are holding in icing conditions regardless of altitude (4.2.8), and recommends that AMR Eagle "encourage" its captains to observe a sterile cockpit environment in icing conditions. These recommendations are in sharp contrast with the Report's incorrect "findings" that the gross distractions of this flight crew and the Captain's departure from the cockpit in known icing conditions "did not contribute to this accident". The BEA suggests that the NTSB recommend that the FAA take steps to emphasize that the sterile cockpit rule applies to all critical phases of flight, and that a critical phase of flight includes all operations in known icing conditions, regardless of altitude. This recommendation is consistent with the FAA's rationale behind the sterile cockpit rule.

4.2. PRE-FLIGHT AND IN-FLIGHT WEATHER INFORMATION

The report's nine recommendations regarding pre-flight and in flight weather information (4.11 - 4.16, 4.3, 4.2, and 4.3) seek to assure that pilots are provided, obtain, and consider all pertinent weather information both for in-flight and pre-flight planning purposes, and that further steps be taken to improve the quality of the information. The BEA agrees with these recommendations, but finds it surprising that the report makes no mention in its findings of the failure of, the Company to provide the flight crew of Flight 4184 with AIRMET information which specifically forecasted icing conditions along their route of flight, and the complete absence in the CVR transcript of any effort by the flight crew to update their weather information while enroute and during their hold.

4.3. PIREPS

The BEA suggests that the NTSB recommend that the FAA and American Eagle/Simmons take steps to enforce the Airman's Information Manual (AIM) requirement that flight crews "report icing conditions to ATC/FSS. " The BEA also suggests that the NTSB recommend that the FAA take steps to enforce FAA Order 7110.65, Air Traffic Control, which requires that ATC solicit PIREPS regarding "icing of light degree or greater. " The failure of the flight crew to provide a PIREP to ATC, and the failure of ATC to solicit a PIREP from the flight crew, and the critical effects of these failures in contributing to this accident are ignored by the report in its findings and recommendations. It is insufficient to simply suggest, as does report Recommendations 4.31 that the definition of PIREP information should be amended.

4.4. AIRCRAFT CERTIFICATION - FREEZING DRIZZLE/RAIN

The report's five recommendations regarding aircraft certification (4.17 - 4.21) properly call for more accurate determination of the parameters affecting ice accretion. However, if the recommendation to expand the icing certification envelope to include freezing drizzle/freezing rain conditions "as necessary" is meant to imply that the NTSB believes aircraft should now be certified for operations in these dangerous conditions where the risks to aircraft are still relatively unknown, instead of focusing on improved detecting and avoidance of these conditions, the interests of aviation safety are not being served. Regarding the report's recommendation for certification test programs and certification criteria, these issues are addressed in Recommendation 3 of the Special Certification Review Report of the FAA and DGAC. The BEA therefore suggests that this recommendation be adopted by the NTSB to replace the current recommendation on this subject.

4.5. CERTIFICATION AND CONTINUING AIRWORTHINESS UNDER THE BAA

The BEA believes that with respect to the report's three recommendations to the FAA regarding certification and monitoring of continued airworthiness of aircraft operating in the U.S. (4.25 to 4.27), the NTSB recognizes that the concern is not with the BAA itself, but instead with the procedures being used for the mutual exchange of significant incident, accident, and other airworthiness information pursuant to either the BAA or other formal or informal agreements between the FAA and DGAC. The BEA suggests that the report recommend that the NTSB and the FAA take steps to assure that all pertinent information from accident and incident investigations conducted by the NTSB or FAA involving a foreign manufactured aircraft, including all facts and analyses of incidents and accidents and other airworthiness information, is provided on a timely basis to the exporting country's airworthiness authority so that it can monitor and insure the continued airworthiness of aircraft certified by it as the primary certification authority.

4.6. ATR

The recommendation the report makes to ATR is written so as to imply that there is a “hinge moment reversal problem” with the aircraft that has not been resolved. The BEA disagrees with this implication. The actions taken as a result of the post-accident investigation and test program, including those addressed to flight crews and the modifications of the boots, addressed and resolved the issue. The BEA also does not believe that this issue is unique to ATR. Rather, it applies to all turboprop aircraft, as evidenced by the recent FAA proposed Airworthiness Directives on this subject, which apply to virtually every model of turboprop aircraft in the world. The BEA encourages the further work being done by ATR to consider redundant safety measures to protect against inadvertent encounters with icing conditions beyond Appendix C certification standards.

4.7. AMR EAGLE

Based on the lack of cockpit discipline, the BEA suggests that the report recommends that the FAA and AMR Eagle take all necessary steps to prevent the recurrence of such conduct. In this regard, AMR Eagle's operating and training procedures should be fully reviewed and corrected if necessary, so as to address such conduct.

The BEA agrees with the report recommendation that the FAA require air carriers to provide standardized training that adequately addresses recovery from unusual events and unusual attitudes (4.29). Based upon this accident, the BEA supports the report recommendation that AMR Eagle takes steps to immediately institute a training program to address these issues with its flight crews.

5. APPENDICES

**APPENDIX 1 : Letter DGAC to FAA Bruxelles (Mr. VAROLI) n°53296
dated 21 Mars 1989**

**APPENDIX 2: Memorandum SIMMONS Airlines - Loss of aircraft
stability (N427MQ) January 23, 1989.**

**APPENDIX 3: STUDY OF METEOROLOGICAL INFORMATION AS
CONTRIBUTION TO THE NTSB REPORT
(April 15, 1996)**

APPENDIX 1

**Letter DGAC to FAA Bruxelles (Mr. VAROLI)
dated 21 Mars 1989**

DIRECTION GENERALE
DE L'AVIATION CIVILE

Paris, le 21 MARS 1989

SERVICE DE LA FORMATION AERONAUTIQUE
ET DU CONTROLE TECHNIQUE

ED210389/EL210389

BUREAU CERTIFICATION

TEL 40.43.45.06

N/RE **53296** SFACT/TC

Monsieur l'Administrateur
de la FEDERAL AVIATION ADMINISTRATION
American Embassy
27 Bd du Régent

B 1000 BRUXELLES

BELGIQUE

(ATN M. VAROLI)

AFFAIRE SUIVIE PAR M. DORMOY

- Ref : 1. FAA facsimile letter RA/VK0969/89
dated March 14, 1989
2. DGAC facsimile letter, same subject,
dated March 17, 1989
3. FAA facsimile letter, RA/vk/1027:89
same subject, dated March 20, 1989
4. FAA letter (from MR. M.C. BEARD) to
RAI, dated May 26, 1988, freezing
rain conditions
5. FAA AC 20.117.

Monsieur l'Administrateur,

Notre lettre référencée en (2) ci-dessus, a exprimé les commentaires de la DGAC sur le projet d'AD de la FAA pour l'ATR 42L. La FAA a accepté d'étudier les propositions de solutions différentes que pourraient fournir la DGAC ou le constructeur de l'ATR, en vue d'arriver à une action commune en France et aux Etats-Unis.

La note jointe en annexe est ainsi proposée pour l'analyse de la FAA.

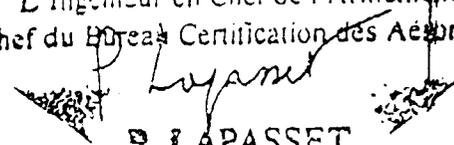
Les commentaires pour la NPRM sur l'AAS vous seront envoyés le 22 mars 1989.

Je vous prie d'agréer, Monsieur l'Administrateur, l'expression de ma considération distinguée.

J. : 1 note

Copies : FAA Washington M. BEARD
FAA Seattle M. LEROY Keith
M. Martenson (ANM 113)
M. CRACKEN (ANM 113)

L'Ingénieur en Chef de l'Armement
Chef du Bureau Certification des Aéronefs


P. LAPASSET

COURTESY TRANSLATION

Our reference (2) letter above expressed comments of DGAC regarding FAA's plans for AD actions for the ATR 42. FAA has agreed to consider the alternate proposals to be provided by the DGAC, in a view of a common US/French action, or by the ATR constructor. The following note is accordingly submitted for FAA consideration.

Comments on NPRM about AAS will be sent on 1989, march 12.

Planned priority letter AD - restricting the use of the autopilot

1. As previously mentioned, the DGAC is concerned about the global crew workload increase that would result from systematically prohibiting the use of the autopilot in such a wide range of conditions as that of the FAA planned AD and the subsequent negative impact on flight safety.

The prime cause of the 5/N 91 incident seems to us moreover to be a prolonged operation within freezing rain conditions, more than an inappropriate autopilot behaviour or an "unusual" airplane response. This would refer to an assessment of likely airplane responses in freezing rain conditions which up to now are not envisaged by the requirements.

For these reasons and as far as the priority AD action is concerned, the DGAC will require to amend the Airplane Flight Manual for both :

a) - emphasizing the need to avoid continued flight in freezing rain conditions. This of course is based on the fact that such conditions are usually predictable, recognizable and avoidable. As mentioned in our previous facsimile letter, the ATR constructor has been requested to publish an appropriate background information, for helping the crews in the observance of this limitation.

b) - giving simple procedures for the cases where freezing rain conditions cannot be temporarily avoided or are inadvertently encountered. These procedures do include the prohibition of the use of the autopilot.

You will find enclosed in Attachments 1 and 2 respectively the proposals of AFM - Limitations Section change and of the relevant O.E.B. Your comments would be very much appreciated.

2. During the FAA/DGAC/ATR meeting held in Seattle on March 6, 1989, it has been shown that the incident most probably occurred as a consequence of asymmetrical ice buildups on the wing in front of the ailerons, after a prolonged flight in freezing rain.

The ATR constructor has very recently been led to investigate, as part of the development of the ATR 72 project, several options for its roll control. Among these configurations, the installation of vortex generators on the upper wing surface forward of the ailerons has proved to be efficient in correcting the local airflow disturbances coming from ice buildups on the leading edge. This improvement should be also worthwhile in the cases of asymmetric ice buildups or deposits. This device has no detrimental effect on the other roll control characteristics.

The constructor is therefore evaluating its effect on the ATR 42. Preliminary flight tests have shown very encouraging results. Additional flight testing are presently made with the French CEV. An evaluation could be made by the FAA flight test pilot at the same time in Toulouse.

2.

This improvement could answer some concerns expressed by the FAA and by the DGAC following the S/N 91 incident. Should this investigation be shown satisfactory, the ATR constructor could complete a retrofit of the US ATR 42 fleet within a short period, of the order of three months.

This action has received a high priority level and is closely monitored by the DGAC.

ATTACHMENT 1

A F M CHANGE LIMITATIONS SECTION

2.01.02 - KINDS OF OPERATION

add to the current paragraph

- Operation in freezing rain shall be avoided.

WARNING: Ice accretion due to freezing rain may result in asymmetrical wing lift and associated increased aileron forces necessary to maintain coordinated flight.

Should the aircraft enter into a freezing rain zone, the following procedure must be adhered to:

- a - autopilot shall not be used
- b - speed shall be increased in keeping with performance in prevailing weather conditions (turbulence), that is:
 - . Flaps retracted: 150 kt minimum
 - . Flaps extended: as close as possible to VFE for the airplane configuration.
- c - excessive manoeuvring shall be avoided
- d - freezing rain conditions shall be left as soon as possible. This can usually be accomplished by climbing to a higher altitude into the positive temperature region or by altering course.

ATTACHMENT 2

OPERATION ENGINEERING BULLETIN

- FREEZING RAIN -



OEB

N 023

ISSUE N° 1

Revised by
OEV/PN

MAR 88

SUBJECT : FREEZING RAIN

1 - Reason for issue

Inform the flight crew on :

- freezing rain phenomenon
- identification of freezing rain
- procedures to adopt in the event of flight through an area where freezing rain is present.

DRAFT

2 - Background information

a) General

Freezing rain is a precipitation of large supercooled water drops. These drops (negative temperature) may be transformed into clear ice when impacting the aircraft's skin in slightly negative temperature condition.

b) Freezing rain phenomenon

- Freezing rain conditions normally occur as a result of weather conditions wherein temperature increases with altitude (temperature inversion). Warm rain falls from or through this warm layer into a region of subfreezing temperature and typically becomes supercooled. These supercooled large rain drops will then freeze upon impact with an object. Freezing rain water drops are known to exist up to about 1300 microns in diameter (instead of 8 to 80 microns for droplets).
- Impact of these large drops on the leading edge of an aircraft wing or other aerodynamic surfaces, under certain conditions, can cause the entire surface to become incrueted in ice. To protect an aircraft from freezing rain of this type would require that the entire aircraft rather than just the leading edges, be equipped with de-icing and anti-icing equipments. This, traditionally, has been considered impractical.

1/4

Validly : All aircraft until further notice



AIR 42

O E B

N° 22

ISSUE N° 1

ISSUED BY
OIV/PH

MAR 19

- ice accretion due to freezing rain may result in asymmetric wing lift and associated increased aileron forces necessary to maintain coordinated flight.

c) Freezing rain localization

Freezing rain rarely occurs and is rarely encountered at high altitudes unless associated with large storm systems such as thunderstorms. It is normally a low altitude weather phenomena and is mainly linked to the presence of a front (temperature ranging from - 40 °C to 0 °C).

d) Freezing rain and certification

Advisory circular 80.117 states :

"It is emphasized that aircraft ice protection systems are designed basically to cope with supercooled cloud water environment (not freezing rain). Supercooled cloud water droplets have a median volumetric diameter (MVD) of 8 to 60 microns. Freezing rain MVD is as great as 1300 microns. Large drops of freezing rain impact much larger areas of aircraft components and will, in time, exceed the capability of most ice protection equipment. Flight in freezing rain should be avoided where practical".

e) Avoidance

Freezing rain conditions are usually predictable, recognizable and avoidable.

* these conditions are predictable :

- on ground by
 - . consulting weather chart
 - . reading AIREP and AIRMET message
 - in flight by
 - . listening to SIGMET message
 - . monitoring outside air temperature for the presence of temperature inversion condition.
- note : Temperature inversion is a zone where temperature increases with altitude.

DRAFT

2/4

Validity : All aircraft until further notice



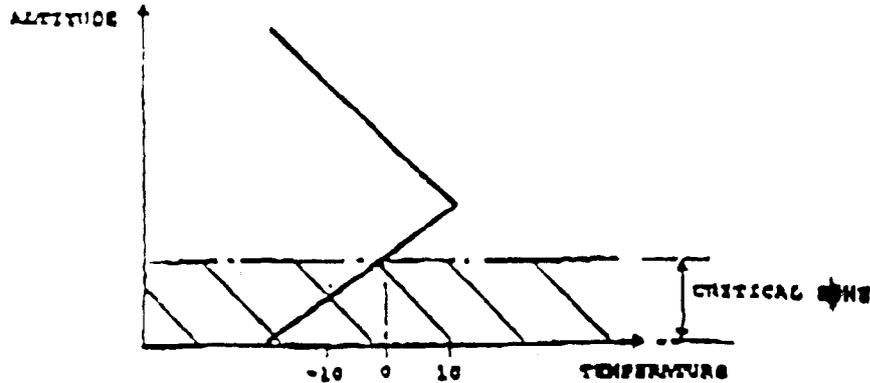
OEB

N°2

ISSUE N°1

ISSUED BY
OGV/PH

MAR 88



* These conditions are recognizable :

If heavy rain occurs whenever the flight crew have identified conditions propitious to freezing rain formation, it is highly probable that freezing rain is involved.

Note : Heavy rain is visually detectable (at night even ON the landing lights) and can be heard striking the fuselage

If all above conditions are met, this heavy rain will lead to clear ice building on aircraft it is :

- transparent and consequently more difficult to detect but gives an unusual shiny aspect to the covered surfaces.
- adhere to most of the surfaces of the aircraft which limits the effectiveness of the deicing boots to the leading edge surfaces.

Zones where freezing rain is likely to be encountered MUST BE AVOIDED.

3/4

Validity : All aircraft until further notice



ATR 42

OEB

N° 23

ISSUE N° 1

ISSUED BY
OSV/BN75
MAR 89

3 - Procedure

Nevertheless, should the aircraft enter in a freezing rain zone, the following procedure must be applied.

- a) Do not use Auto Pilot.
- b) Increase speed in keeping with performance and prevailing weather conditions (turbulence)
flaps retracted : 180 kt minimum
flaps extended : as close as possible to VFE for aircraft configuration.
- c) Avoid excessive manoeuvring.
- d) Leave freezing rain conditions as soon as possible. This can usually be accomplished by climbing to a higher altitude into the positive temperature region or by altering course.

DRAFT

4/4

Validity : All aircraft until further notice.

APPENDIX 2

**MEMORANDUM SIMMONS AIRLINES
LOSS OF AIRCRAFT STABILITY (N427MQ)
JANUARY 23, 1989**

SIMMONS AIRLINES

TO: All Flight Crewmembers
FROM: Dave Wiegand, Director of Flying *DW*
RE: Loss of Aircraft Stability (N427MQ)
DATE: January 23, 1989

The following is a synopsis of events that occurred with N427MQ during the initial approach phase to CWA on Thursday December 22, 1989. The subsequent events following the incident will be presented along with a summation and recommendations.

INCIDENT

N427MQ, ATR-42, departed ORD as MQ Flight 4295. Departing ORD the load manifest lists a take-off weight of 34,051 pounds, which included a fuel load of 4000 pounds and 34 passengers.

The enroute flight to CWA was described by the crew as normal. The cruising altitude was 16,000 feet with a TAT of -25 oC. The crew was running level 3 ice protection systems because light rime ice was being experienced enroute. All aircraft systems were functioning normally. The Captain was the flying pilot and continued as the flying pilot, until the A/C was safely on the ground at CWA.

The descent and initial approach phase were conducted in controlled airspace under the control of MSP Center. The planned procedure was to receive radar vectors for a straight in approach to the ILS RWY 8 at CWA. The initial approach vectoring was done at an altitude of 6000 feet because of MSP Center radar coverage limitations in the CWA area. The crew reports that conditions at 6000 feet were IMC with a TAT of + 10 oC, in light precipitation. Level 2 anti-ice systems were selected ON. When the flight was located northwest of the outer marker and north of the localizer, they were given a final heading for the localizer intercept, a descent to 3000 feet and clearance for the ILS RWY 8 approach. Prior to passing the Outer marker, the Captain decided the vectors given from MSP Center were unsatisfactory, attributable to a strong southerly air flow experienced at their altitude. A request was made from MSP Center for clearance direct to AUW VOR and the ILS RWY 8 to CWA via their own navigation.

After the requested clearance was issued by MSP the flight proceeded directly to the AUW VOR at 3000 feet. After crossing the AUW VOR Flight 4295 proceeded to track outbound on the AUW VOR 237 o radial until intercepting the ICWA localizer outbound, to be followed by a published procedure turn and straight in ILS RWY 8 approach to CWA. The remainder of the flight, up to the

point of the incident was conducted at 3000 feet. The aircraft was experiencing light precipitation until entering the procedure turn. Shortly before the incident the precipitation increased significantly. The autopilot was on, with the high bank mode selected.

The crew had initiated a turn toward the inbound procedure turn heading when they experienced an aircraft vibration, described as being similar to a prop imbalance. Immediately following the vibration, the auto pilot disconnected and the A/C rolled sharply to the left. At this point the flight crew implemented stall recovery procedures. The rapid response of the flight crew to the situation, enabled the aircraft to be controlled to less than 500 feet of altitude loss. After aircraft control was regained the flight proceeded safely and without further incident for a landing at CWA.

Following the incident, as the flight was being vectored for the final approach to CWA, the crew received an updated weather report on the field conditions at CWA. This update reported that freezing rain had just moved through the CWA area. The airport maintenance department was in the process of applying de-ice chemical to the runways. The airport was still open.

SUMMATION

The data obtained from the DFDR at the time of the incident shows the following:

- Temperature + 10 TAT
- Airspeed 151 Knots
- Flaps and gear Retracted
- Aircraft heading..... 295 Degrees
- Props..... 86%
- Torque..... 20% left and 30% right
- Auto pilot..... ON
- Stick Pusher..... Not activated
- Maximum Bank Angle.... 65o
- Radar Altimeter..... 1145 AGL

The Aerospatiale analysis of the DFDR and CVR has established that:

1. The A/C was submitted to freezing rain
2. This freezing rain affected control forces on the ailerons in such a manner that the autopilot was no longer able to maintain the bank angle in the procedure turn.
3. As a consequence the A/P was normally disconnected by its monitoring system.
4. The A/C rolled to a large bank angle until the pilot took

over the control manually. From that point the response of the A/C to pilot aileron inputs was correct. However, due to the accumulation of ice on the control surfaces the aircraft response was sluggish.

5. The rest of the flight was uneventful including the landing on an ice covered runway.
6. The ice collected on the aircraft surface was dissipated during the climb to 6000 feet following the incident recovery.

Taking into account the information presently available, the A/C manufacturer considers that nothing needs to be changed on the A/C or in the operating procedures. This position has the agreement of the French Airworthiness Authority.

The manufacturer wishes to recall the general recommendation of the FAA Advisory Circular AC 20-117 issued in December 1982. (A reprint may be found in the Simmons Airline Training Department, Winter Operations for Flight Crews Manual, issued in November of 1988.)

It is emphasized that aircraft ice protection systems are designed basically to cope with the supercooled cloud environment (not freezing rain). Supercooled cloud water droplets have a median volumetric diameter (MVD) of 5 to 50 microns. Freezing rain MVD is as great as 1300 microns. Large droplets of freezing rain impact much larger areas of aircraft components and will in time exceed the capability of most ice protection equipment. Flight in freezing rain should be avoided where practical.

(REF. Telex DCS/E 1/89)

RECOMMENDATIONS

The incident most probably occurred as a result of the effects of a significant accumulation of airframe ice degrading the aircraft's stability and control characteristics, such that the crew had to apply stall recovery techniques. It is important that crews continue to practice the safe procedures they currently utilize. Those procedures are outlined in a memo dated January 6, 1989 referencing Flight in Icing Conditions, generated by the Manager of Flight Standards. This memo is a restatement of company operations policies. For your convenience the contents of that memo are included on the attached pages.

Flight In Icing Conditions

The winter of 1989 is surpassing our expectations for severe weather. We are experiencing more adverse weather than in the previous couple of years and icing encounters appear to be more prevalent. Please review the following procedures pertaining to our winter operations.

REF. (Dispatch Into Forecast Severe Icing - G.O.M., 3-4-8; paragraph E)

Simmons Airlines aircraft will not be released or flown into known severe icing conditions. Positive confirmation that severe icing conditions do exist shall constitute two similar pilot reports in the same specific area.

The reports should be from the same type of aircraft which are operating along our planned route of flight.

If icing or adverse weather is experienced, make a PIREP so your fellow pilots may benefit from your experience. This is important if the weather is better or worse than forecast.

Aircraft may be flown into light or moderate icing conditions only when full de-icing and anti-icing equipment for wings, propellers, empennage, windshield and pitot-static systems are installed and operable.

The temperature range favorable for ice formation is generally 0 to -15 degrees Celsius. However, supercooled water droplets in liquid form at temperatures above freezing, can freeze on impact with the aircraft. Exercise caution when operating your aircraft near the freezing level in visible moisture.

Freezing rain may also form ice on an aircraft that is operating near the freezing level (+/- a few degrees above and below the OAT 0 degrees Celsius). This phenomenon is usually associated with a temperature inversion. If freezing rain is encountered, you should exit the condition immediately. This diversion should consist of a turn towards better conditions and/or a climb to a warmer altitude.

Freezing rain and clear ice can be very difficult to recognize on an aircraft, therefore it is strongly recommended when operating in conditions favorable to this type of icing that an extra vigilance be maintained. This should include periodic cycling of the wing boots to aid in the detection of ice.

The temperature ranges stated in the AFM for the SD3 is +6 degrees Celsius OAT and the FCOM for the ATR-42 is +7 degrees Celsius TAT. These are the minimum temperatures at which deice equipment must be turned on. If a pilot has reason to believe an encounter with icing is imminent, the systems should be turned on sooner.

The normal use of the pneumatic leading edge deicing system in the SD3 is to cycle the system after a sufficient amount of ice has formed on the leading edge. This will allow proper shedding of accumulated ice.

In the ATR-42 the Level 3 deice system must be operated as soon as, or before, ice develops. Again, if you have reason to believe that an icing encounter is imminent, select the system on.

For both aircraft, cycling the pneumatic deicing system during a period of what appears to be a wet or clean wing should not cause any bridging of ice or affect future deicing system cycles. However, it will provide a valuable aid in the detection of clear ice or freezing rain. The weather radar may also be useful when operating in visible moisture, near the freezing level. Use of weather radar may help identify areas of greater precipitation.

The Company Policy for dispatching both the SD3 and the ATR-42 into forecast icing conditions remains the same. An aircraft may be dispatched into forecast freezing rain.

However, our aircraft are not to be operated in known freezing rain or severe ice. If these conditions are experienced, the procedure is to exit these conditions immediately. If the conditions are reported or being experienced at the airport of intended landing, then the crew must evaluate their situation relative to remaining fuel, distance to your alternate, etc. With time allowing, coordinate your plan of action with Dispatch. Some of the obvious possibilities are; holding until conditions improve, diverting to the listed alternate, or diverting to an amended alternate.

If you have any question about our procedures, please call the Flight or Training Departments for further clarification. We prefer to discuss any questions you may have before a undesirable situation develops.

Thank you for your attention.

APPENDIX 3

**STUDY OF METEOROLOGICAL INFORMATION
AS A CONTRIBUTION TO THE NTSB REPORT
(APRIL 15, 1996)**

MINISTERE DE L'AMENAGEMENT DU TERRITOIRE , DE L'EQUIPEMENT ET DES TRANSPORTS
SECRETARIAT D'ETAT AUX TRANSPORTS

INSPECTION GENERALE DE L'AVIATION CIVILE
ET DE LA METEOROLOGIE

Le Bourget, le 15 avril 1996

BUREAU ENQUÊTES-ACCIDENTS

CAZ

**ACCIDENT TO THE SIMMONS AIRLINES ATR 72
REGISTERED N401AM
(AMERICAN EAGLE FLIGHT 4184)
NEAR ROSELAWN (IN) ON OCTOBER 31,1994**

**STUDY OF METEOROLOGICAL INFORMATION
AS A CONTRIBUTION TO THE NTSB REPORT**

Note: *The original French version of this study was issued on August 25, 1995. This is the corrected English version with revisions and updated data integrated from material subsequently supplied to the BEA by the NTSB.*

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1. INTRODUCTION

The meteorological data and documents quoted and used in this study were provided to the BEA by the NTSB, in particular:

- general plotted and analysis altitude and ground charts;
- available data based on from radiosoundings;
- weather radar and satellite imagery;
- available ACARS data transmitted during the flight, relevant PIREPs and testimonies.

DFDR data from aircraft N401 AM and Chicago air traffic control radar data¹ (altitude and coordinates) are used to determine the atmospheric structure in the flight environment, from the descent from 16000 feet to the holding pattern at 10000 feet, then during descent towards 8000 feet and finally, during the uncontrolled descent down to 5000 feet.

The CVR and ATC records are used to provide cross-correlation with the DFDR data, with the results of calculations and with certain information and procedures drawn from the ATR 72 FCOM.

Information related to results of models and simulations generated by research centers or universities commissioned by the NTSB are quoted to allow comparison. Neither analysis nor detailed critical study of this research has been undertaken by the BEA.

Weather forecasts and available meteorological information (flight release to the crew, information at disposal of ATC) are not dealt with in this study.

The objective of this report is to establish a reconstitution of the atmospheric conditions prevailing in the holding pattern on October 31, 1994 between 21 h 00 and 22 h 00 UTC².

2. GENERAL SITUATION BETWEEN 18h00 AND 22h00

2.1- Situation at Altitude

At 500 hPa (see appendix 1), a low pressure belt was located to the north of 50 °N (over Canada), extended by a thalweg (trough) over Minnesota (MN), Wisconsin (WI), Iowa (IA) and Illinois (IL)

¹ Radar data and trajectography relative to the part of the flight in the holding pattern were not provided in full to the BEA until February 1996.

²Time in this report is Universal Time Coordinated (UTC). Central standard time (CST), which is local time, corresponds to UTC minus six hours.

At 700 hPa and 850 hPa, (see regional charts in appendix 2) the same low pressure belt existed. The thalweg concerned Michigan (MI), Wisconsin and Illinois at 700 hPa, and Wisconsin, Michigan, Illinois, Indiana (IN) and Ohio (OH) at 850 hPa.

On the Indianapolis (IN) - Chicago (IL) route, winds and temperatures evaluated at the corresponding altitudes were :

-500 hPa (5600 to 5500 m) :230° / 50-60 kt to 210° /40-50 kt, -17 to -20 °C;

-700 hPa (2970 to 2930 m) :220° / 40 kt to 160° /20 kt, 0 to -6 °C;

- 850 hPa (1400 to 1380 m) : 210°/35 kt backing to 050° /20 kt, +7 to 0 °C.

2.2- Surface Situation

Regional surface analyses at 1800 h, 2000 h, 2100 h and 2200 h are attached in appendix 3.

A large area of low pressure covered the United States to the east of the Mississippi. The minimum centered 1004 hPa to the east of Saint-Louis was slowly deepening (1000 hPa at 2000 h, deepening to 998 hPa at 2200 h), while moving to ENE.

At 2200 h, the low was centered slightly to the west of Terre-Haute (WSW of Indianapolis). A complex system was associated with this depression:

- a main disturbance moving ENE of the warm front was moving very slowly to the north; it extended from Lafayette to Fort-Wayne (IN) and to Cleveland (OH) between 2100-2200 h; the cold front extended from Nashville (TN) to Indianapolis and Lafayette (IN) at 2200 h;
- a secondary cold front located along the Mississippi, Ohio and Wabash rivers at 2200 h;
- an air mass limit, as an occlusion, separating the wet air ahead of the warm front from the polar dry and cold air; at 2200 h, it was located to the NE of Illinois and was passing over Michigan and the south of Ontario; its western part was backing to the south, due to northerly air flow, and its eastern part extended to the north or north-west.

2.3- Synoptic meteorological conditions

In the warm disturbance area, near the warm front (air temperature T = 12 to 15 °C and dew point Td = 11 to 14 °C), there was mist with stratus (St) and stratocumulus (Se) under altocumulus (Ac) and altostratus (As). Some rainfall or scattered showers were noticed.

The main cold front was not very active. It formed the limit between the preceding air (warm sector) at 15-18 °C (Td), with wind blowing from south to SSW gusting up to 25 kt, and the following air at 10-12 °C (Td).

The secondary cold front formed the limit with unstable cold air ($T_d = 4$ to 7 °C), characterized by several cloud layers with generalized rainfall or rainshowers and many stratus layers.

Above the areas located to the north of the warm front ($T_d=5$ to 7 °C), the sky was overcast by stratocumulus and altocumulus - altostratus with frequent drizzle and rainfalls, and near the occlusion, rain and showers. It must be pointed out that precipitation was general and much more intense to the north of the front than in the immediate vicinity. **LUCIT intersection and the associated holding pattern, which N401AM was flying in, was in this area.**

To the north of the occlusion, and northwards of the Great Lakes and Wisconsin, the sky gradually became clear. The air mass temperature dropped from between 2 and 5 °C (T_d), to the north of the precipitation area, to between -2 and -4 °C (T_d) in the clear sky area.

3. ATMOSPHERIC STRUCTURE

3.1- Radiosoundings at 0000 h

The radiosounding launch time was around 2300 h, thus one hour after the time of the ATR 72 accident (see diagrams in appendix 4).

The Peoria (IL) sounding took place in wet arid cold air following the secondary cold front. In addition to the marked instability of the low layers, below 950 hPa (saturated pseudoadiabatic temperature $\Theta^*w = 3$ °C), it was characterized by a relatively stable wet air mass between 900 and 500 hPa. The Θ^*w reached 8 to 13°C between 750 and 450 hPa. The wind was blowing from north to NNE from ground to 650 hPa, with a speed of 20 to 30 kt. Between 940 and 820 hPa, its speed was 50 to 55 kt, and it gradually weakened down to 10 kt at 680 hPa. Above, it backed west, then south-west 20 to 30 kt at 500 hPa.

According to the Pontiac (MI) radiosounding, in stable wet cold air prior to the warm front, the air mass had a Θ^*w of 7 °C from surface up to 860 hPa; it was topped by a temperature inversion of 3 °C, due to the warm front surface (slope of 1.3 %). Above, the wet and stable air mass temperature increased up to 16 °C (Θ^*w) at 550 hPa. The wind was ENE to ESE 15 to 25 kt from the ground to 830 hPa. It veered SSE to SSW, reaching 30 kt at 700 hPa; then it stayed SW 35 to 45 kt until 450 hPa.

Dayton station (IN) was located in the warm area. In the lower layers, the air mass temperature (Θ^*w) was 15-16 °C from ground to 850 hPa. Drying appeared up to 600 hPa, this being the evolution of the subsidence inversion existing at 1200 h above 650 hPa, at the limit with the air mass at 16 °C. The light southern wind turned to SSW at 900 hPa, its force increasing with altitude, from 30 to 65 kt at 500 hPa.

On the north - west of Lake Michigan, Green Bay station was in the polar cold air forward of the north of the occlusion, at the edge of the area of the disturbance. The atmospheric structure was characterized by a Θ^*w of 3 °C between ground and 800 hPa, then 6 to 8 °C up to 570 hPa. The wind

was steady NNE 10 to 20 kt from surface to 650 hPa; it then turned E to SE 10 to 15 kt and veered to S to SSW above 500 hPa, with an increase in speed of 20 up to 35 kt.

3.2- ACARS Measures

ACARS messages from six United Airlines flights, transmitted between 20 h 30 and 00 h have been studied and analyzed. These aircraft were flying to the north and much more to the east or to the west than N401 AM, especially during the holding pattern phase at LUCIT intersection.

These flights were leaving from or going to Chicago (see navigation map and diagrams related to ACARS messages in appendices 5 and 6) :

- UAL 128, ORD - MIA : climbing at 20 h 32, approaching Kankakee (IKK) at 20 h 42 (420 hPa);
- UAL 176, SFO - ORD : moving away from Dubuque(DBQ) at 20 h 54 (415 hPa), on final at 21 h 15;
- UAL1046, IAH - ORD: crossing Bradford (BDF) at 21h 40 (400 hPa), on final at 22 h 02;
- UAL 379, ORD - OAK : climbing at 22 h 35, cross-wise to Rockford (RFD) at 22 h 45 (425 hPa);
- UAL 793, SJU - ORD : towards Knox (OXI) at 23 h 21 (425 hPa), on approach at 23 h 44 (750 hPa);
- UAL 708, ORD - BOS : climbing at 23 h 42, en route towards Keeler (ELX) at 23 h 51 (425 hPa).

Taking into account the general weather situation, with specific reference to the atmospheric structures based on radiosoundings, these flights took place in the active disturbance area:

- the air mass crossed by the flights on the routes BDF - ORD, ORD - RFD and ORD - ELX was the same as that of the Peoria sounding at 0000 h, and the structures were very similar. However, the NNE to NE wind 30 to 45 kt up to 750 hPa veered SE at 700 hPa, increasing from 20 up to 40-50 kt above 550 hPa;
- the atmospheric structure on the route DBQ - ORD was in an intermediate position between the Green Bay and Peoria soundings : the NNE to NE wind speed was not more than 35 kt from ground to 750 hPa; then it weakened, veering SSW 20 kt at 550 hPa, increasing up to 50 kt between 450 and 400 hPa;
- the start of flight ORD - IKK took place in cold air; then the structure became similar to the one encountered by flight OX1 - ORD above 720 hPa; the winds were quite similar and are comparable to those measured during the Dayton sounding above 650 hPa.

3.3- Atmospheric structure based on N401AM DFDR data

The static air temperatures (SAT), calculated from the total air temperature (TAT) measurements (see diagram in appendix 7) between 21 h 12 (540 hPa) and 21 h 58 (850 hPa) give a structure which can be superimposed over that of the Pontiac sounding from 850 to 670 hPa and 570 to 540 hPa. Between these two altitudes, it is characterized by a $\theta'w$ of 14 °C constant up to 600 hPa and by an inversion of 1.5 °C with a thickness of 250 m.

In the atmospheric layer centered on 700 hPa, where the aircraft was flying between 21 h 18 and 21 h 57 (during the approach to LUCIT intersection, then in the holding pattern), the temperatures varied between -2 and -4 °C. None of the available information could lead us to question the reliability of the temperature probe and recorded values, nor the calculation method based on the diagrams of the ATR 72 FCOM. The temperature values did not vary suddenly, but rather through consistent stages, doubtless linked to the state of the atmosphere : wet air (outside of clouds), saturated air (in clouds), saturated air with precipitation.

At 10000 ft, the data used to calculate the wind are those provided by the air trajectory and by the ATC radar trajectory. Various calculations made with time periods of between 9 and 60 seconds give an average wind of 210°140 kt.

3.4- Satellite imagery analysis

The various satellite images taken between 20 h 30 and 22 h 00 (see appendices 8 to 10) show cloud cover whirling around the low pressure area centered above Illinois. They also show the warm sector and the secondary cold front, the northern part of which was in the whirling cloud cover.

In the warm sector, the thermal analysis shows that the temperatures at the tops of the clouds varied between -15 and -10 °C (4500 to 4000 m) and reached -3 to +3 °C (3000 m to 1000-1500 m) locally.

The thermal gradient provides an interesting indication on the warm frontal limit : a significant extension in altitude of cloud layers up to 9000 m (-40°C).

In the holding pattern, N401AM initially flew in an area where the temperature at the tops of the highest cloud layer varied between -25 and -35 °C (7000 -8000 m), then at about -20 °C (6000 m) for the 15 last minutes. This finding is at variance with the conclusions drawn by American scientists, who deduced temperatures of only -15°C at the tops of the clouds.

3.5- Radar echo analysis

The precipitation echoes (drizzle, rain, mixed rain and snow) are obtained by the reflection of a signal from drops of water in the atmosphere. Reflection from crystals (ice, dry snow) is significantly weaker than from water droplets or drops.

Ground weather radar equipment in use is of centimetric type, with a wave length of between 3 and 10 cm, and more generally of between 3 and 5 cm. With this kind of radar, reflection from drops

or “wet” crystals with a size of at least 100 μm becomes possible. In comparison, millimetric radars have a lower reflective threshold: about 20 μm (cloud droplets).

Airborne radar equipment has the same characteristics and the reflectivity of precipitation echoes is expressed on a four-level scale, depending on precipitation intensity (reference ATRFCOM and Pilot Handbook PRIMUS 800 Color Digital Weather Radar) :

- level 0, black: no detectable cloud (intensity of less than 1 mm/h corresponding to a reflectivity of less than 23 dBz).
- level 1, green: normal cloud, corresponding to light echoes (intensity of 1 to 4 mm/h corresponding to a reflectivity of between 23 and 33 dBz).
- level 2, yellow: dense cloud, corresponding to moderate to strong echoes (between 4 and 12 mm/h corresponding to a reflectivity of between 33 and 40 dBz).
- level 3, red : severe storm, corresponding to very strong echoes (intensity more than 12 mm/h corresponding to a reflectivity of more than 40 dBz).

Aircraft N401AM was equipped with the Honeywell PRIMUS 800 weather radar (wave length 3.2 cm). During the section of the flight in the holding pattern, whenever the radar was functioning in WX position, precipitation echoes were detected, appearing in green, or at a higher value, on the EHSI screen.

Thus the more common meteorological radars (wave length of between 3 and 5 cm) detect drops of atmospheric phenomena classified as drizzle (diameter of 50 to 500 μm) or rain (diameter > 500 μm). Reflectivity, expressed in dBz, depends on drop size and mean concentration, hence also on the liquid water content.

Measurements from the doppler radar of Lockport (KLOT) between 21 h 30 and 22 h 00, at a variety of elevations (0. 5°, 1.5°, 2.4° and 3 .4°) showed a general extension of the echoes towards NNE as well as an increase in their reflectivity. The holding pattern was situated at the edge of the extended area at the time period under consideration (see appendices 11 to 13).

These elevations correspond respectively to the following average altitudes, vertical to the holding pattern: 4600,9400, 13700 and 18700 ft.

3.5.1- Determination of the wind

A wind field was calculated, by scientists commissioned by the NTSB, on the basis of data provided by the Lockport radar (about 40 NM of the hold) within a 22 NM radius. The profile of the wind calculated between 21 h 45 and 21 h 55 was similar to that established with the measurements taken by flight BDF - ORD. Lockport station was in cold air and the S to SSW flow existed only above 700 hPa (about 10000 feet).

The evolution of the precipitation echoes was examined by the BEA in order to determine direction and speed of the noticeable echoes vertical to the holding pattern. The profile thus obtained was superimposable on the profile obtained from Dayton radiosounding measurements, in the warm

sector. **At the level of the holding pattern, this calculation confirms those made by the BEA, using the airborne and ATC radar trajectories of the aircraft: 200 to 210° /40 kt.**

3.5.2 -Reflectivity of the echoes corresponding to N401AM movements

The acceptable reflectivity threshold in operational conditions is 5 dBz. In France this threshold is extended to a minimum of 15 dBz so that the results obtained are completely reliable (in terms of potential precipitation quantity and intensity)

Echoes related to the 0.5° elevation of the radar were not considered, except during the final descent; they corresponded to a mean altitude of 4600 ft (1400 m) in the holding pattern.

The major successive passages through the known precipitation areas are as follows (see appendix 14) :

- at about 21 h 24-21 h 25, turning right at LUCIT intersection : 15-20 dBz at 1.5°;
- between 21 h 25 and 21 h 29, turning right and initiation of outbound leg: 5 to 15, briefly 20 dBz at 1.5°, and intermittently 5 to 10 dBz at 2.4° and 3.4°;
- from 21 h 33 to 21 h 35, in right turn after LUCIT intersection :5 to 15 dBz at 1.5°;
- between 21 h 37 and 21 h 39 mn 30 s, in southern turn to return to the intersection :5 to 10 dBz at 1.5°;
- between 21 h 40 and 21 h 45, on the northern part of the circuit : 10 to 15 dBz rapidly increasing to 15-20 dBz (25 dBz around LUCIT intersection) at 1.5°, and 15 dBz at 2.4° around LUCIT;
- between 21h 46 and 21 h 48, on southern part of the circuit :5 to 15 dBz at 1.5° and 0-15 dBz at 2.4°;
- from 21 h 51 to 21 h 55, end of inbound leg, then turning South and on outbound :10-15 dBz, briefly 20 dBz at 1.5°, and 5 to 10 dBz at 2.4° and 3.4°;
- **between 21 h 55 and 21 h 58, end of outbound leg, then turning in descent and accident sequence : 15-20 dBz quickly increasing up to 30 dBz at 0.5° and 1.5° (possibly 35 dBz at 1.5°) and 15-20 dBz at 2.4°.**

3.6- Ground Reports and Measurements

The ground meteorological observation closest to the site was performed at Lowell airfield, at about 3 NM from LUCIT intersection, 30 mn or so after the accident:

- **wind : SW / 20 kt with gusts,**
- **significant weather: light drizzle,**
- **clouds : BKN 1400 ft, OVC 3000 ft.**

Between the time the aircraft entered the holding pattern (21 h 24) and the time of the accident (21 h 58) a total of 2..5 mm of precipitation was measured at Demotte (between 21 h 45 and 22 h 00). Demotte is situated NNE at a distance of 9 NM from the site of the accident and 6 NM to the east of LUCIT intersection.

At Demotte, a witness testified that he heard the accident at about 22 h 00. At that time he was driving his car and affirmed that weather conditions were bad with heavy rain and strong wind.

3.7- Crew reports

Several PIREPs were transmitted by United Airlines crews to Chicago ATC between 21 h and 22 h 30. **No real time PIREPs transmissions seem to have been made by the controllers to inform other crews in flight.**

These PIREPs indicate light to moderate icing: rime and/or glaze at various flight levels :

- above FL 120 in the warm sector;
- at 6000 ft and above in the preceding cold air, near Lake Michigan;

- 0 °C at 4000 ft with freezing rain at 22 h 01 above Pontiac (IL) VOR, in cold air in the low area.

An airline Captain's report communicated some accurate information concerning the period between 22 h 10 and 22 h 40: descending from 14000 ft to HALIE intersection (26 NM NNE of the site) at 2000 ft on approach to Chicago, continuous icing (rime), with rapid accretion reaching 1.3 to 2 cm on the probe. **The Captain also revealed the detection of green echoes on the airborne weather radar.**

Information about conditions closest to the accident site were provided by two B727³ crews in flight near LUCIT at the time of the accident, who indicated that, in the cloud layers they were flying in, rain and even heavy rain and some sleet were occurring. The icing layer extended between 15000 and 5000 ft according to one of them and, according to the second one, whilst descending, it started at 14000 feet and was prevalent down as far as 6000 feet.

3.8- Results from numerical model used by the NTSB

The results of the numerical model NCAR-MM5 valid at 0000 h vertical to the accident site established a parallel structure, 1 °C lower than the one determined with the DFDR between 850 and 720 hPa, then 2 to 30 lower up to 660 hPa; the difference became less than 1 °C from 660 to 600 hPa and suddenly increased above, reaching 3 to 4 °C (see NCAR-MM5 diagram in appendix 7).

³ These two B 727's were reported in CVR and radiocommunications transcriptions as KIWI AIR 17, which was the source of the TCAS warning about one minute before the accident, and KIWI AIR 24, which had crossed LUCIT intersection at a 10 NM distance to the east at about 22 h 10.

This result was very much like the thermal profile obtained with the ACARS data of flight ORD - IKK from 750 to 700 hPa; above, it was very close to the values obtained on the other routes, essentially between 600 and 500 hPa, except for the DBQ - ORD route.

Results concerning the calculated wind were very similar to the values measured during the sounding realized at Pontiac at 0000 h or to ACARS measurements performed three hours earlier on route ORD - IKK (with an error margin of 10 to 15 kt below 750 hPa).

There is also an analogy between the winds calculated with the NCAR-MM5 model and the data provided by the radar of Winchester (IL), near Jacksonville (north of Saint-Louis), though in cold air and too far from LUCIT in order to apply them to the accident site.

At altitude, the structure (temperatures and winds) calculated with the numerical models, whose results were used by the NTSB, cannot be considered to be a reference. Indeed, the BEA calculated the various trajectories on the basis of the data from American models and wind profiles, and these show significant variations with those of this study. The trajectory calculated by the BEA corresponds more exactly to those based on the ATC radar tracks (see appendices 15 and 16).

On the ground, the results obtained with the NCAR-MM5 model also seemed to be far removed from reality, as expressed on the charts, if we consider such parameters as time, position, values at the center of the minimum and pressure gradient. Real data existed, however, and accurate weather charts could have been plotted and drawn in order to generate more accurate analyses , as the BEA did (see appendices 2 and 3).

4. INTERPRETATION OF THE RESULTS

4.1- Analysis of the situation at altitude

The atmospheric structure between 800 and 600 hPa, corresponding to an altitude of 2000 to 4200 m (6700 to 14000 ft), between parallels 36 and 42 °N and meridians 82 and 92 °W is now considered.

Three discontinuities related to three conflicting air masses can be noted:

- the warm sector, to the east of 88 °W and to the south of 41 °N, where the strong SSW to SW current prevailed at every altitude, with a speed of 25 to 30 kt from 900 hPa and reaching 60 kt at 600 hPa; according to the analysis at 700 hPa, this sector was characterized by a light thermal gradient in the warm advection extending as far as Kankakee (IL) and Pontiac (MI) with temperatures of -1 to -2 °C;
- in the following cold air, to the west of 88 °W meridian, the thermal gradient was strong: the temperature value -5 °C could be found near Lockport (KLOT) with a calculated thermal

wind of SE / 50 kt; this zone was the center of the depression and was linked to a thermal minimum of about -12 °C or so which tended to deepen the thalweg southwards;

- in the air ahead, to the north of 41 °N parallel and to the east of 88 °W meridian, the E to NE wind, from ground up to 850 hPa, veered SE to S 20 to 30 kt to turn SSW above 700 hPa, the speed increasing to 45 kt ; the thermal gradient was light and temperature at 700 hPa downed from -2 °C to -6 °C to the north-west, from LUCIT intersection toward Chicago-O'Hare airport.

4.2- Analysis of the atmospheric structure above the LUCIT intersection holding pattern

Ground conditions corresponded to the ones ahead of the warm front (ground trace).

At altitude, air mass heating had begun to develop from the passage over Lafayette, in the warm sector, despite the fact that the mean structure was the same as that of the Pontiac sounding. Conversely, the wind flow seemed to be similar to that at the Dayton sounding at all levels and to that at the Pontiac sounding above 700 hPa.

Towards 600 hPa (about 4000 m), the temperature inversion was typical of the top of cloud layer in latent instability (Ac - As) liable to develop up to 500 hPa, if the false isothermal layer representing the interpolation between two measures recorded to the north of Kankakee during flight ORD - OAK was taken into account.

Between 765 and 685 hPa (2700 -3200 m), the quasi-isothermal layer at 2 °C with a thickness of about 400 m indicated a fluctuation at the level of the cloud tops (mean top and maximum top). In this layer, no significant wind flow discontinuity appeared and even less wind shear, in contrast to assertions made by some scientists whose results on weather conditions were used by the NTSB. Indeed a clue was visible on the satellite imagery, the Kelvin-Helmoltz waves which are characteristic of wind shear phenomena: the altitude of these Kelvin-Helmoltz waves was determined on the imagery by using the temperature of the associated cloud layer, between -13 °C and -16 °C, corresponding to an altitude of 5000 to 5700 m, or 17000 to 19000 feet (7000 to 9000 feet above the altitude at which aircraft N401AM was flying in the holding pattern!).

The intensity of the precipitation echoes in terms of reflectivity generally varies between 5 and 15 dBz, briefly 20 dBz. After 21 h 50, the maximum reached 25 dBz at the various elevations : at the level of the holding pattern, two kinds of drops may have existed together, those relative to the precipitation within the cloud under study and those falling from a cloud above, also inducing enlargement of drops by coalescence. **This is also a point of disagreement with some of the conclusions drawn by the NTSB, since there is no mention of the precipitation (rain or drizzle, freezing drizzle, or mixed rain and snow, even sleet) which originated from the upper cloud layer and which was detected on the KLOT radar (2.4° elevation) and which was confirmed by the determination of cloud layers from satellite imagery and radiosoundings or ACARS, consistent with the testimonies of the two Boeing 727 flightcrews.**

The examination of the radar images showed there was no bright band (clue admitted as a melted snow area at temperature close to 0 °C) between 0. 5° and 2.4° elevations in the warm area and its limits, as defined above (§ 4.1). This leads to the idea that most of water droplets or drops above

isotherm 0 °C (about 2200 m) in this area were supercooled. Some PIREPs, even though they related to areas at some distance from the site, seem to confirm this fact.

Regarding reflectivity, precipitation was still considered to be light, sometimes moderate.

4.3- Reconstitution of the conditions in the holding pattern

Between 21 h 15 and 21 h 57, the ATR 72 was flying in the layer 685-725 hPa (about 12000-9000 ft). The study results, detailed in the previous paragraphs, and their interpretation leads to the discovery of a certain number of characteristics of this layer.

4.3.1- *Cloud conditions*

The flight took place at the edge of a stable cloud layer whose mean top was at 2750 m and the maximum top at 3200 m. Turbulence did not exist or was very light, certainly limited to the maximum level of the tops, possibly associated with an effect of the strong wind whose laminarity was disturbed by the proximity of the warm frontal surface (wind shift).

A more unstable layer was located just above, adjoining the previous one (top 4300 m), reaching 5500 m at the level of the warm sector. **After 21 h 50 these layers thickened noticeably, while the rainy area linked to the depression was moving to NE, this being revealed by the intensification of the precipitation echoes detected on the Lockport weather radar. This confirms the detection of supercooled rain and drizzle drops as precipitation.**

4.3.2- *Conditions of temperature and liquid water content*

The precipitation detected on the Lockport weather radar was partly generated by the cloud layers located above 3000 m and played a role in the enlargement of water droplets and drops contained in the layer in which N401 AM was flying, where temperatures varied between -2 and -4 °C (SAT). This can be directly linked to the water vapor and liquid water contents through the air mass mixing ratio (saturating or not), depending on the aircraft location in time and space (holding pattern legs) :

- outside the cloud layer (humid air);
- in the cloud layer, without precipitation (saturated air);
- in the cloud layer, with precipitation (saturated air with increasing liquid water content).

In fact, on the basis of adiabatic theory, a decrease in temperature from -2 to -4 °C at approximately 3000 m (10,000 ft) would induce a global increase in cloud liquid water content (LWC) of 0.7 g/kg dry air, which corresponds to 0.65 g/m³ , without taking into account the extra liquid water due to the precipitation falling from the layers above. In this case, temperature variations must be correlated to the corresponding areas traversed.

4.3.3- Icing conditions

Calculation of the time spent by the ATR 72 in precipitation leads to a cumulative time of almost 24 minutes, out of a total time of more than 30 minutes in such conditions in the holding pattern, with Static Air Temperature varying between -2 and -4 °C (Total Air Temperature between +1.5 and +3.5 °C). This duration is based on precipitation echoes detected on the weather radar in the area of the holding pattern of the aircraft, which means, by deduction, drop size diameters detected of about 100µm or more (see appendices 11 to 14).

Between 21 h 24 and 21 h 29 and then from 21 h 33 to 21 h 35, the aircraft was flying intermittently and briefly in low to moderate precipitation (15-20 dBz). SAT varied between -2.5 and -4 °C (LWC = 0.45 g/m³) and TAT between +1.5 and +2.8 °C. **The crew, who had activated the airframe de-icing at 21 h 16 mn 32 s (DFDR time) switched it off at 21 h 23 mn 22s (DFDR time), and although the NP had remained at 86% since take off (during climb, cruise, initiation of the descent phase), they reduced it to 77% at 21 h 24 mn 13 s (DFDR time, steady state). At 21 h 33 mn 56 s a caution alert single chime was recorded on the CVR which was not acknowledged by the crew.**

Between 21 h 37 and 21 h 39 mn 30 s, the plane passed through a light precipitation area (5 to 15 dBz); then, from 21 h 40 to 21 h 45, precipitation became moderate (15-20 to 25 dBz), and precipitation was also falling from upper layers. Temperatures varied between -2.5 and -4 °C (LWC = 0.45 g/m³) and TAT between +1.8 and +2.2 °C. **In that interval a caution alert single chime sounded, which can be considered to be the aural warning from the ice accretion detector (21 h 41 mn 07 s, CVR time⁴); the crew immediately activated the airframe de-icing and modified PRPM, increasing NP from 77% to 86%.**

At 21 h 48, the aircraft left an area of generally light precipitation (5 to 15 dBz), including precipitation from an upper layer; SAT varied between -2.3 and -3.2 °C (LWC = 0.27 g/m³), TAT by +1.8 and +2.5 °C. At 21 h 48 mn 43 s, one of the pilots remarked “I’m showing some ice now”.

At 21 h 55 mn 42 s, the First Officer said “we still got ice”, getting no answer from the Captain. The ATR had been flying under precipitation becoming moderate for more than four minutes (10 to 20 dBz) with SAT between -2.6 °C and -3.5 °C (LWC = 0.27 g/m³) and TAT between +1.2 °C and +2.2 °C.

From 21 h 56 until 21 h 58, the plane was descending, from 10000 feet to about 9000 feet, in moderate precipitation (20 to 30 dBz). SAT varied between -1.2 and -3.5 °C (LWC = 0.5 g/m³) and TAT between +2.8 and +4.5 °C.

4.3.4- Ice accretion

The aim of this paragraph is not to discuss the size of water drops and droplets in clouds or in precipitation. The radar echoes considered are precipitation echoes; the minimum diameter for drop detection being about 100 µm.

⁴CVR transcription starts at 21h27 mn 59s

Using parameters set out in this study (liquid precipitation, air temperature, liquid water content), it is possible to try to make a simple ice accretion calculation, using the “ Lucas Aerospace ” diagram : accretion per minute in relation to liquid water content, The values calculated are provided for information only and are no more than a rough estimate. **Ice accretions (rime or glaze) would have reached 1 to 2 mm/mn, which overall represents a thickness of between 35 and 65 mm during the time spent in the holding pattern for more than 30 minutes, independently of freezing drizzle or freezing rain falling in the layer or from a layer above for almost 24 minutes..**

AS an example, in the layer or for the different major phases described above, the following rough values were obtained (regardless of drop size or water runoff capacity and liquid precipitation):

- between 21 h 24 and 21 h 35: thickness of 10 to 12mm;
- between 21 h 37 and 21 h 45 : 11 to 13mm;
- between 21 h 46 and 21 h 48 :2 mm;
- between 21 h 51 and 21 h 55 : 4mm;
- between 21 h 55 and 21 h 58 : 4 to 6 mm.

No calculation or information could lead to a conclusion as to the possible shape of ice accreted on the wing, nor regarding an ice ridge behind the de-icing boots. **However, we can assume, considering the size of the drops (100 µm or more), the temperature of about -2 °C and the aircraft configuration (flaps at 15°, leading to AOA reduction through 0°) that water drop impacts occurred both aft of the upper wing leading edges and that, due to a deficiency in heat transfer, significant water run-back could have occurred aft of the de-icing boots. These observations mainly relate to the time from 21 h 37 to 21 h 45 (including the AAS warning time) and between 21 h 51 and 21 h 58 (last minutes before the accident).**

5. CONCLUSION

The icing conditions in which the ATR 72 N401AM was flying do not appear to be exceptional in terms of meteorological conditions, considering the results highlighted by the present study. The conditions were light to moderate icing, since the flight was taking place in a stable cloud layer at negative temperatures, close to 0 °C . **These moderate icing conditions, conducive to ice accretion, were seriously aggravated by liquid precipitation (supercooled drops of rain or drizzle) generated in this layer or originating in an upper layer.** This explanation can be considered to be typical of a meteorological forecast lacking in detail, such as the AIRMET broadcast’s summary concern with icing conditions. **The excessive duration of the flight in such conditions, with no recorded comments (as shown by the CVR transcript) on the severity of the icing, nor any upon the procedures to be applied in the conditions, seems incomprehensible on the part of the flightcrew.**

Another major element is the domain of aircraft certification in icing conditions. The reference is Appendix C of FAR - JAR 25 regulation : which sets the certification limits. This regulation does not consider the existence of supercooled droplets or drops having a diameter over 40 μm in continuous maximum atmospheric icing conditions, with a liquid water content over 0.8 g/m³ in the cloud layer, nor the case of freezing drizzle or freezing rain.

Thus the study points up the following five findings:

- 1. According to the content of the flight release, the crew was aware of the existence of light to moderate icing on the Indianapolis - Chicago route at the levels at which they were flying.**
- 2. In an available AIRMET, valid before and for the flight, rainfall was forecast at the altitude of flight N401AM, with negative air temperatures.**
- 3. Precipitation was detectable on the airborne radar on WX position.**
- 4. The flight in the holding pattern lasted over 30 minutes in a cloudy atmosphere with liquid precipitation and at a SAT varying between -2 and -4 °C. This was in complete contradiction with the limits specified in the certification and operational procedures.**
- 5. Procedures relative to flights in icing conditions, specifically those related to the surveillance of environment, Static Air Temperature, ice indicators and detectors, as well as some visual cues, were not respected by the flightcrew. In addition, standard procedures relating to propeller speed adjustment and anti-icing and de-icing system activation in icing conditions were not properly applied.**

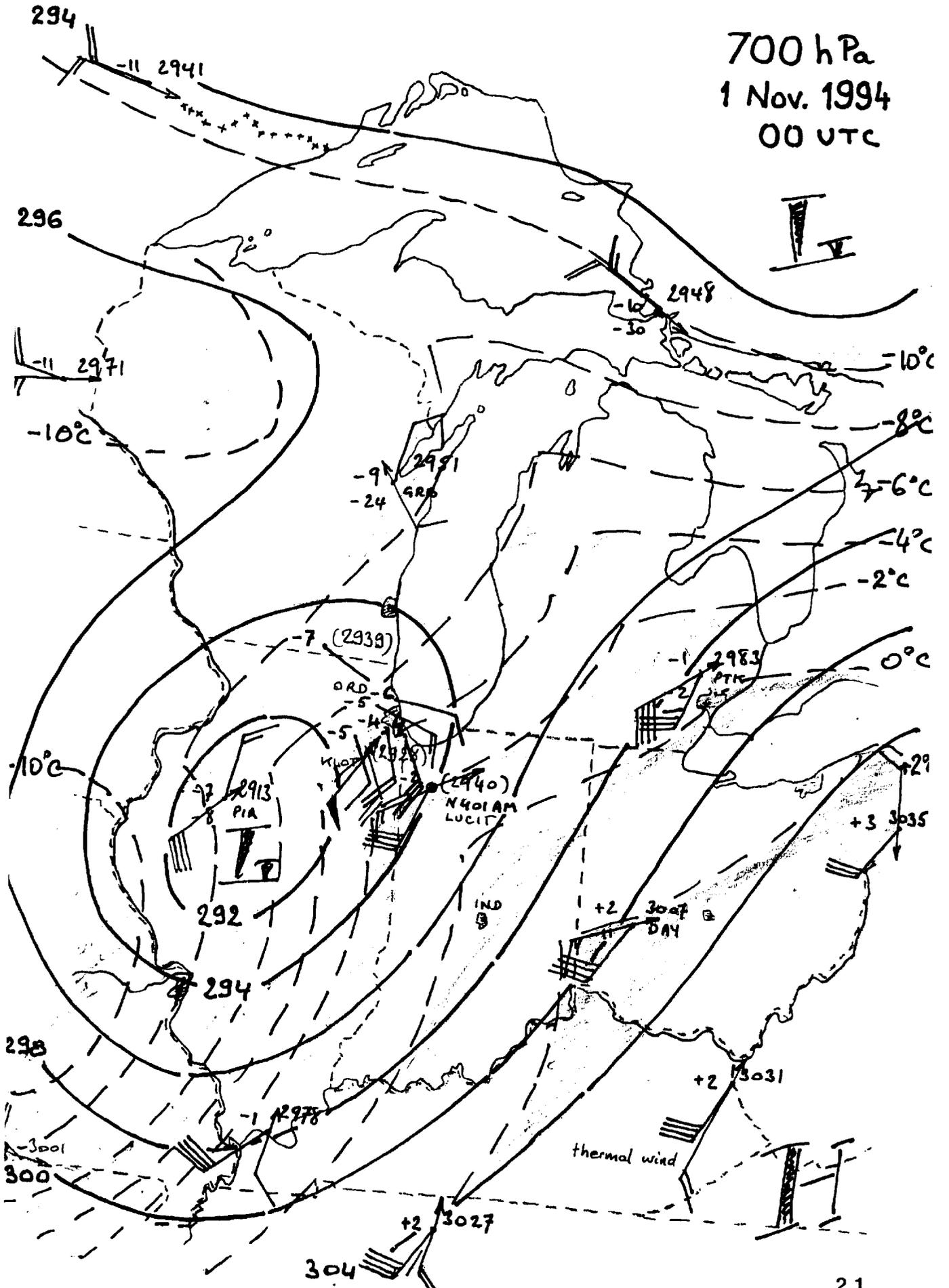
In conclusion, overall crew vigilance and awareness did not correspond to the basic rules to be applied on such a flight, occurring in icing conditions conducive to ice accretion.

APPENDICES

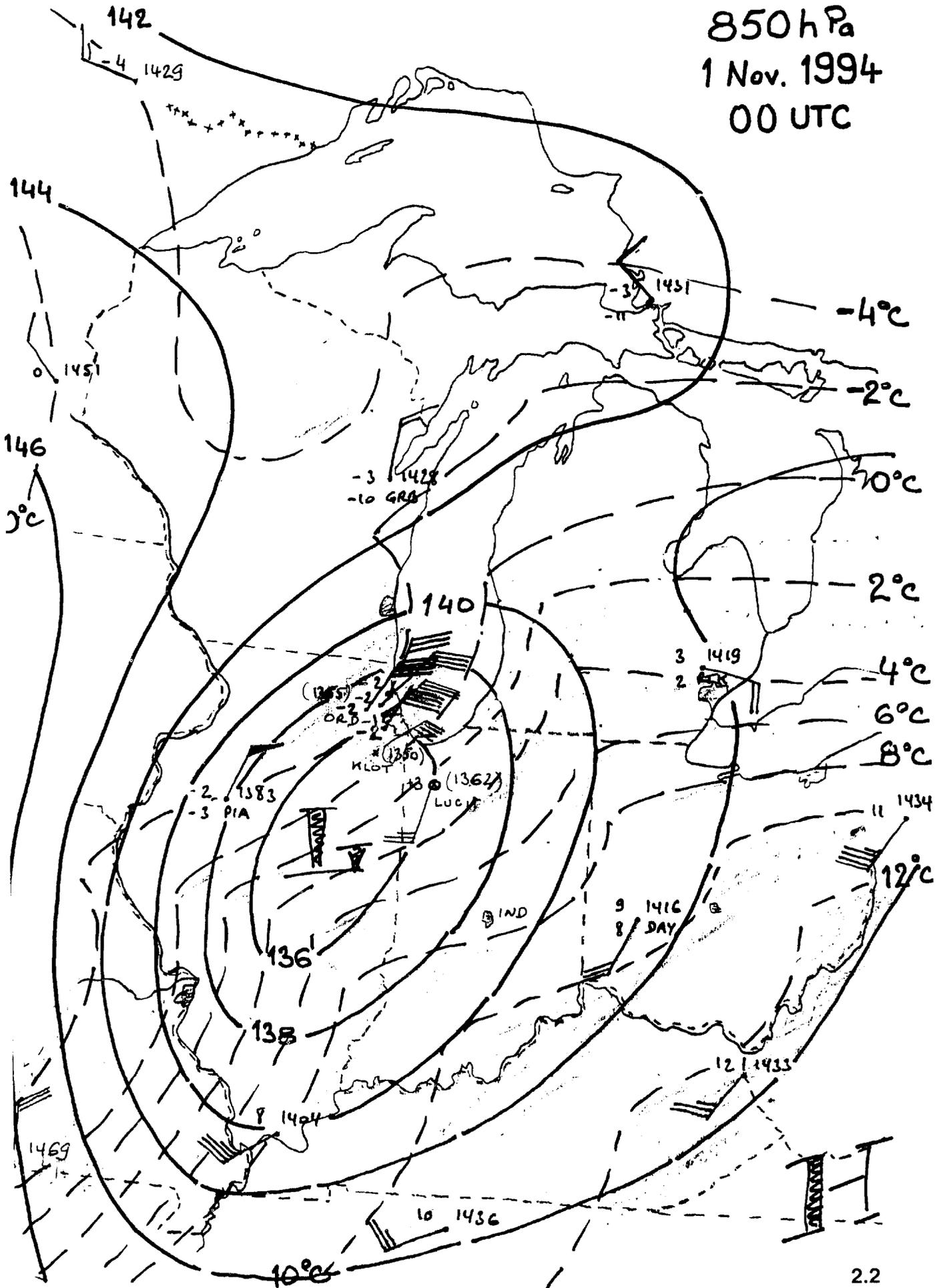
1. Weather Chart at 500 hPa
2. Weather Charts at 700 and 850 hPa
3. Ground Weather Charts between 18 h 00 and 22 h 00
4. Radiosoundings Diagrams at 00 h 00
5. Chicago Area Navigation Chart with six Aircraft Routes added (ACCARS data)
6. ACCARS Data Diagrams
7. N401 AM DFDR Data Diagram
8. Visible Spectrum Satellite imagery
9. Infra-red Spectrum Satellite Imagery
10. General Satellite and Radar Pictures
11. Radar Imagery at 0.5° elevation at 21 h 54 and 22 h 00 (UTC)
12. Radar Imagery at 1.5° elevation between 21 h 30 and 22 h 00 (UTC)
13. Radar Imagery at 2.4° elevation between 21 h 30 and 22 h 00 (UTC)
14. Precipitation Echoes in the Holding Pattern
15. Comparison between the BEA Computing and Radar Track.
16. Comparison between BEA Computing and Results provided by the NTSB.

APPENDIX 2

700 hPa
1 Nov. 1994
00 UTC

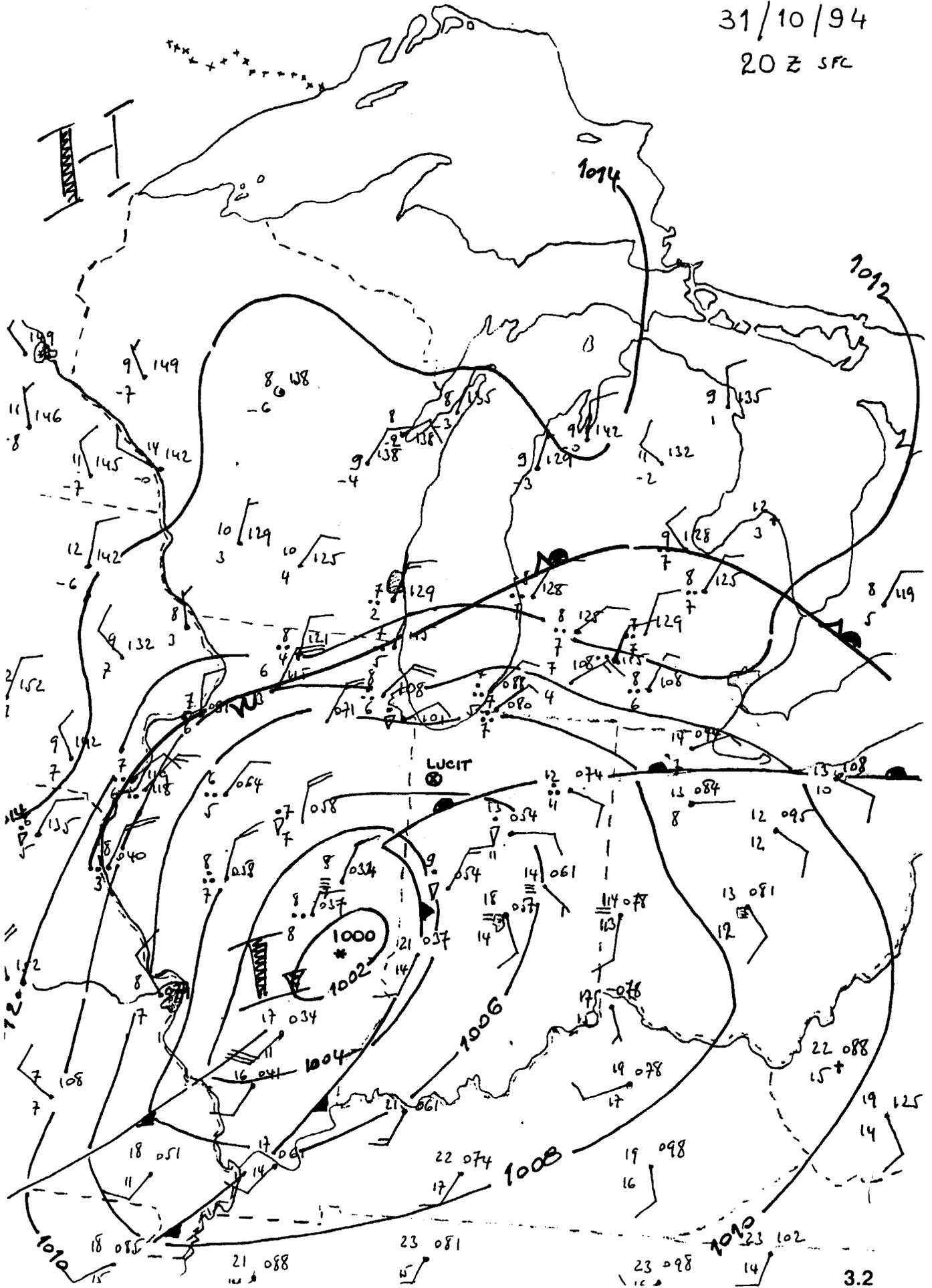


850 hPa
1 Nov. 1994
00 UTC

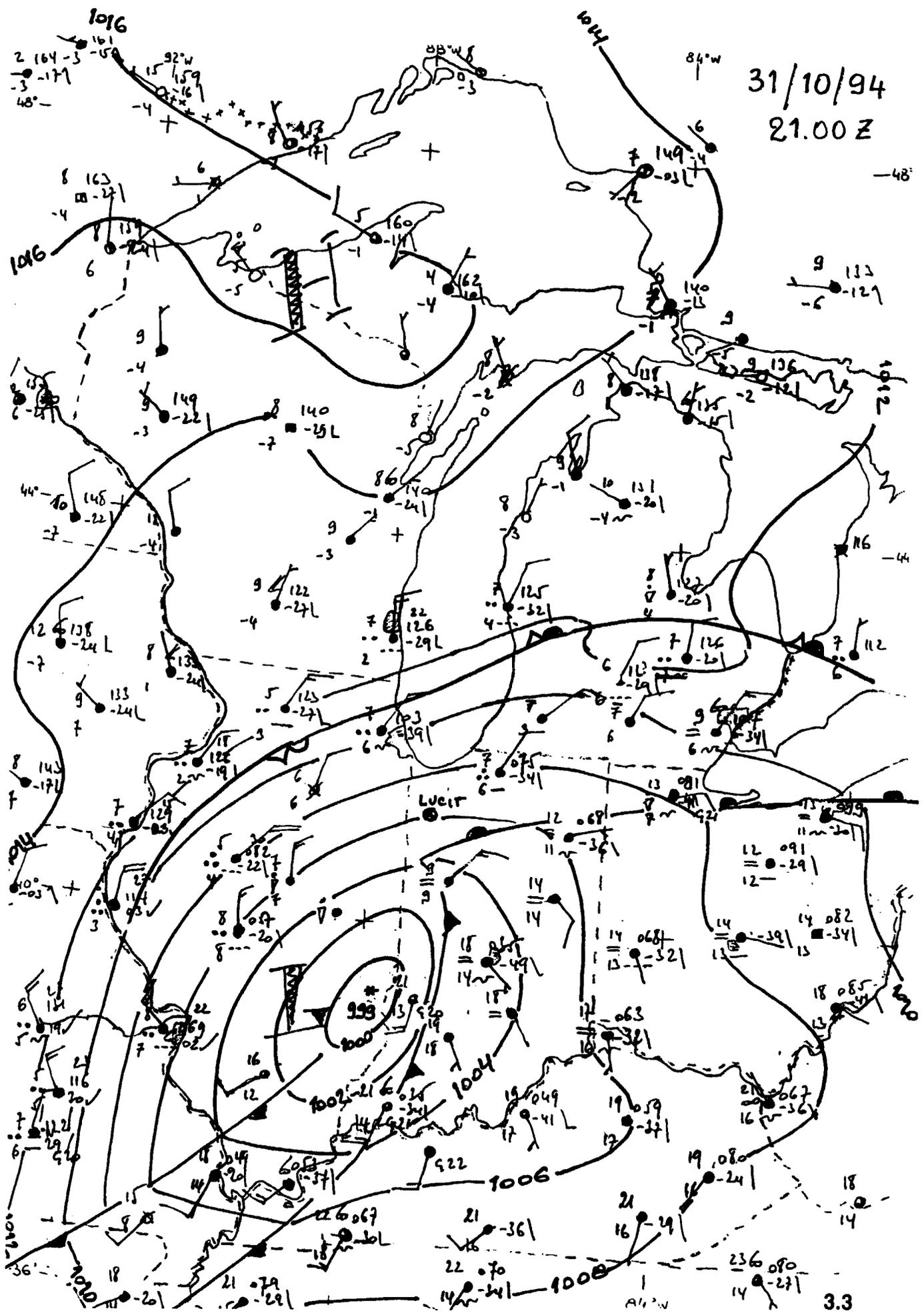


31/10/94

20Z SFC



31/10/94
21.00 Z

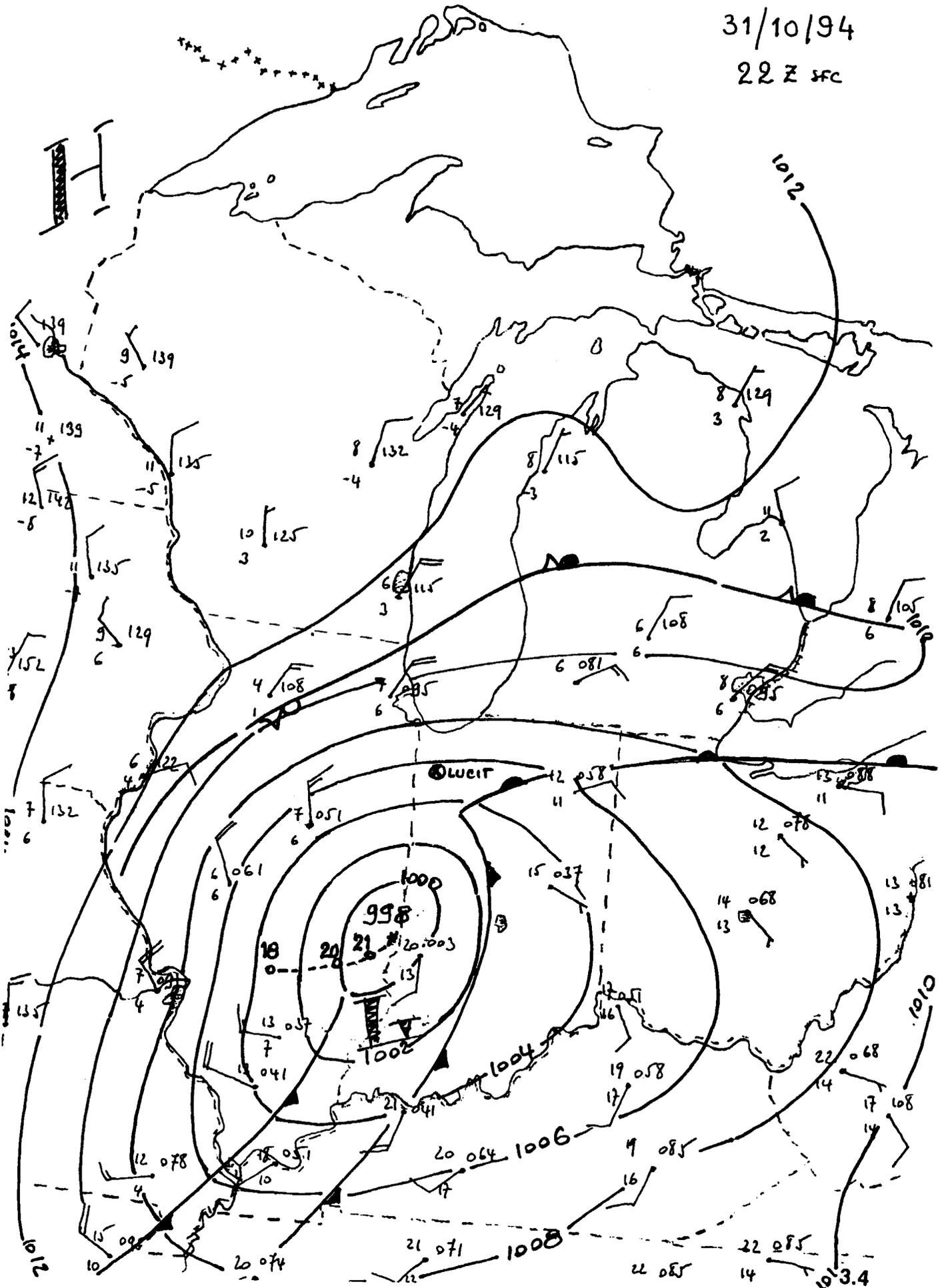


-48°

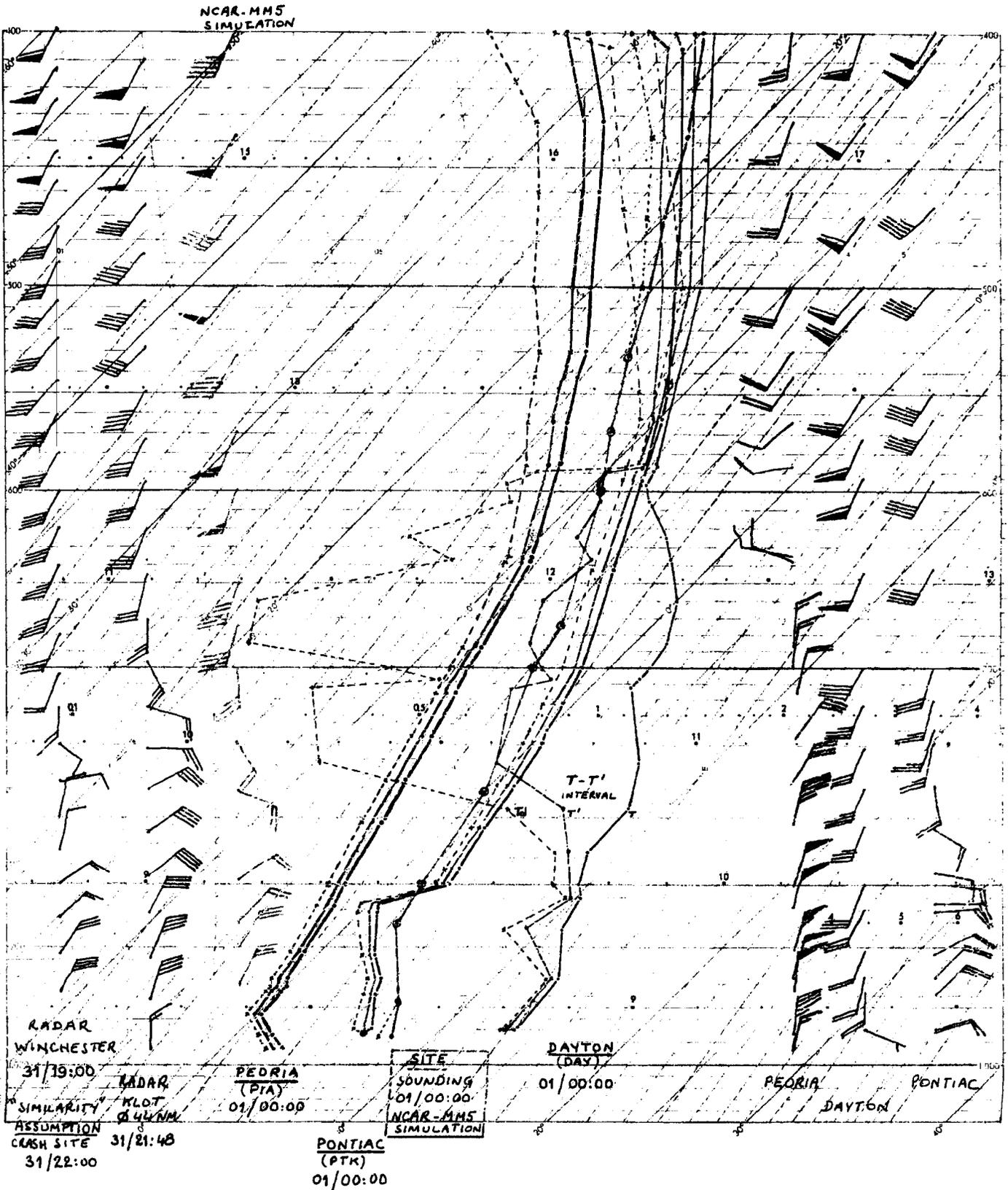
3.3

31/10/94

22 Z sfc



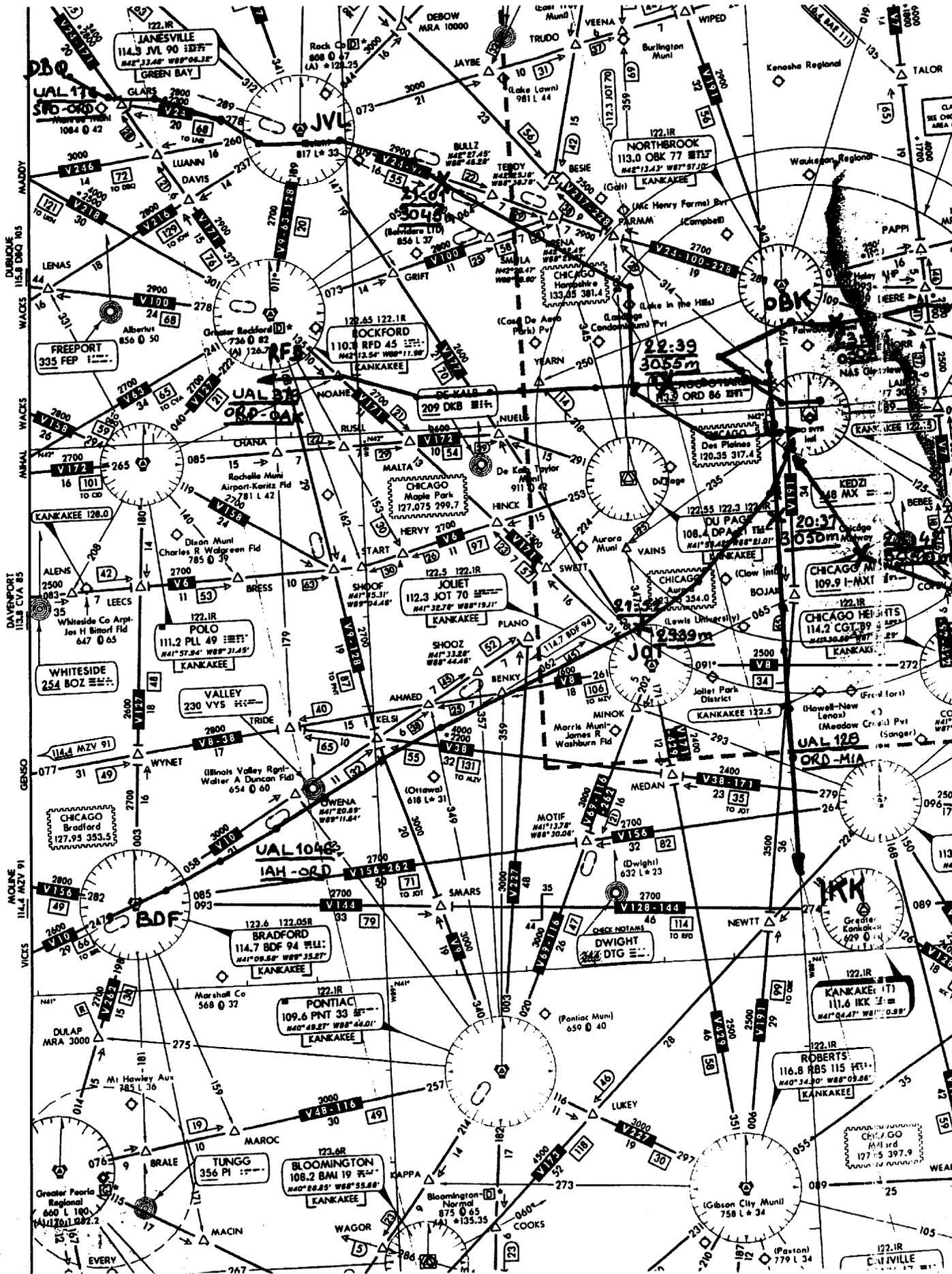
APPENDIX 4



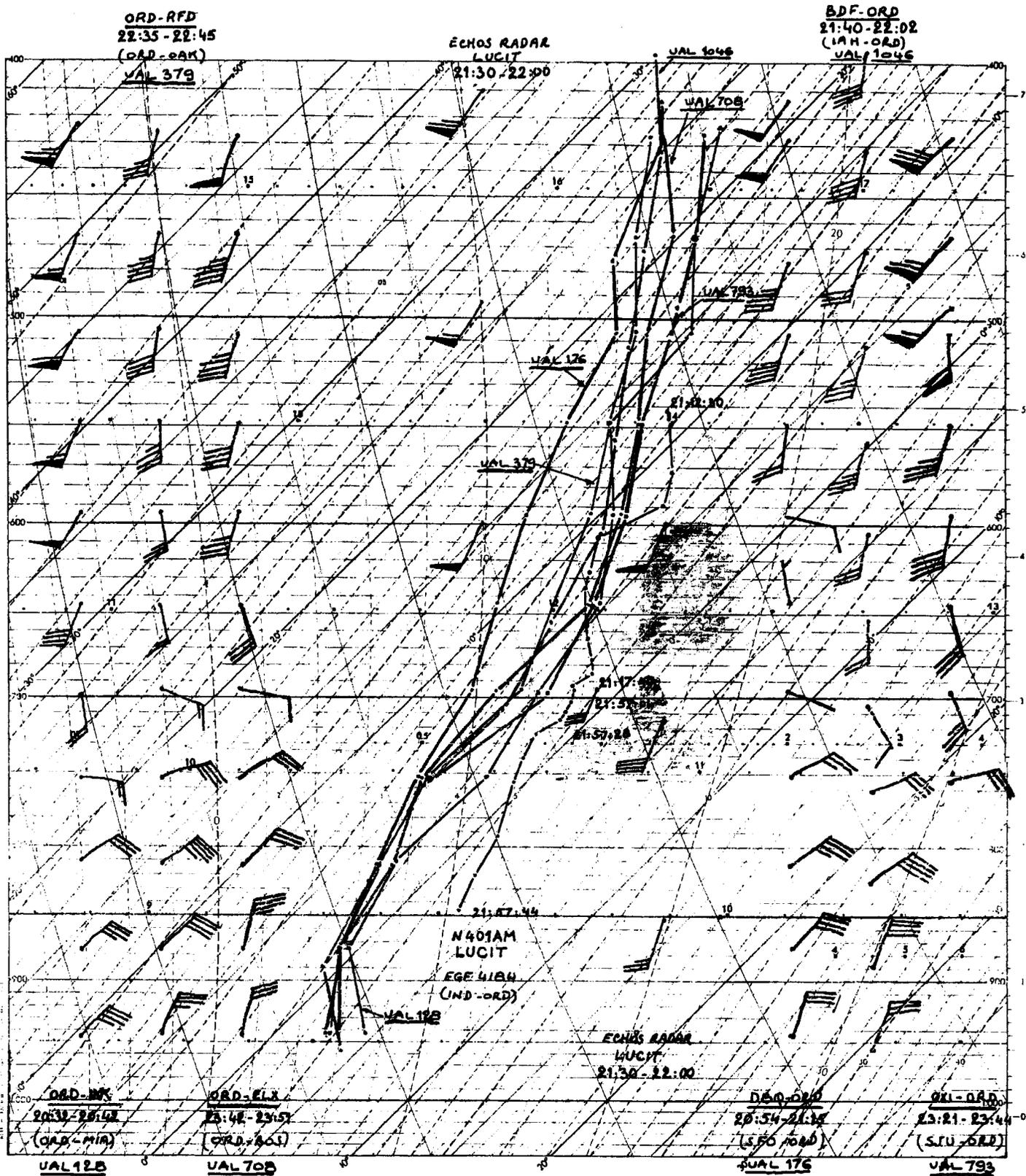
APPENDIX 5 - I

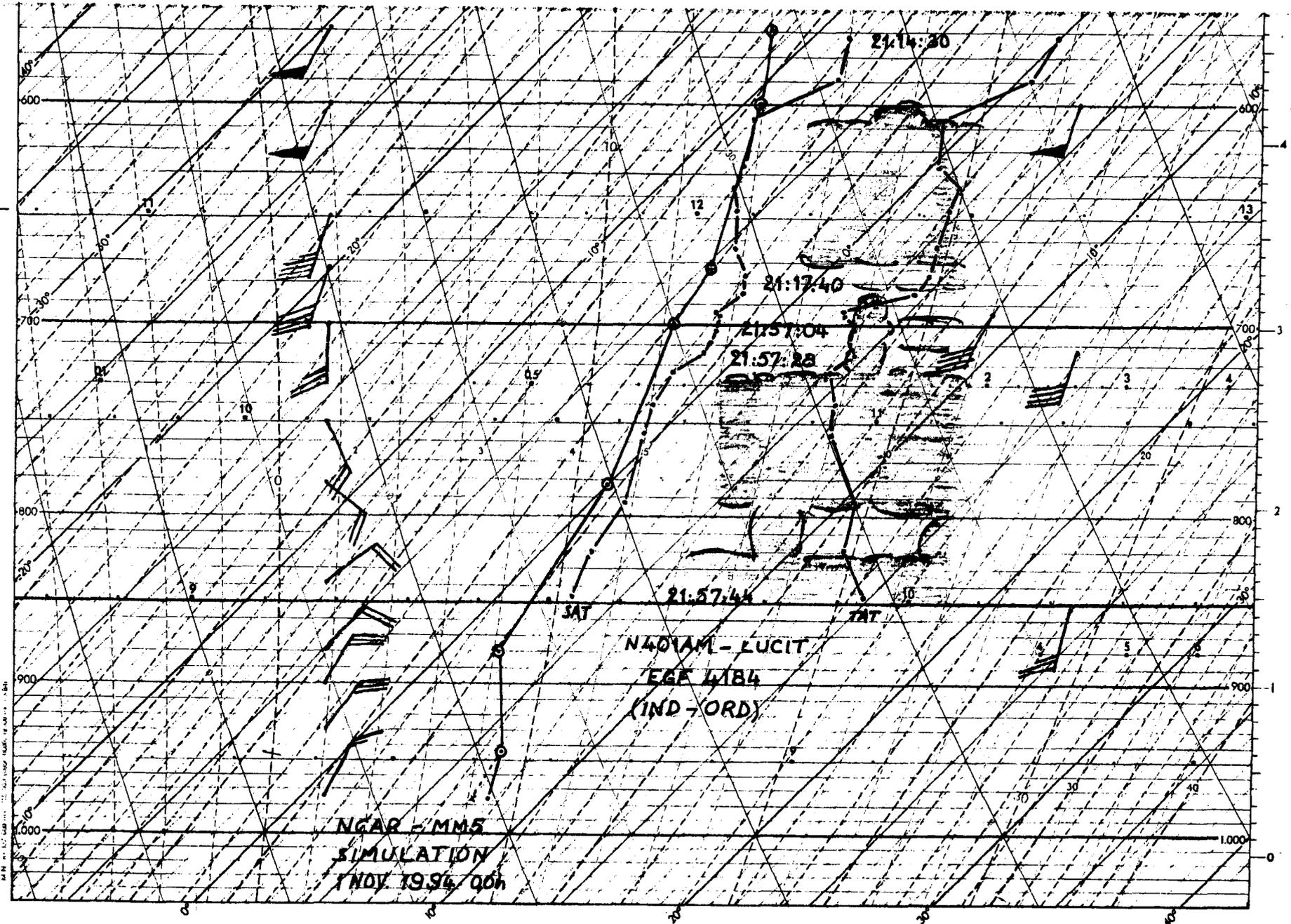
Overlaps Chart Nr L-11

Overlaps Chart Nr L-11

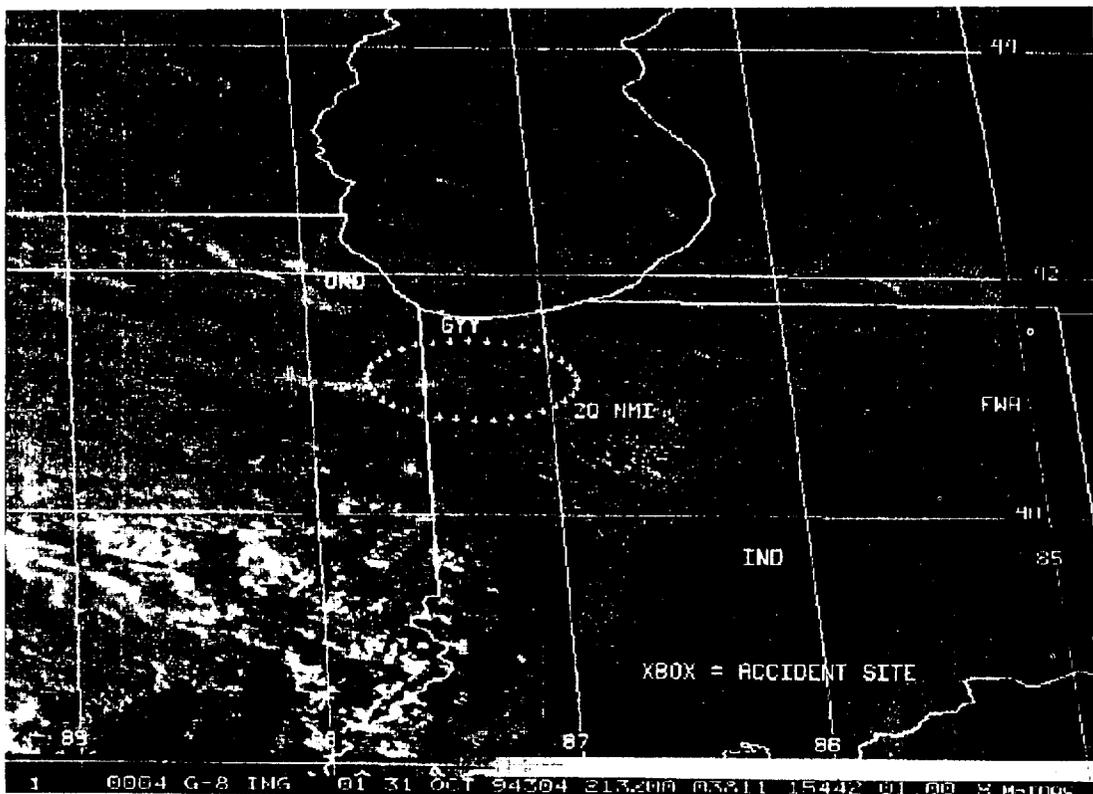
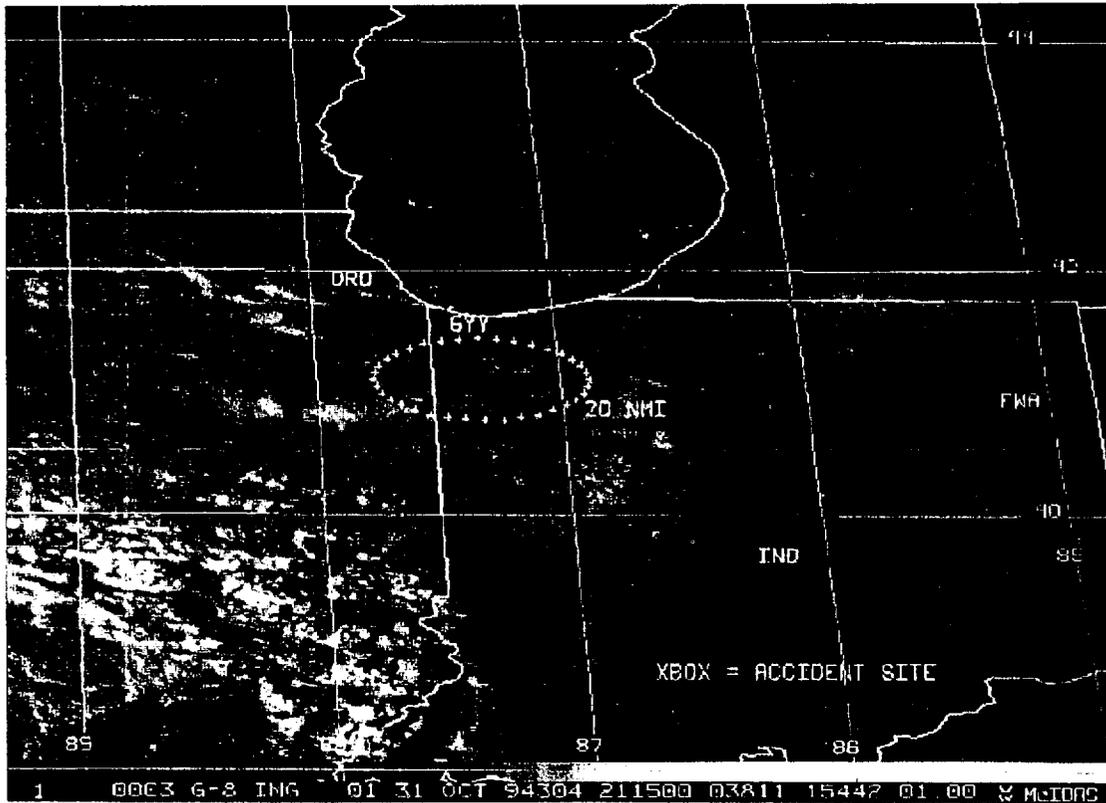


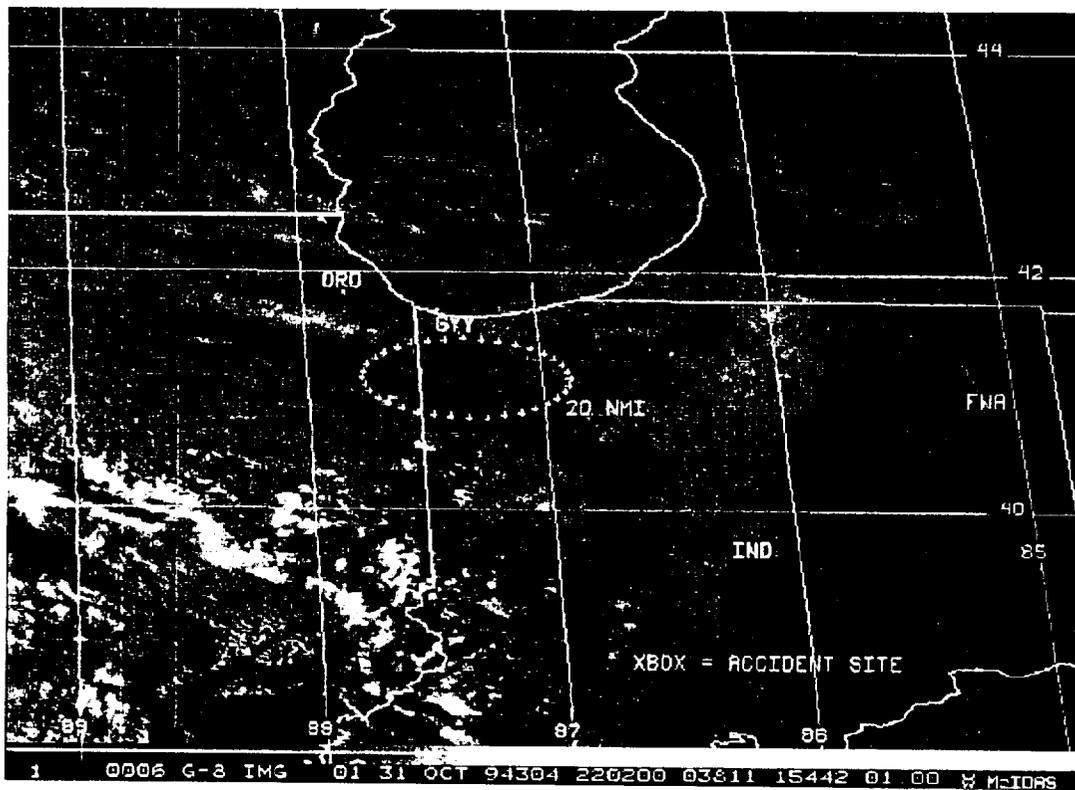
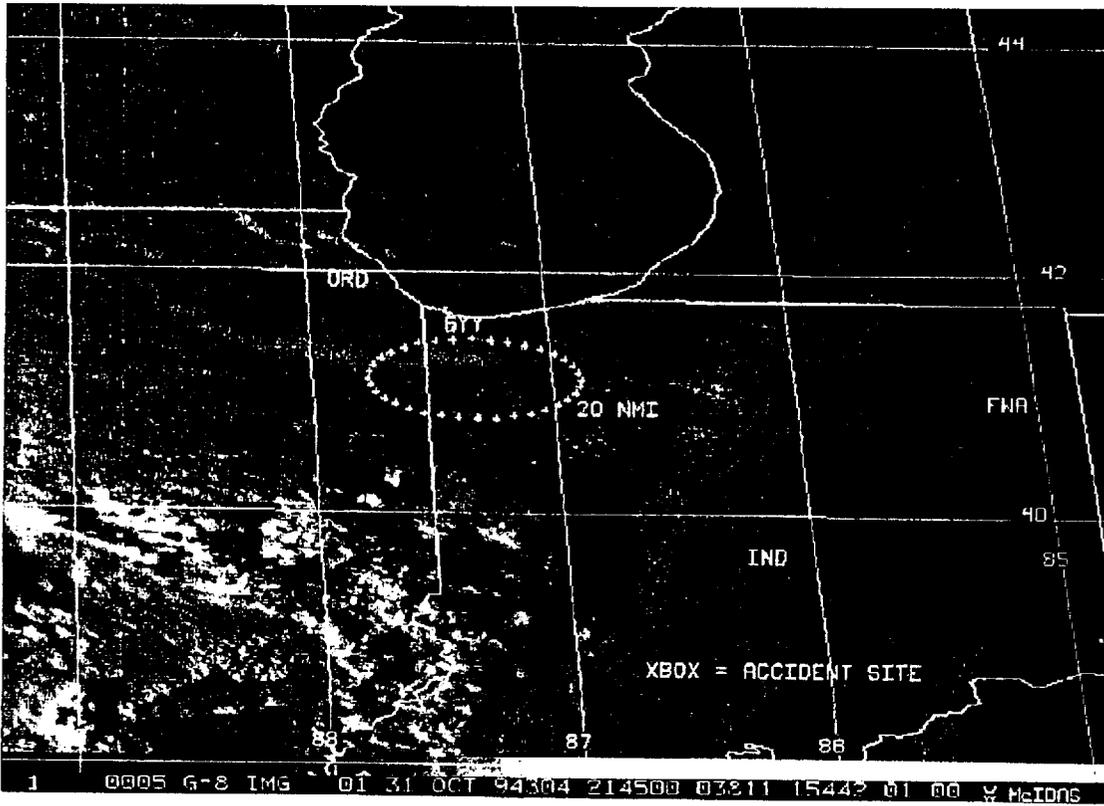
APPENDIX 6



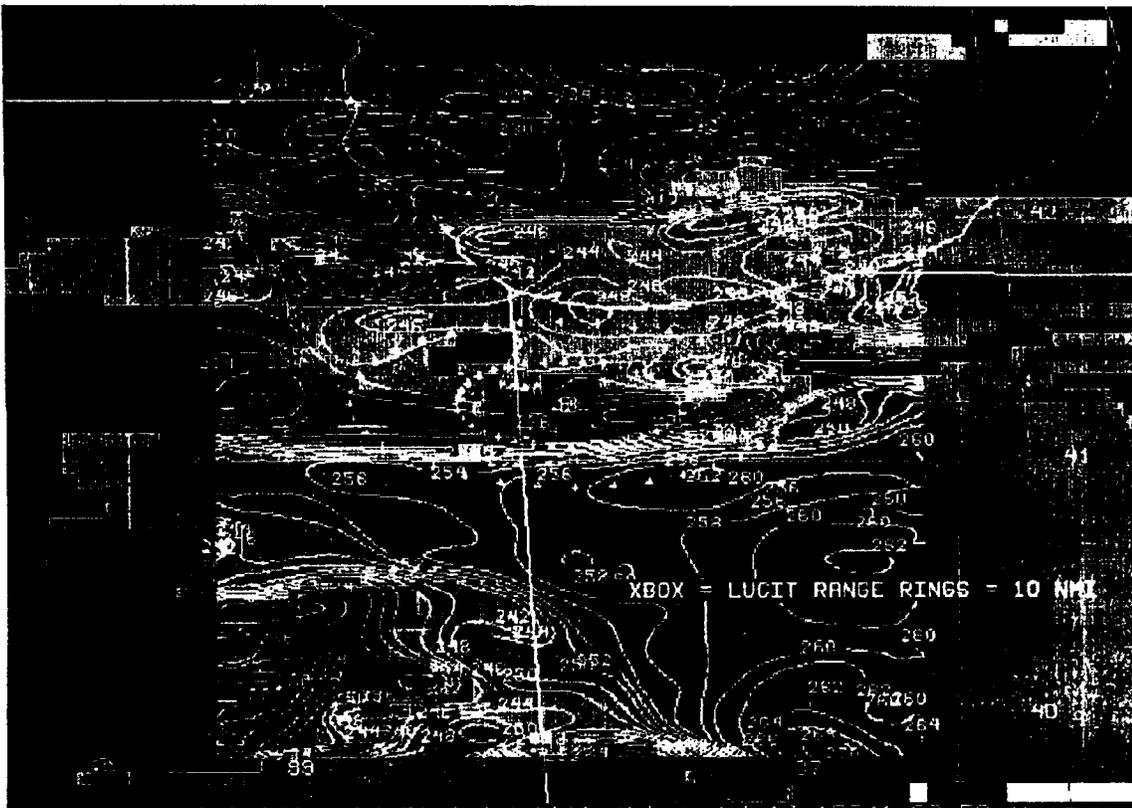
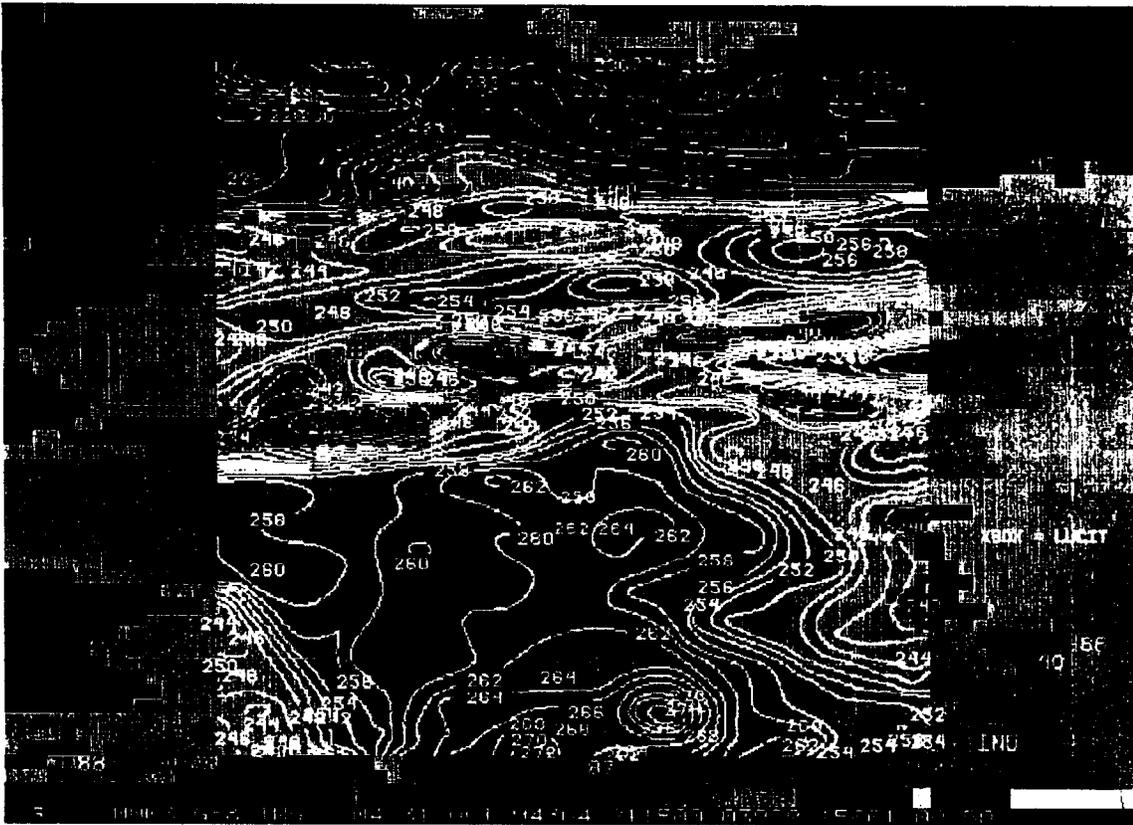


APPENDIX 8



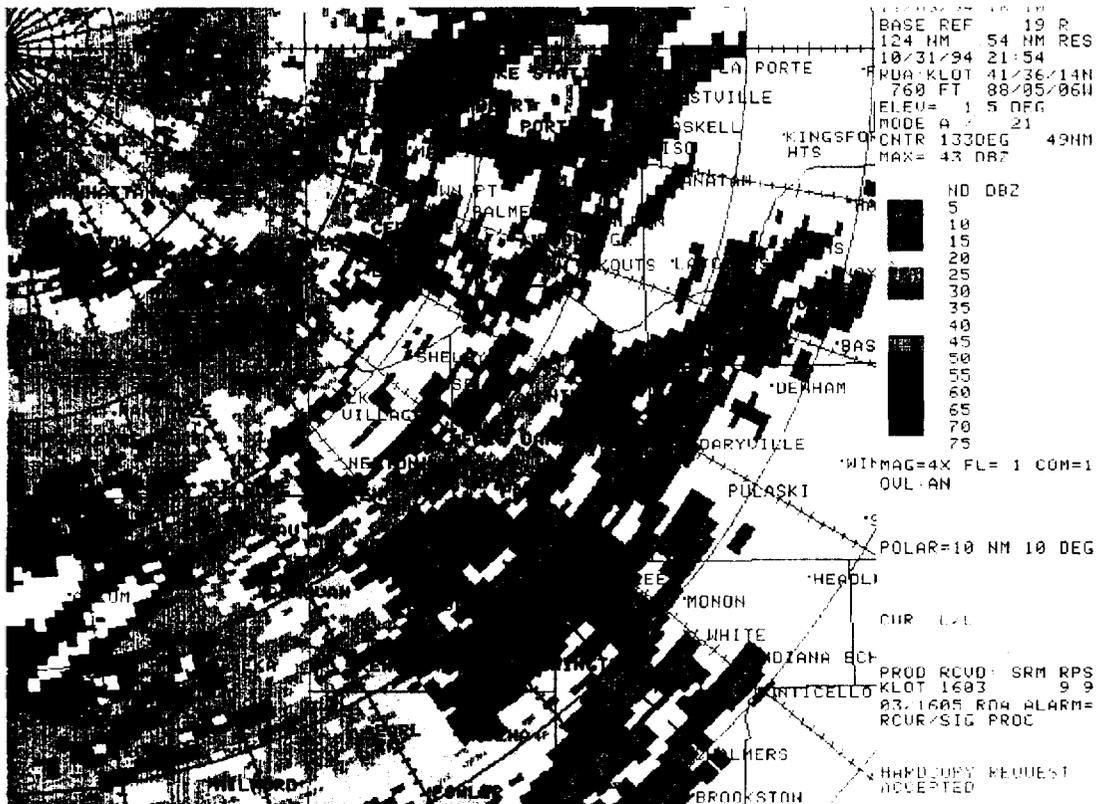
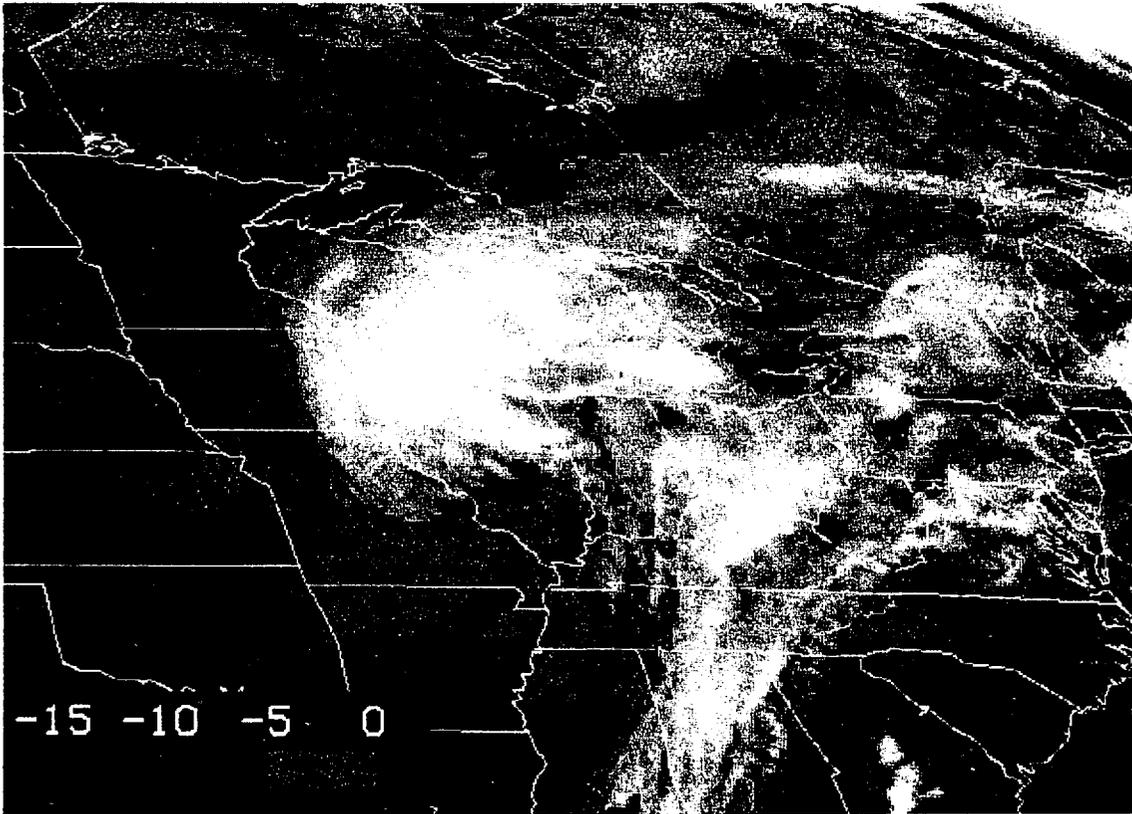


APPENDIX 9

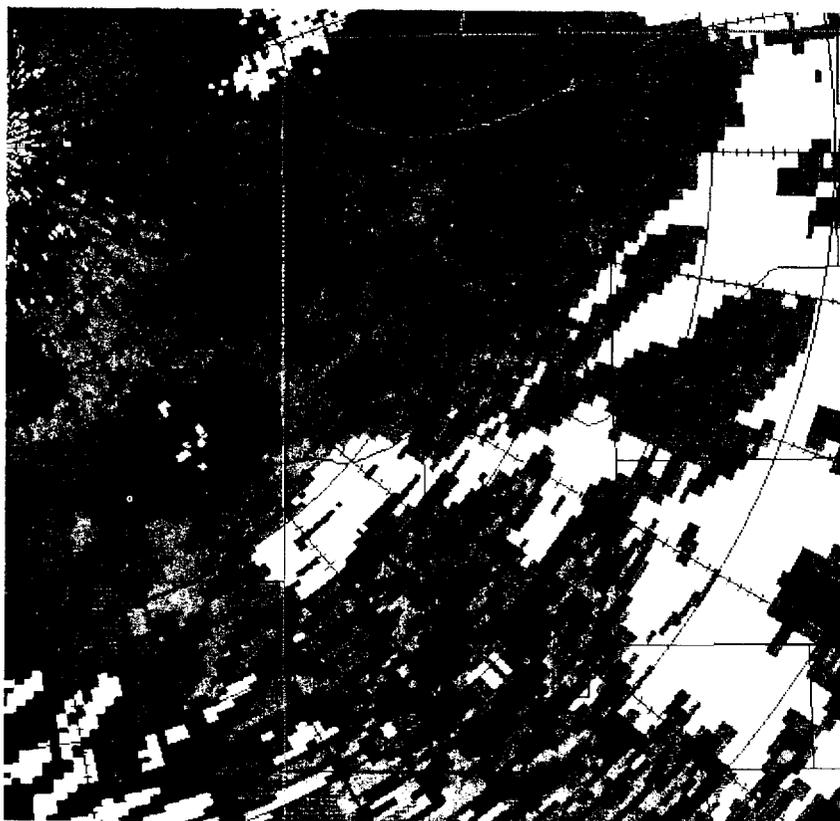




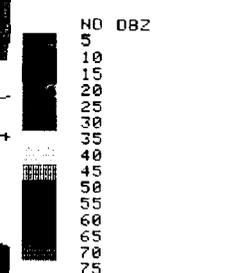
APPENDIX 10



APPENDIX 11



12114294 13:12
BASE REF 19 R
124 NM 54 NM RES
10/31/94 21:54
RDA: RLUT 41:36/14N
760 FT 88:05/06W
ELEV= 0.5 DEG
MODE R 21
CNTR 1250FT 45NM
MAX= 55 DBZ

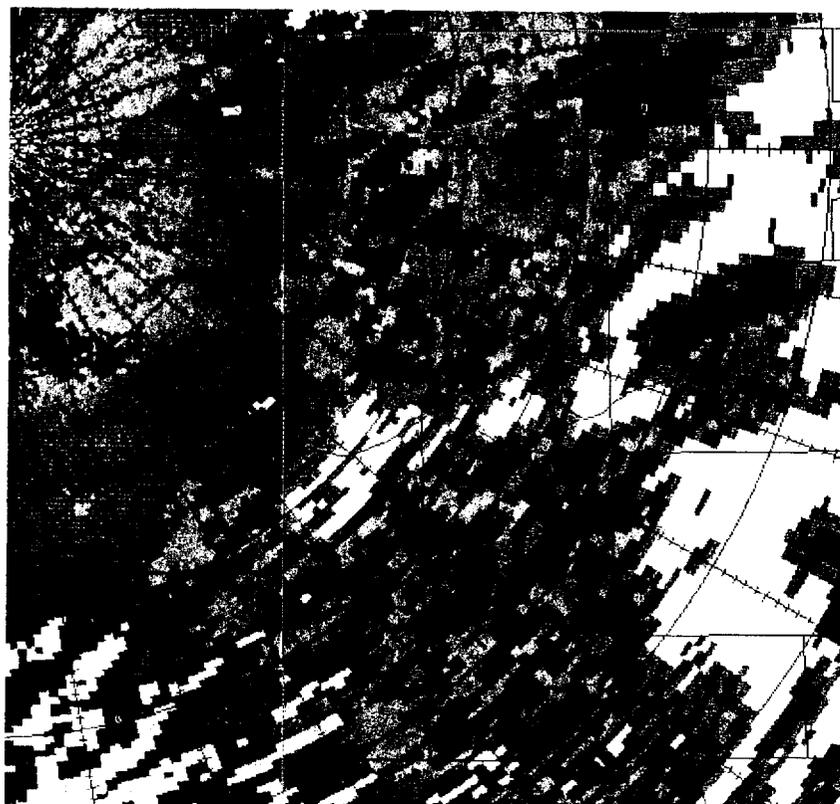


MAG=4X FL = 1 COM=1

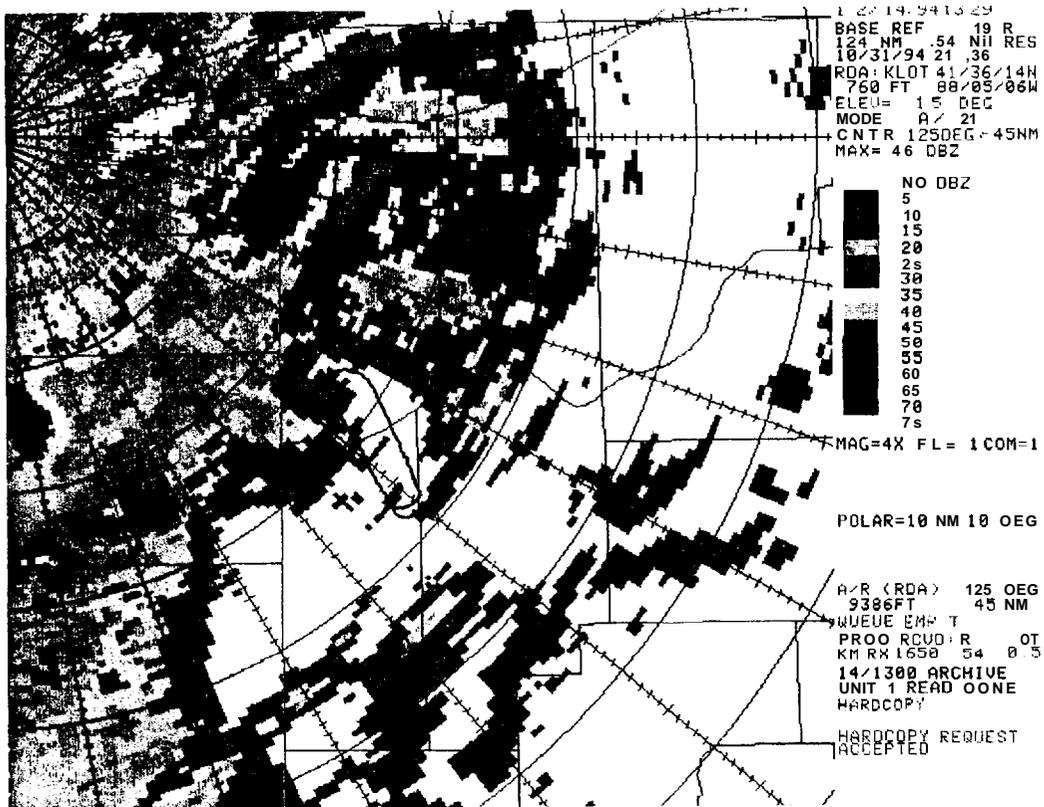
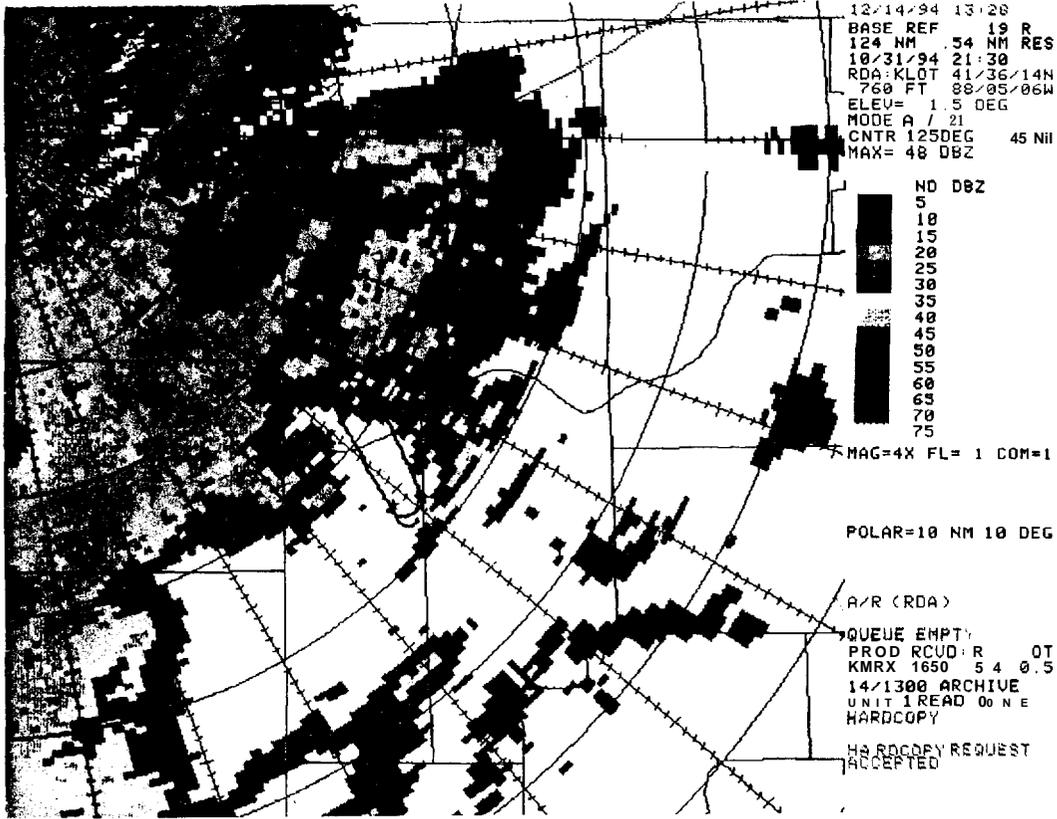
POLAR=10 NM 10 DEC

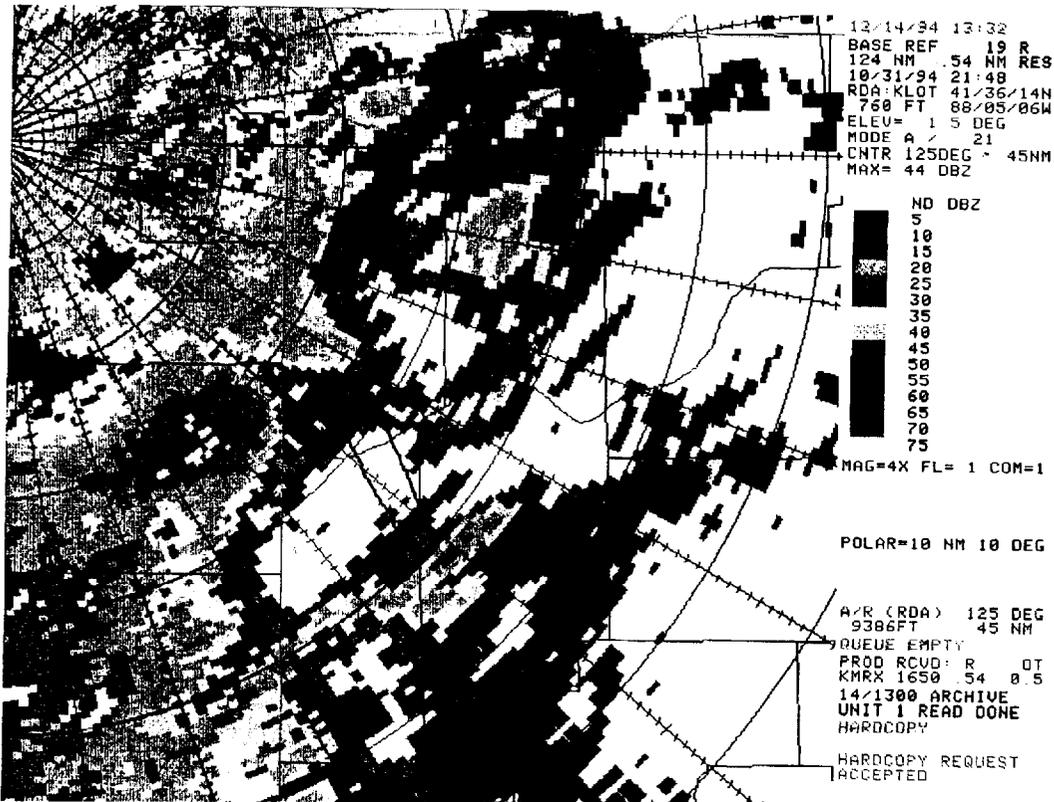
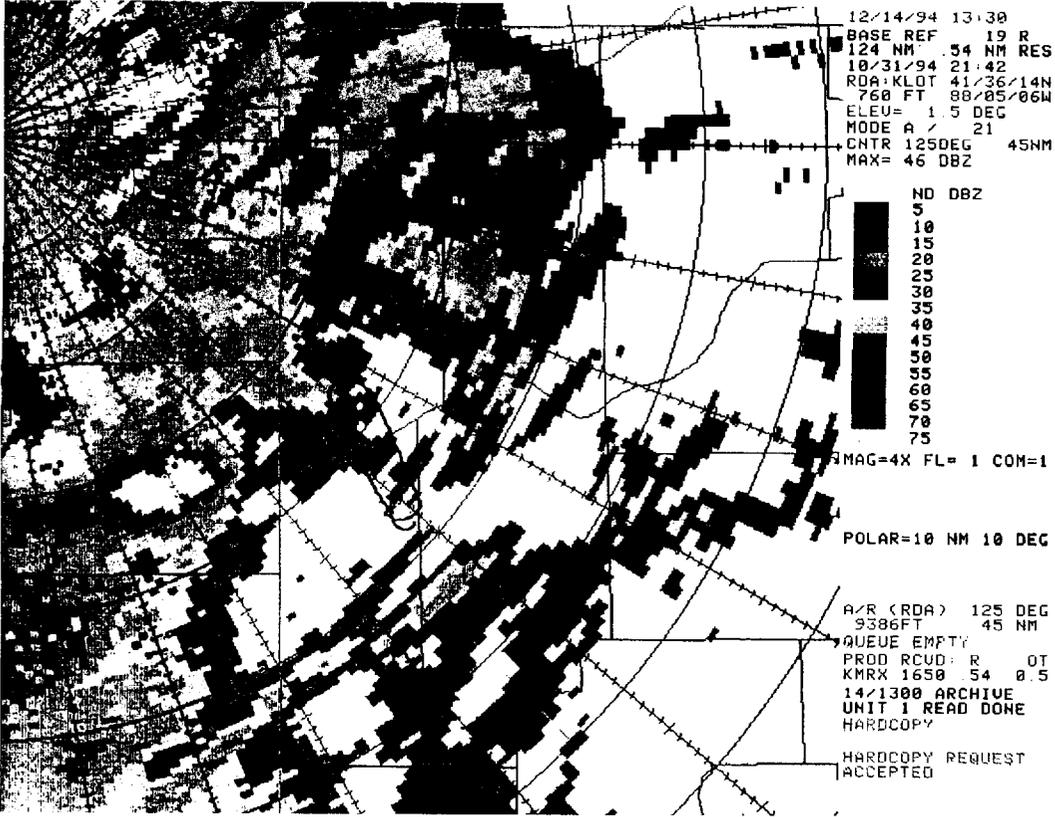
R P (RDA) 125 DEG
450FT 45 NM
10/31/94
PRD RCH: R DT
RMP 1250 54 0.5
14/1300 ARCHIVE
UNIT 1 READ DONE

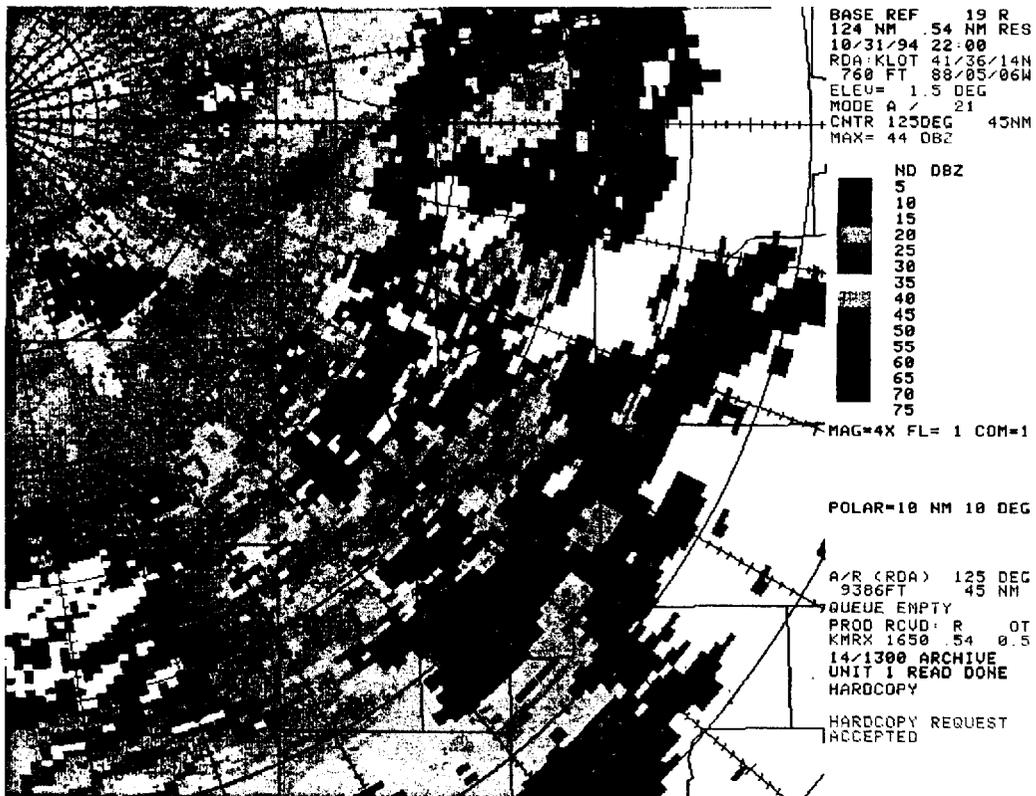
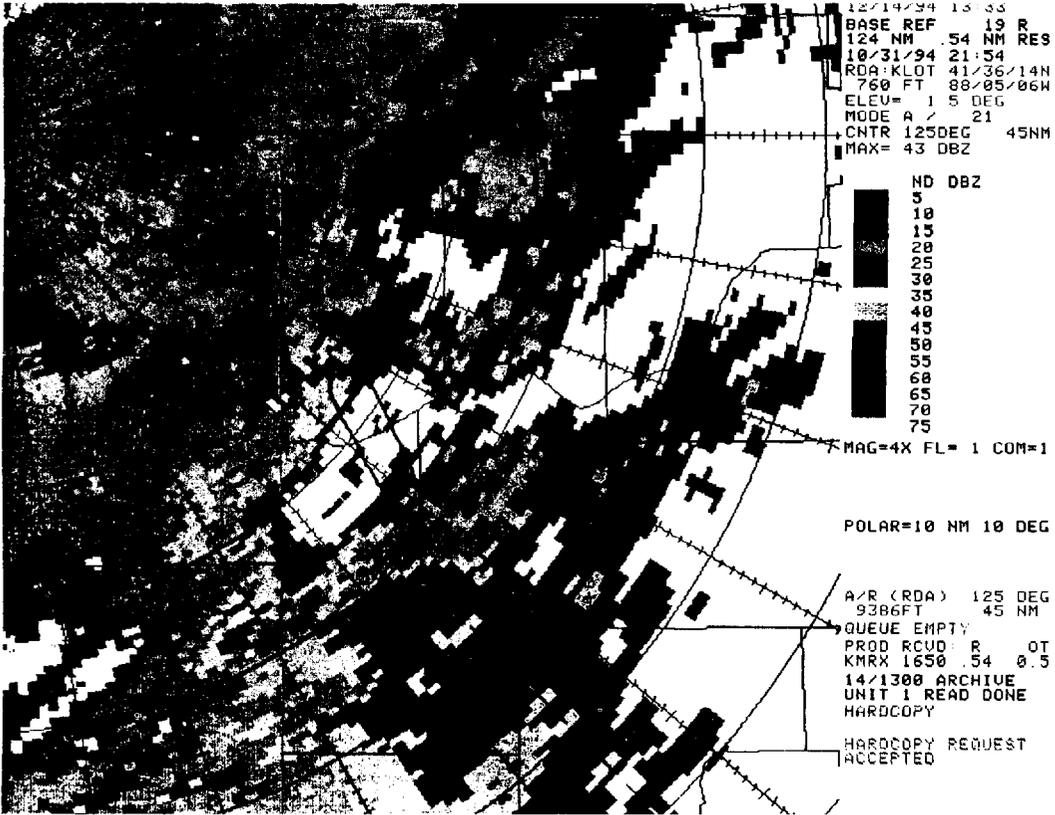
HARDCOPY REQUEST
ACCEPTED



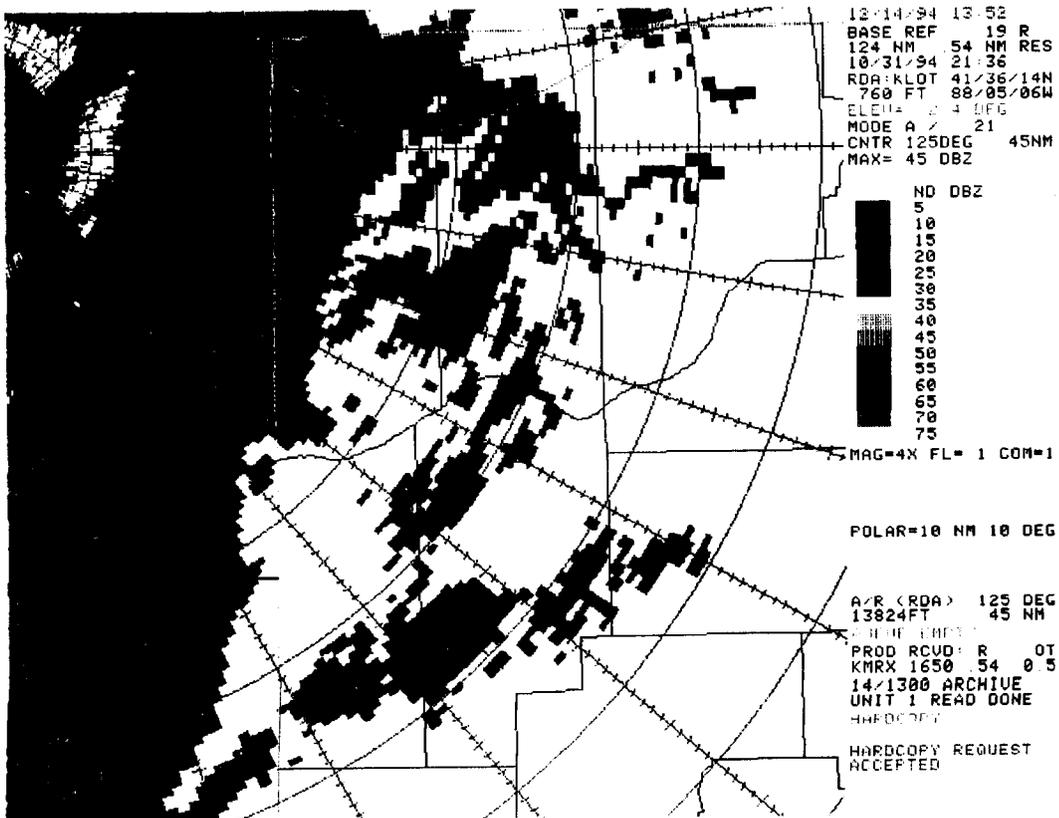
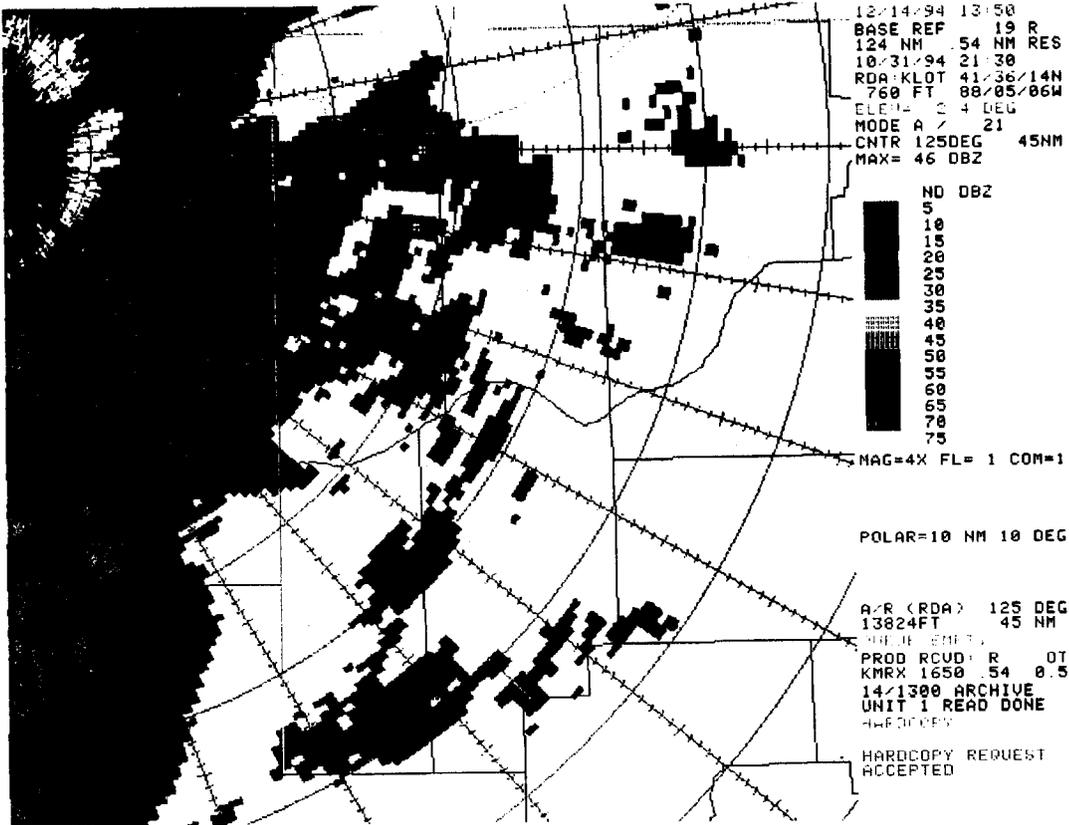
APPENDIX 12

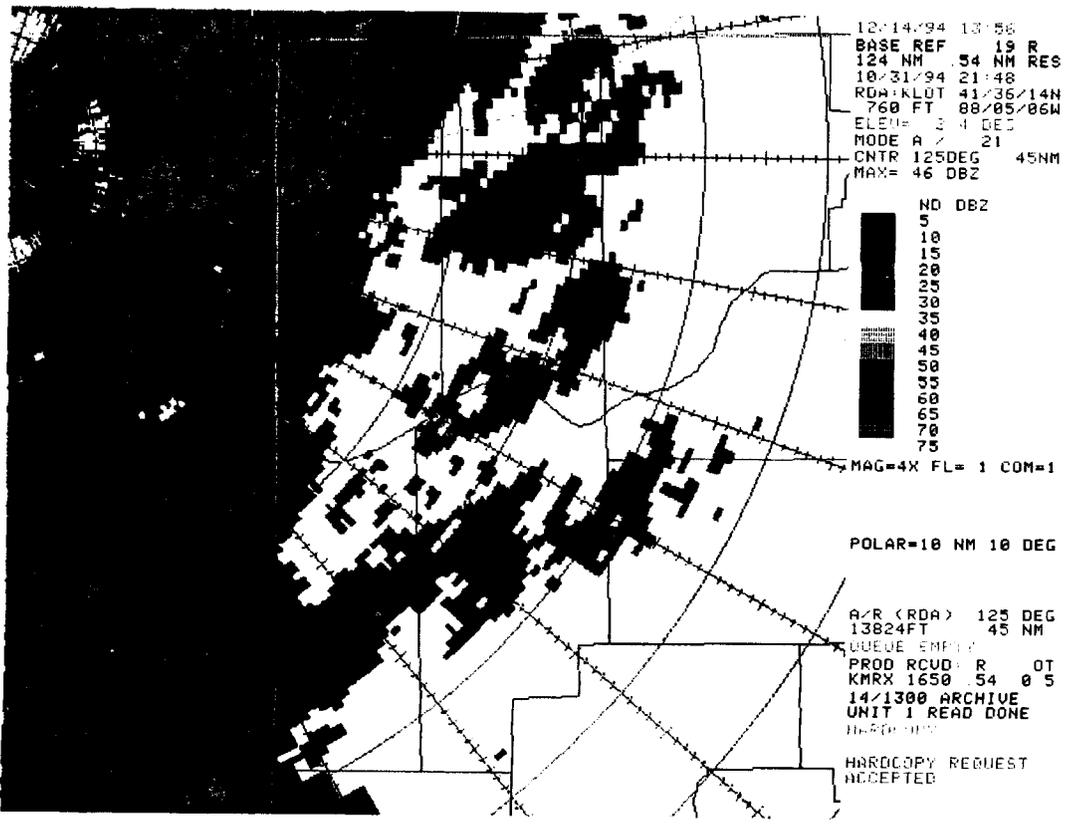
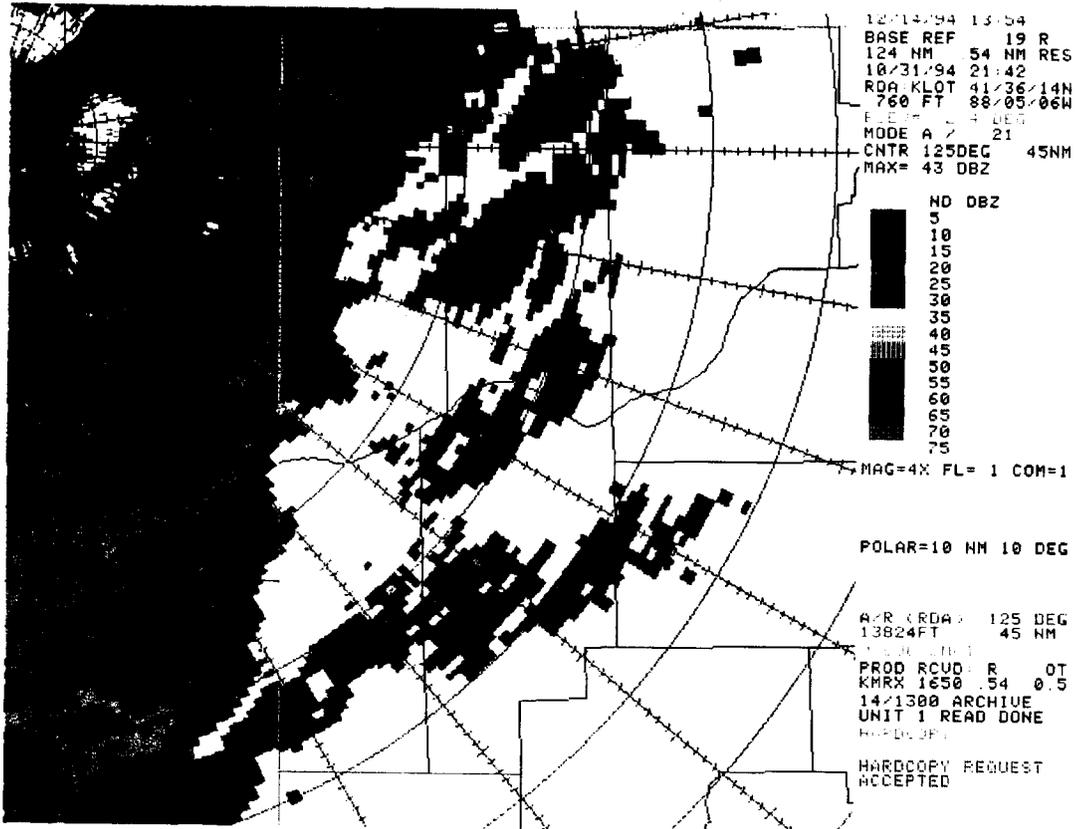


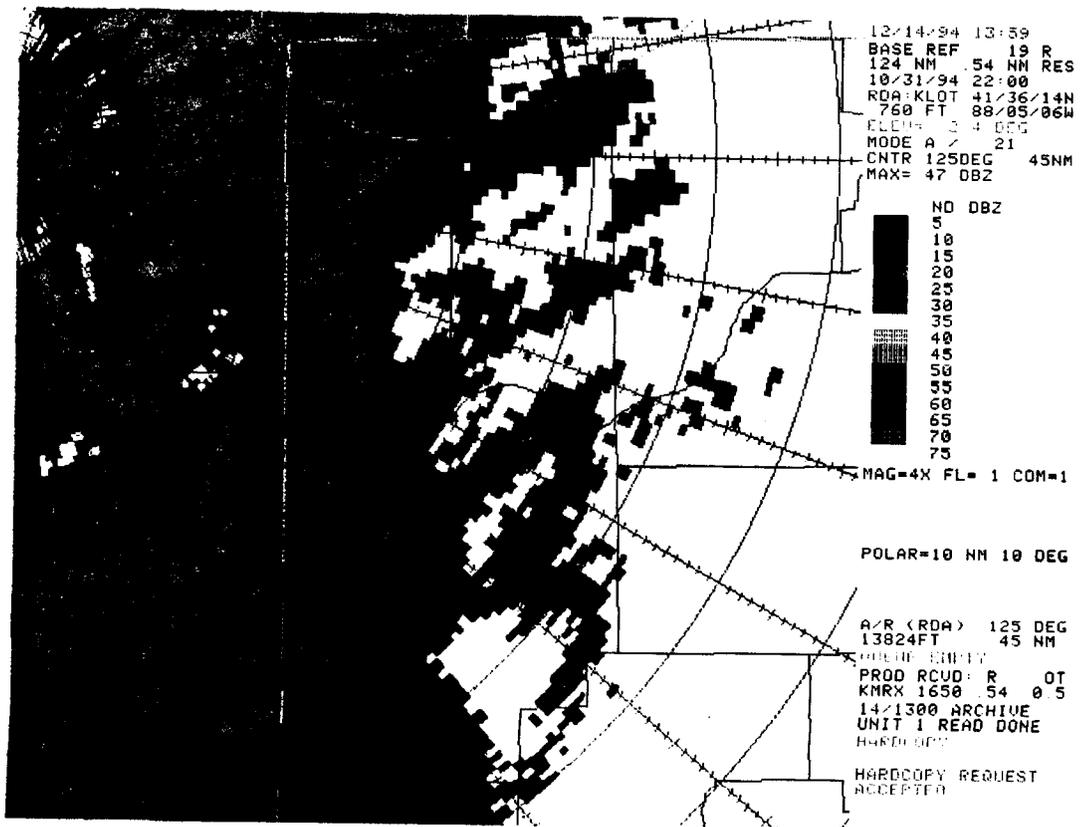
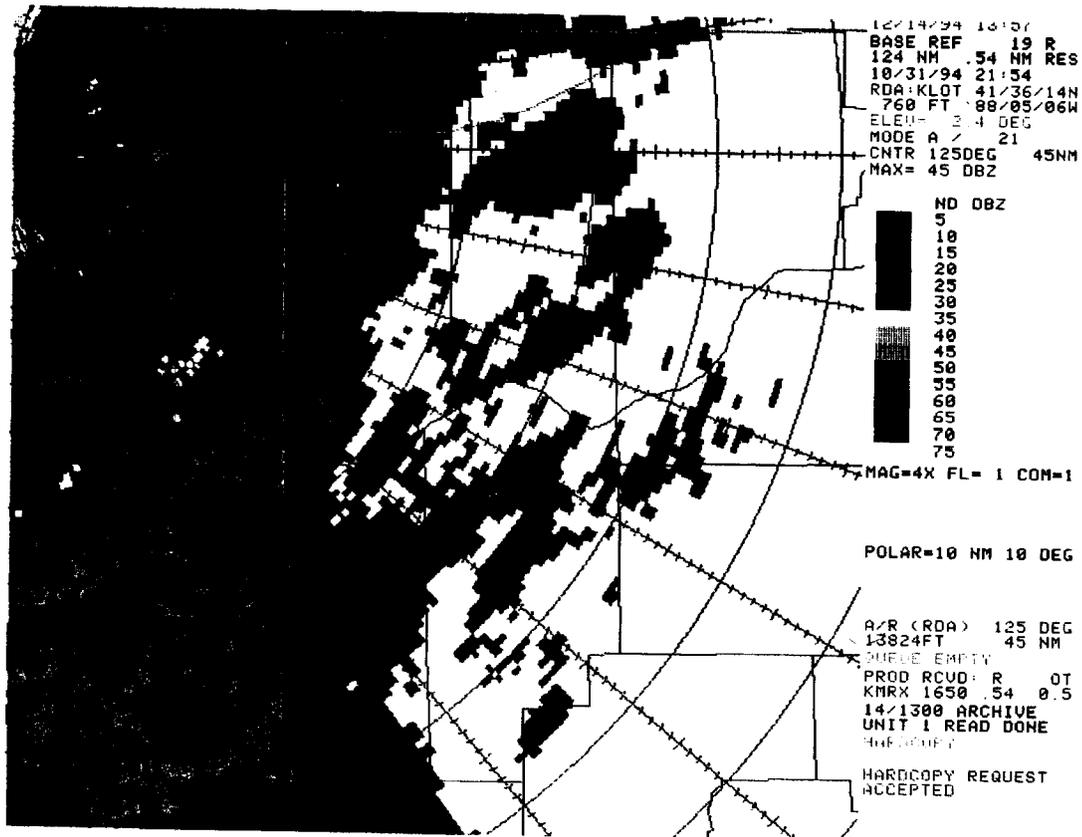




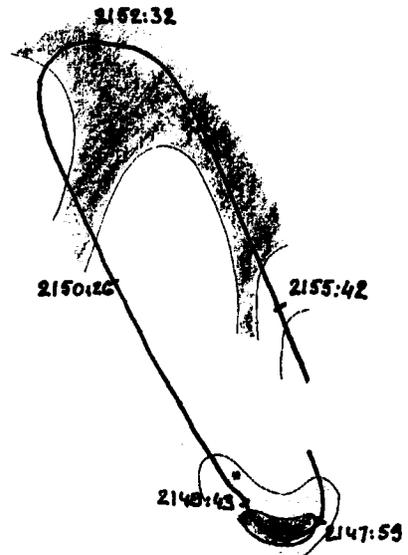
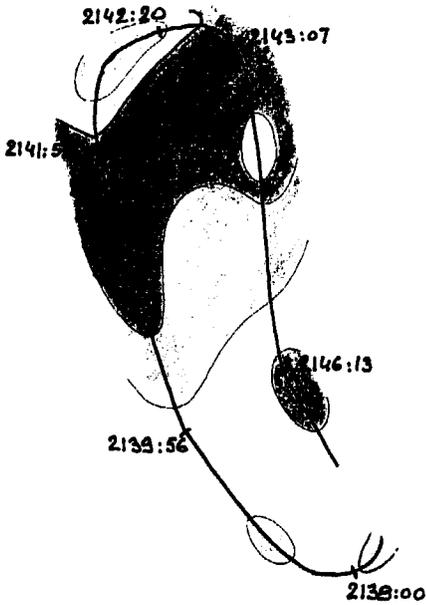
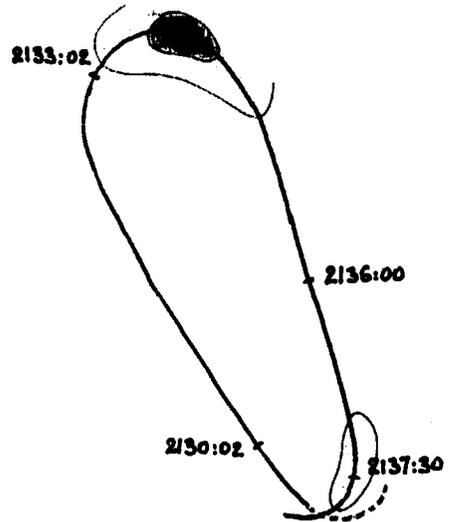
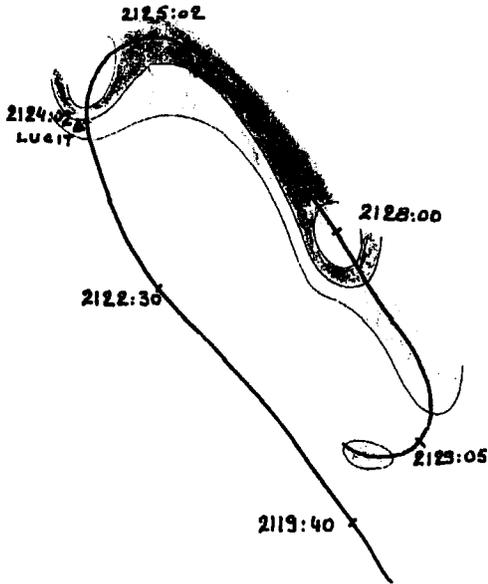
APPENDIX 13





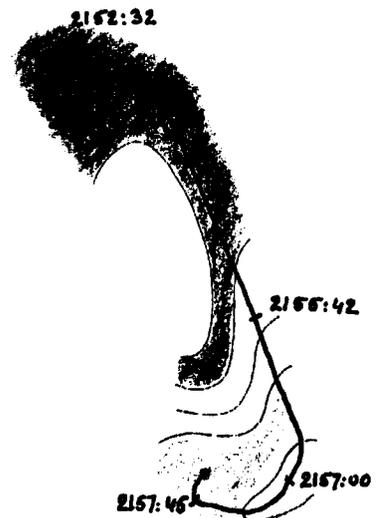


APPENDIX 14



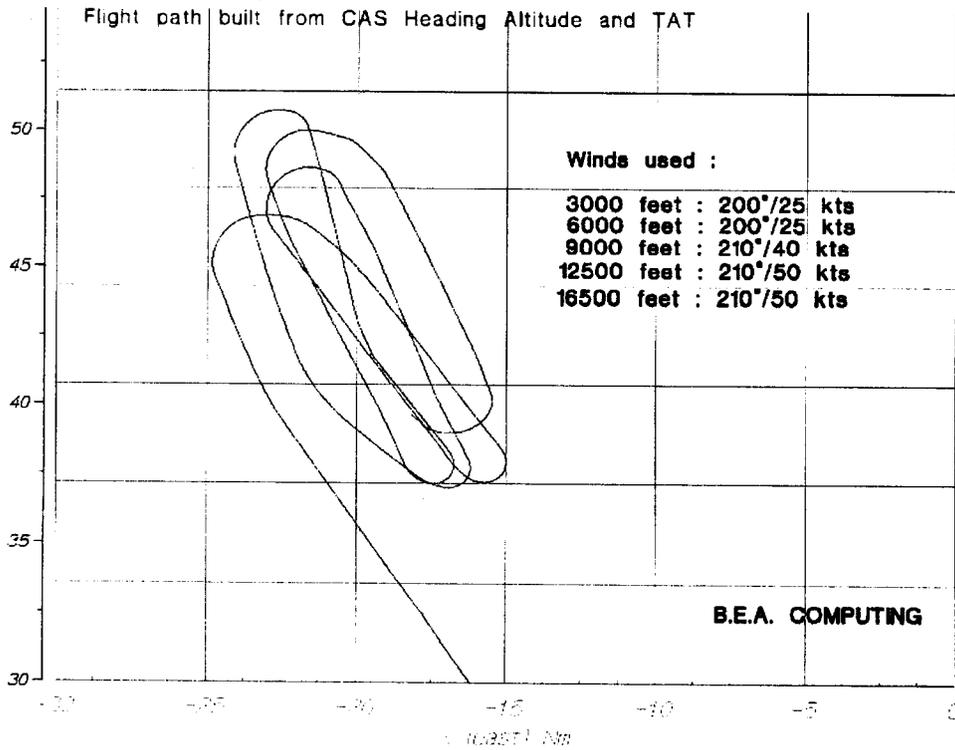
PRECIPITATION ECHOES IN THE HOLDING PATTERN (WEATHER RADAR REFLECTIVITIES)

	10 dBz
	15 dBz
	20 dBz
	25 dBz
	30 dBz
	35 dBz

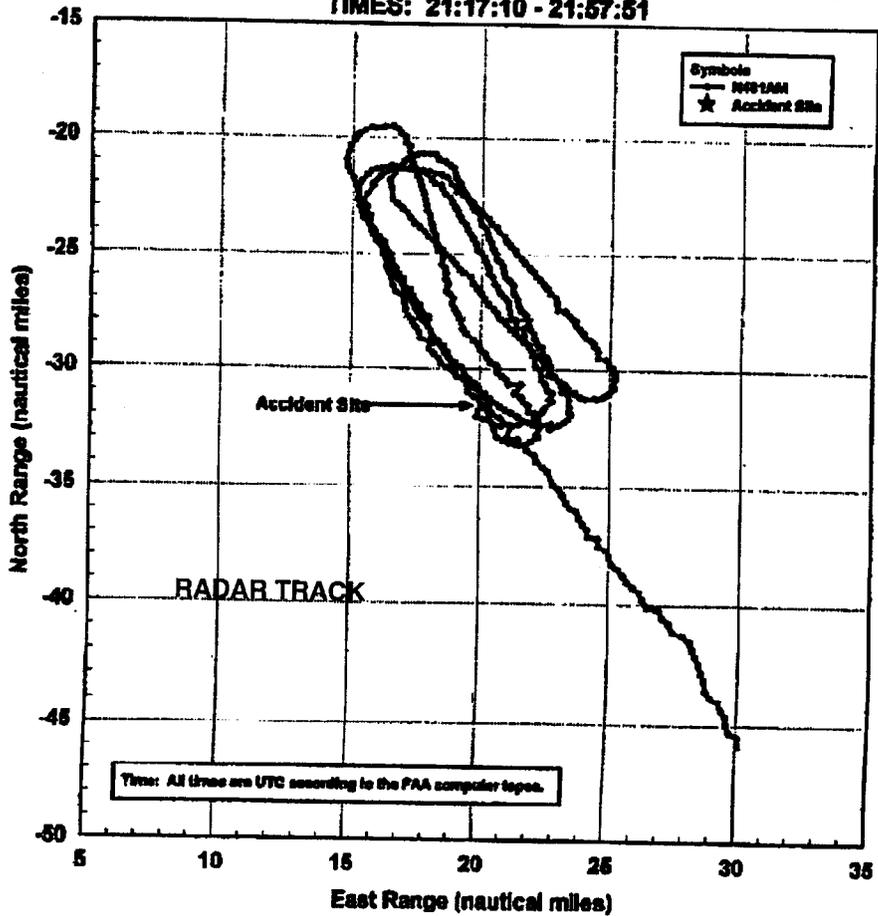


APPENDIX 15

COMPARISON BETWEEN B.E.A. COMPUTING AND RADAR TRACK



North Range vs. East Range
 (DCASMA001, 10/31/94, Roselawn IN, ATR-72-210, N401AM)
 TIMES: 21:17:10 - 21:57:51



COMPARISON BETWEEN
BEA COMPUTING AND RESULTS PROVIDED BY THE NTSB

