M-06497/AIG-24

AIRCRAFT INCIDENT REPORT

(Ref. Law on Aircraft Accident Investigation, No. 59/1996)

Flugfélag Íslands hf.
TF-JML, Fairchild SA-227-DC (Metro-23)
Near Álftafjörður in Ísafjarðardjúp bay, Iceland
16 August 1997

The aim of aircraft accident investigation is solely to identify mistakes and/or deficiencies capable of undermining flight safety, whether contributing factors or not to the accident in question, and to prevent further occurrences of similar cause(s). It is not up to the investigation authority to determine or divide blame or responsibility. This report shall not be used for purposes other than preventive ones.
(Law on Aircraft Accident Investigation, No 59/1996, para 1 and para 14.)

Abbreviations and definitions used in this report

AAIB	Aircraft Accident Investigation Board
AOA	Angle of attack
ACC	Air Traffic Control Centre
BA	British Airways
ICAA	Icelandic Civil Aviation Administration
CG	Centre of Gravity
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
FP	Flying Pilot
~~Fps~~	~~Feet per second~~
g	Accelation due to Earth gravity, international standard value, being 9.80665 m/sec square.
IAS	Indicated Air Speed
IMO	Icelandic Meteorological Office
IOG	Ögur
LLZ	Localiser Navigational Aid
NDB	Non Directional Beacon
~~Performance Class "A"~~	~~A multi-engine, turboprop airplanes with a maximum approved~~ seating of more than nine passengers or a maximum takeoff mass exceeding 5.700 kg, and all multi-engine turbojet airplanes.
RE	Reykjanesskóli
RPM	Rotations Per Minute
VMC	Visual Meteorological Conditions

Aircraft: Fairchild SA-227-DC (Metro-23).	**Registration:** TF-JML. Public Transport.
Registered owner: Fairchild Aircraft Inc., San Antonio, Texas 78216, USA.	**Operator/user:** Flugfélag Íslands hf., Reykjavik Airport, Iceland.
Crew: 2.	**Number of passengers:** 19.
Place of accident: Near Álftafjördur, in Ísafjardardjúp, at appr. 66°07′N 23°00′W.	**Date and time:** 16 September 1997, at approximately 19:46 hrs *)

SYNOPSIS: The aircraft was climbing through 4.200 feet after departure from Ísafjörður. Less than two minutes after take-off, it was subjected to severe vertical gusts that lasted for 90 seconds. The aircraft made three dives and lost 2.244 feet of height in 13 seconds of which 1.866 feet were lost only in 7 seconds during the second dive. It also went through several vertical gust reversals as well as "g" load reversals in the range from minus 1.25 g to plus 4.23 g.
This report concludes that, the aircraft encountered severe, if not extreme, updrafts and downdrafts with speeds of 35 to 57 knots, with reversals of wind directions in periods, averaging 7. 5 seconds.
The aircraft suffered structural damage to the wings, but there were no injuries to the passengers or to the crew. In the right nacelle a hydraulic pressure line cracked, where it connects aft of the firewall, due to the distortion between the wing and the nacelle during the high "g" load excursions. This caused loss of hydraulic pressure and subsequent loss of flap usage during landing and the landing gear was extended with alternate means.

1.1 History of the flight: See page 2.

1.1 Injuries to persons: None.

1.2 Damage to Aircraft: The wings were damaged by excessive positive "g-loads" and hydraulic pressure line cracked causing total loss of system pressure.

1.2 Other damage: None.

1.5 Personnel information:

1.5.1 The Captain. A 33 years old male. Holding an Airline Transport Pilot Licence, issued 20 August 1990 by the Icelandic Civil Avation Administration (ICCA). At the time of the incident the licence and appropriate ratings were valid, as well as the Medical Certificate. He qualified on the SA-227-AC type of aircraft on 16 May 1997 and the differences training for the SA-227-DC was completed on 13 June 1997. At the time of the incident, his total flying time was 4314:42 hrs of which 184:18 hrs was on SA-227-DC.

1.5.2 The Copilot. A 28 years old, male. Holding a Commercial Pilot Licence issued by the ICAA on 27 May 1993. At the time of the incident the licence and appropriate ratings were valid. His total flying time was 1509:06 hrs of which 87:36 hrs were on the type and 9:12 hrs of these were acquired during the type training. The SA-227-AC training and the SA-227-DC differences training was completed and the appropriate type rating endorsed by the ICAA on 27 June 1997. The Co-pilot's total flying time in multi engine aircraft was 694:42 hrs.

1.6 Aircraft information: The aircraft was manufactured in 1997 by Fairchild Aircraft Inc. The type is Fairchild SA- 227-DC (Metro-23), Manufacturer's Serial number DC-881B. The aircraft was registered in Iceland 2 July 1997, registration marks TF-JML. The registered owner is Fairchild Aircraft Incorporated, 1082 Northern Entrance Road, San Antonio, Texas 78216, USA. The aircraft was maintained in accordance with an ICAA approved Maintenance Schedule and it was operated by Flugfélag Íslands hf., Reykjavik Airport, Iceland.
It is powered by two Allied Signal TPE331-12UHR-701G, turboprop engines. At the time of the incident, the total flying time of the aircraft was 261:54 hrs and the number of cycles was 328. The same number of flying hours and cycles applies to the engines and the propellers. The maximum take-off weight is 7.484 kilos and the maximum passenger capacity is 19.
At the time of the incident, the Certificate of Airworthiness was valid until 31 July 1998. The aircraft was fully serviceable and it's documentation was in order. The aircraft was loaded within allowable limits (See para 1.18.3).

1.7 Meteorological information: See page 4.

1.8 Aids to navigation: Not relevant.

1.9 Communications: Not relevant.

1.10 Aerodrome information: Not relevant.

1.11 Flight recorders: See page 7.

1.12 Wreckage and impact information: Not relevant.

1.13 Medical and pathological information: Not relevant.

1.14 Fire: Not relevant.

1.15 Survival aspects: Not relevant.

1.16 Tests and research: See page 7.

1.17 Organizational and management information: See page 8.

1.18 Additional information: See page 9.

1.19 Useful and effective investigation techniques : Not applicable.

2. ANALYSIS:

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3. CONCLUSIONS:

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4. SAFETY RECOMMENDATIONS:

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5. APPENDICES:

5.1 A Radio Navigation Map – Iceland.
5.2 A Map of the Ísafjarðardjúp bay Area.
5.3 Ísafjörður Approach Charts (NDB 342 and LLZ 335).
5.4 Map transcripts of the Bolafjall Radar data.
5.5 Transcripts of the aircraft Digital Flight Data Recorder (DFDR) data.
5.6 Fairchild analysis of the DFDR data.
5.7 Page 57, ICAO Circular 186-AN/122.

*) All times in this report are UTC unless otherwise stated.

1. FACTUAL INFORMATION.

1.1 The flight.

This was a Flugfélag Íslands hf. scheduled domestic flight with passengers from Reykjavik to Ísafjörður and back to Reykjavik. The flight number was FAXI-20 to Ísafjörður and then FAXI-21 back to Reykjavik. The aircraft being operated was TF-JML, a Fairchild SA-227-DC, which had recently being acquired from the manufacturer by the operator. The crew consisted of two pilots both were employees of Flugfélag Íslands hf. Faxi-20 took off from Reykjavik at 18:49 hrs and it proceeded normally, from Reykjavík direct to Reykjanesskóli (RE) NDB. The aircraft was overhead the beacon (RE-NDB) at 19:15 hrs and a normal descent was made in the Ísafjarðardjúp bay, along the Ögur localizer (IOG LLZ).

According to the Captain, the aircraft was out of clouds shortly after RE-NDB or between 5.000 feet and 4.000 feet and the descent proceeded in Visual Meteorological Conditions (VMC) towards Ögur (OG NDB). The pilots noticed a bank of clouds with a sharp northern edge over the Ísafjarðardjúp bay. According to them, this cloudbank was at lower level than the clouds over the Snæfjallaströnd, the northern coastline of the bay.

During the last part of the flight until abeam Skutulsfjörður (IS-NDB), both pilots state that they noticed and discussed rotor flow blowing out from the mouth of Jökulfirðir fjords, on the northern side of the Ísafjarðardjúp bay. They also noticed and discussed wind patterns on the surface of the ocean in the middle of the bay, that were moving towards Skutulsfjordur fjord.

The visual flight into Skutulsfjörður fjord was uneventful. The existing wind at Ísafjörður airport was 90° at 15 to 20 kts and the pilots state that the left hand approach to the runway 09 and the landing, was carried out normally. The aircraft landed at 19:23 hrs.

When the aircraft was prepared for departure, the surface wind was still given as 90° at 20 kts, there was no precipitation in the vicinity of the airport and the visibility was good.

The following description of the flight is based on the pilots´ reports, the Bolafjall radar data and the aircraft Digital Flight Data Recorder (DFDR) data, where altitude is based on 1013 hPa atmospheric pressure at sea level. The pressure at Isafjörður at the time of the incident was 996 hPa. Therefore the actual heights were 510 feet lower that the height figures refered to. The aircraft altimeters were set to 996 hPa.

Faxi-21 took-off at 19:44:34 hrs from runway 09. The aircraft climbed normally straight out of the Skutulsfjörður fjord towards the Ísafjarðardjúp bay and according to the pilots, the climb was smooth, about 2.000 feet/min and no turbulence was experienced.

The aircraft was not equipped with an Autopilot. The Co-pilot was the flying pilot (FP) and the aircraft´s weather radar was not being used.

At 19:46:04 hrs or 90 seconds after take-off, the Captain contacted Reykjavik Air Traffic Control Centre (ACC), reported climbing through 3.500 feet for Flight level 180 and the ACC acknowledged. At this time the aircraft had reached the altitude of about 3.600 feet, off the Arnarnes peninsula, east of the fjord, Skutulsfjörður.

As another aircraft from the same airline was starting its descent from RE-NDB into the Ísafjarðardjúp bay along the IOG-LLZ and occupying that route, Faxi-21 was manoeuvred into a right hand turn, in order to pick up and maintain the direct course south, to Stykkishólmur NDB (SU-NDB). The FAXI-21´s pitch attitude was now gradually increasing by about 1 degree per second and a full climbing power (99% to 100 % RPM and torque) was maintained unchanged.

At about 19:46:14 hrs, shortly after having entered clouds when passing trough 4.200 feet, with the aircraft at 20 degrees pitch and 13 degrees bank to the right, the aircraft entered an up-gust that the FP perceived as quite severe. The indicated airspeed (IAS) was at 174 kts and started to drop at the approximate rate of 3 knots per second. The Captain cautioned the FP to watch the speed but did not take command of the controls. Both pilots perceived the speed decrease as quite rapid and the FP pushed the stick forward, in order to reduce the pitch.

The aircraft continued climbing and IAS continued to fall, the pitch and the vertical acceleration was also decreasing, but the angle of attack (AOA) was increasing. Both pilots were now pushing the elevator forward, as they had the sensation that the aircraft was not responding fast enough. The horizontal stabiliser trimmed position remained unchanged and was not altered during this manoeuvre.

During the next seven seconds, the IAS dropped by 25 knots to a minimum of 151 knots, the aircraft pitch decreased by 10 degrees and continued decreasing, but the AOA was still increasing, apparently due to severe up-gust. Also the vertical acceleration became negative.

At 19:46:24 hrs or three seconds later, the altitude peaked at 4.860 feet the pitch reached 3 degrees nose down and continued decreasing. The AOA peaked at 9.8 degrees and the IAS, at 155 kts, as well as the vertical acceleration started going up again and the right roll began going back to level.

One second later, with the IAS, as well as the pitch and the vertical acceleration increasing, the AOA started decreasing rapidly, indicating that the aircraft had entered a down-gust.

Four seconds later, the vertical acceleration peaked at 1.97g, the IAS peaked at 183 knots and the pitch continued increasing, but the AOA was relatively steady.

Two seconds later the aircraft started to re-gain altitude, the IAS was still 183 knots, the vertical acceleration was decreasing, the AOA was still relatively steady, but the pitch was increasing rapidly, indicating that the down gust was still prevailing.

At 19:46:36 hrs or five seconds later, the pitch decreased momentarily, the AOA increased momentarily and the vertical acceleration went through more than "one g" reversal, indicating a momentary gust reversal.

Nine seconds later, the aircraft pitch peaked at 26.1 degrees, the vertical acceleration started decreasing again and the IAS started decreasing rapidly, loosing 27 knots in three seconds. With the pitch decreasing, the AOA was increasing, indicating again an up-gust. Right bank had eased off, but then started to increase again.

Six seconds later the IAS reached the minimum of 146 knots and started to increase rapidly again with the pitch gone nose down and decreasing rapidly with the AOA exceeding 10 degrees.

One second later, or at 19:46:52 hrs, the altitude peaked at 5.844 feet and the right bank peaked at 31.8 degrees, IA S being at 153 kts.

Two seconds later, the IAS was at 168 kts increasing rapidly, the vertical acceleration reached a minimum of minus 1.25 g, the pitch was down to 30.6 degrees nose down, the AOA peaked at 12.5 degrees and the aircraft wings were level. The high AOA with the rapidly decreasing pitch indicated the presence of a severe up-gust with the estimated speed of 35 knots. The right hand engine was now indicating the onset of a flameout.

Two seconds later, the pitch reached a maximum of 45.1 degrees nose down. With the AOA at 12.4 degrees the vertical acceleration started increasing rapidly.

One second later or at 19:46:57 hrs, the vertical acceleration had reached plus 2.75 g, the IAS was at 197 knots and the aircraft was loosing altitude rapidly. With the pitch increasing rapidly but the AOA decreasing, it was as if the aircraft had been hit with a severe down-gust of the order of 55 knots. The left-hand engine was now indicating the onset of a flameout.

Four seconds later, the vertical acceleration peaked at plus 4.23 g and longitudinal at plus 0.43 g, when the rate of pitch change peaked at 13.5 degrees in one second. The IAS was at 243 knots, increasing, and engines had re-lit and were still at full power settings that had not been changed during the disturbance. The aircraft was also rolling to the left.

Four seconds later, the lowest altitude of 3.600 feet was reached, the aircraft had 20,7 degrees nose up pitch and increasing. A maximum of 24.9 degrees left bank was reached, and the IAS was decreasing again, having reached the maximum of 253 knots one second earlier. The vertical acceleration was plus 3.84 g, but decreasing.

Two seconds later, or at 19:47:07 hrs, the pitch peaked at 34.3 degrees nose up, the left bank was at 22.2 degrees and the vertical acceleration was plus 3.32 g, but decreasing fast.

Two seconds later, the vertical acceleration went momentarily to minus 0.72 g. The pitch was decreasing but the AOA increased suddenly, indicating an up-gust.

Four seconds later the IAS was 191 kts, the pitch increased again with the AOA decreasing, indicating a down-gust, lasting for another four seconds, when the pitch started decreasing again and the AOA started increasing, indicating an up-gust, and the altitude was increasing rapidly.

Three seconds later with the pitch decreasing rapidly and the AOA increasing rapidly, the vertical acceleration became negative again.

Four seconds later, or at 19:47:24 hrs, the altitude peaked at 6.584 feet and the vertical acceleration was still negative, but increasing. The pitch reached a maximum of 9.8 degrees nose down and the AOA peaked at 11.7 degrees, indicating the end of the up-gust, the IAS was 157 kts.

Seven seconds later, the aircraft had descended to the altitude of 6.391 feet and started to climb again. The vertical acceleration peaked at 1.66 g, pitch was 6.2 degrees and stabilising, IAS was stabilising and increasing slightly.

Thirteen seconds later at the altitude of 7.169 feet, the aircraft started a right roll, changing the heading from east, which it had more or less maintained since the minimum altitude of 3.600 feet was reached, 39 seconds earlier.

At this time or at 19:47:44 hrs, the flight had now lasted three minutes and thirteen seconds since take-off.

Seven seconds later or at 19:48 hrs, the Captain called ACC and reported the occurrence.

There were no injuries to the passengers and the flight to Reykjavik Airport proceeded otherwise normally at 15.000 feet.

At 19:51 hrs, the Captain reported that the aircraft had lost the hydraulic pressure and that there might be problems with lowering the landing flaps and the landing gears. The landing gears were successfully lowered manually and the aircraft landed at 20:24 hrs, with 0-degrees flaps at Reykjavik Airport.

The loss of the hydraulic pressure was later found to be due to the hydraulic pressure line in the right nacelle where it connects aft of the firewall had cracked due to the distortion between the wing and the nacelle during the high g-load excursions.

1.7 Meteorological information.

At the request of the Air Accident Investigation Board (AAIB) in Iceland, the Icelandic Meteorological Office (IMO), made a special study and analysis of the weather situation in the area at the time of the incident, using also data from the DFDR and the Bolafjall radar.

This comprehensive Study-Analysis report is in Icelandic and parts of it have been translated and included in this report.

1.7.1 The general weather situation.

At the time of the incident, there was a 985 hPa low-pressure system just off the southern tip of Iceland. It was deepening and moving northwest and the air pressure was falling over the country. A warm front extended from the southwest part of Iceland to the northeast, moving to the west towards the Ísafjarðardjúp bay area. A precipitation belt accompanied the front and at 20:00 hrs, this precipitation belt was located over the eastern parts of the Breidafjörður bay in the south, to the inner areas of the Ísafjarðardjúp bay.

To the west of the front, the winds were blowing from the north and from the northeast. The wind speed at most of the observation stations in the Ísafjarðardjúp bay area was 10-20 kts, but at Æðey island just off the northern coast of the bay, the wind speed was 32 kts. At 18:00 hrs the pressure gradient indicated, that wind speed at the mountain heights in the area was estimated 30-35 kts. At 21:00 hrs the pressure gradient had increased and therefore increasing the estimate to 35-40 kts wind speed.

1.7.2 Weather in the area.

Earlier in the day, the weather was clear, winds were light and it was very warm in the Ísafjarðardjúp bay area. In the middle of the day, the maximum temperature went up to +15.8°C at the weather observation station in Bolungarvík, up to +16.2°C in Æðey island and up to +18.1°C in Súðavík, but the temperature started to decrease after 15:00 hrs. Then the drop in the pressure gradient had increased, enabling cooler air to start flowing into the Ísafjarðardjúp bay area. This flow of cooler air was at first prevented by the mountains north of the area, but at about 15:00 hrs, the pressure gradient had increased enabling the cooler air to flow across the mountains into the Ísafjarðardjúp bay.

In the afternoon, clouds started to build up and the rain belt approached from the east. In general, the winds were light in the area. In the Æðey island the wind speed started to increase after 15:00 hrs. The average wind speed in the period 17:00 hrs until 19:00 hrs was 29-33 kts, with gusts up to 49 kts. The wind speed started to decrease after 19:00 hrs and at 21:00 hrs, the wind speed was again similar to what it had been earlier in the day.

The maximum average wind speed at Ísafjörður airport was 16 kts at 20:00 hrs. At Þverfjall mountain (elev. 752 m) approximately 8 km to the SW of the airport, the wind speed was similar and the maximum gusts were recorded 23 kts at 21:00 hrs. In Súðavík the wind speed increased in the evening, average wind speed was recorded 23 kts at 21:00 hrs, with peaks up to 35 kts. The wind speed started to decrease after 21:00 hrs.

The wind speed recorded at 400 meter height at Steingrímsfjarðarheiði, east of the Ísafjarðardjúp bay, was gradually increasing in the afternoon and from 19:00 to 21:00 the average wind speed was 25 kts with peaks up to 28 kts.

According to the reports given by the pilots of Faxi-20, they noticed and discussed, during the descent before landing at Ísafjörður airport, a strong wind current blowing out from the Jökulfirðir fjords on the northern side of the Ísafjarðardjúp bay. They also noticed wind patterns on the surface of the ocean in that area, indicating strong winds. They also noticed a bank of clouds with a sharp northern edge over the Ísafjarðardjúp bay. According to them, this cloudbank was at lower level than the clouds over the Snæfjallaströnd, the northern coastline of the bay.

Based on the DFDR and radar data analysis it is considered likely, that the horizontal wind speed was increasing up to the altitude of 5.000 feet and that the wind speed was at maximum between 5.000 and 6.000 feet, or at 50-60 kts. It then decreased rapidly above 6.500 feet.

1.7.3 Special observations and witnesses reports.

The IMO weather observer at Æðey island made a special observation immediately after the incident and his report was taken.

He maintained, that the movement of the clouds in that area was noticeably prominent at that time, as stratus clouds rolled down the mountain side at the Snæfjallaströnd coastline north of the Ísafjarðardjúp bay. Also the clouds went down to about 500 feet altitude before disintegrating, instead of drifting out over the Ísafjarðardjúp bay as usually seen during north easterly winds in the area. He also maintained that he had on many occasions seen down flowing air in clouds over the coastline, but this time it was unusually prominent.

Snæfjallaströnd is the northern coastline of Ísafjarðardjúp bay and it is uninhabited. According to a hiker who was this afternoon on the Snæfjallaströnd coast, the wind speed there increased considerably in the afternoon, with strong wind currents coming from the gullies and small valleys also with white clouds “streaming” down the mountainside and over the ocean.

Later or in the evening, this hiker took the ferry from the inner part of Ísafjarðardjúp bay to the town of Ísafjörður. At about 20:00 hrs, the ferry was exactly located in the area where the incident occurred. The hiker said that he and his companions discussed a very dark cloud formation that was over the middle of the Ísafjarðardjúp bay. They also observed an aircraft flying just under the cloud and then later heard a sudden and a brief engine noise.

1.7.4 Mountain waves and breaking waves.

Description of clouds and winds indicate that here were mountain waves present in the area at the time of the incident. Typical wave clouds were, however, not reported or observed on satellite pictures. The energy in the waves that were formed over the Ísafjarðardjúp bay, was “returned” close to where the waves were being created, either in the form of a rotor or in the form of “breaking waves”.

At certain conditions mountain waves may rise, so that they start overturning and breaking backwards at the top. Then the air becomes unstable, similar as experienced in rotors and severe turbulence can be expected. Waves may break at any altitude, but turbulence caused by breaking waves is most frequently found where the wind speed starts decreasing with altitude. Breaking waves are considered to be associated with strong downdraft and strong wind speed at the surface, on the leeward side of mountains.

The turbulence experienced by Faxi-21 was strongest at the altitude of 4.000 - 6.000 feet. Calculations based on the aircraft DFDR and the Bolafjall radar data indicate that the wind speed decreased above 6.500 feet.

"Breaking waves" are described as follows by the World Meteorological Organisation, Technical Note No. 158:

> "Under conditions of a strong vertical wind shear, wave slopes may steepen until the waves break - similar to waves breaking in the ocean surf. Wave breaking leads to the most severe turbulence in mountain waves, because in the stably stratified atmosphere breaking waves move cold air on top of warm air. ....
> Wave breaking may occur at lower levels in the rotor zone or near the tropopause in the lower stratosphere, for example in the negative shear zone on top of the jet stream core."

1.7.5 The Conclusions of the IMO Study-Analysis Report.

- There was a very warm air mass in the Ísafjarðardjúp bay area during the day, but when a front approached from the east in the afternoon, cooler air began to flow into the bay area. The mountains north of the bay kept the cool airflow away while the wind was light, but the cooler air may to some extent have been flowing over the existing air mass and thus causing considerable local thermal turbulence.
- At about 15:00 hrs, the wind speed became high enough to enable the airflow over the mountains (ref.: The wind observations at Æðey island). This initiated the formation of mountain waves and during the next hours the conditions were such that the waves were breaking slightly lower than at the level, where the wind speed started to decrease. Breaking waves are known to cause severe turbulence.
- It is considered likely that areas of rising air and turbulence, formed by the two previously mentioned causes, did merge and therefore, the turbulence became much more severe than either cause would justify on their own.
- Initially, the mountain waves were formed by the mountain Drangajökull glacier and by the mountain ridge south of it, by the Snæfjallaströnd coastal mountains as well as by the mountains between the fjords Skötufjörður and Mjóifjörður. This, however, cannot be ascertained and it would be desirable to study the formation of air streams and airwaves in the bay using a numerical prediction model.
- At about 20:00 hrs the wind speed had become high enough to prevent the waves from breaking. This can be deduced from the rapidly decreasing wind speed in the Æðey island. Later, the mountain waves were of the regular type, possibly with minor rotors at mountain heights.

1.7.6 Wind shear and mountain waves.

ICAO Circular 186-AN/122, page 163, contains this description of wind shear:

"A wind shear is a change of wind speed and/or direction over a short distance along the flight path. Severe wind shear is that which produces airspeed changes greater than 15 kts or vertical speed changes greater than 500 feet per minute."

Also from page 117 of the same Circular: "Mountain waves normally form at levels above 500 m (1.600 feet) as stationary wave trains of decreasing amplitude, streaming downwind from the ridge line or specific mountain peaks." And: "The presence of a marked low-level temperature inversion at ground level, may prevent this wind from actually reaching the surface, thereby producing a shear zone at the top of the inversion layer. In extreme cases the amplitude of the waves may be sufficient enough to form a separate and very turbulent rotor flows with or without an attendant rotor cloud under the first and possibly subsequent wave crests. Intense rotor flows may contain downdrafts/updrafts as strong as 50 kts (5.000 ft/min)".

Also: "It is often very difficult to forecast the actual wind speeds and wind shear quantitatively. The presence of lenticular clouds and rotor clouds is of course an immediate indication of the existence of mountain waves. As far as forecasting is concerned, a set of empirical "rules of thumb" must be prepared for each location, which will normally include criteria based upon:

a) The critical wind speed at the mountain ridge (probably in excess of 15 kts) with wind speed increasing with height.
b) A stable upwind layer or an inversion below the 600 hPa level and preferably sandwiched between two less stable layers.
c) Light winds in the stable layer.
d) Removal of moisture on the windward side of the mountain range as precipitation; and
e) Sea-level pressure differential across the mountain range".

The "BA-Safety Services-Flight Deck", Issue 16, 1995, contains this description:

"Mountain waves are a form of atmospheric waves. Atmospheric waves can form everywhere. They can form between any two layers with significant density and wind speed differences. Turbulence is generated when the magnitude of the vertical shear, causes a smooth wave to "break". When the wave breaks, it forms a series of turbulence, producing vortices. Research has shown that these vortices have diameters of 900 - 1.200 feet and tangential velocities of 70 - 85 feet (or up to 50 kts) per second."

1.11 Flight recorders.

The aircraft TF-JML was equipped with the following Flight Recorders:

a) A Fairchild A 100,Voice Recorder (CVR).
b) A Loral S-703-1000-00, Digital Flight Data Recorder (DFDR).

Both recorders were removed after landing at Reykjavik Airport and both were functioning properly. The CVR had a recording capability of 30+ minutes. It was played by the AAIB, but the data recorded during the time the incident took place had been erased due to the time elapsed until power off after landing at Reykjavík Airport.

The DFDR recording was downloaded with the assistance of the aircraft manufacturer´s representative, who brought the necessary software to Iceland to do this. The information was subsequently read under the supervision of the AAIB. The DFDR was working properly and it gave most of the information used to analyse the incident.

1.16 Tests and research.

1.16.1 DFDR data analysis done by AAIB in Iceland.

At the request from the AAIB in Iceland, the data retrieved from the DFDR was analysed by Fairchild Aircraft Inc. The results are attached as appendices to this report in graphical form.

Aircraft climb angle (GAMMA) was computed as ARC SIN[Rate of Climb / (DFDR IAS x 1.6878)] and Aircraft angle of attack (ALPHA) as DFDR PITCH minus aircraft climb angle. The Rate of Climb was computed by curve fitting segments of the DFDR altitude data and differentiated the data to determine Rate of Climb.

The vertical gust velocity was approximated as Vertical gust (fps) = (DFDR IAS x 1.6878) x SIN[(Computed GAMMA) - (Average climb GAMMA)] ; where Computed GAMMA is the aircraft climb angle computed above, and Average climb GAMMA of 10 degrees is the average aircraft climb angle between DFDR time references 4:13:22 to 4:14:14. The vertical gust velocity was approximate since the aircraft's climb angle will actually decrease with increasing altitude and the aircraft was never in smooth enough air to determine a good average climb angle.

All the data assumed no errors in the DFDR parameters and that the pitch angle value was the angle at the one second interval and not an average of all five values.

The Fairchild analyst commented that the calculated vertical gust velocities appeared to be excessive. Vertical gust components in excess of 300 feet per second are not realistic, however, the method used produced these results. There was no doubt that the airplane encountered severe turbulence and that the turbulence was a significant factor in this incident.

The AAIB agrees with the Fairchild analyst that their method produced excessive estimates for the vertical gusts encountered. Almost all the altitude changes seem to have been attributed to the gusts and not enough allowances were made for altitude changes due to the pitch attitude changes, not caused by the gusts as such, and the IAS of the aircraft. As the Fairchild analyst did not have any quantitative information about the pilots´ elevator inputs during the encounter, he apparently chose this conservative approach, a kind of a "stick fixed" analysis.

It should also be noted that the aircraft was never close to stalling speeds or stalling AOA according to the DFDR data. Also the Stall Avoidance System (SAS), installed in this aircraft, was apparently functioning but never received inputs to interfere with the control of the aircraft.

Therefore, a more realistic approach to estimate the severity of the gusts was provided by analysing the AOA and aircraft pitch data from the DFDR.

AOA should change due to sharp-edged gusts without immediate change in pitch. A rapid change in pitch should have a corresponding change in AOA, unless vertical sharp-edged gusts cause different rate of change, including change of direction. At DFDR time ref. 4:15:20 (IAS 162 kt) to 4:15:21 (IAS 168 kt), pitch decreased by 12.2°, from minus 18.4° to minus 30.6°, but AOA was steady or increasing by 0.1°. Thus an estimate of an up-gust was obtained: Sin (12.2 + 0.1)° x (162 + 168) / 2 = 35 kt.

At DFDR time ref. 4:15:23 (IAS 184 kt) to 4:15:24 (IAS 197), pitch increased by 7.6°, from minus 45.1°to minus 37.5°, but AOA decreased by 5.5°, from minus 12.4° to minus 6.9°. Thus an estimate of a down gust was obtained: Sin (7.6 + 5.5)° x (184 + 197) / 2 = 43 kt.

At DFDR time ref. 4:15.24 (IAS 197 kt) to 4:15:25 (IAS 206), pitch increased by 9.3°, but AOA decreased by 7°. Thus an estimate of a down gust was obtained: Sin (9.3 +7)°x (197 +206) / 2 = 57 kt.

Also looking at the seven seconds between DFDR time ref 4:15:22 and 4:15:29, where the altitude loss was 1866 ft, the average IAS was estimated as 212 kt and the average pitch estimated as minus 33°. The altitude loss due to this pitch and IAS would be: Sin 33° x 212 x 6080 (ft/ kt) x 7 (sec) / 3600 (sec/ hour) = 1365 ft. The remaining altitude loss of 501 ft could thus correspond to an average down gust of : 3600 x 501 / 7 / 6080 = 42 kt

Both the analyses of AAIB and Fairchild Aircraft Inc, however, produced similar results for finding the time reference for the gusts and when the gusts would change directions. The gust reversals had an average period of 7.5 seconds.

1.17 Organizational and management information.

1.17.1 The training of the Flight Crew.

At the time of the incident, Flugfélag Íslands hf was operating one SA-227-AC and two SA-227-DC aircraft. The company recently acquired two SA-227-DC and a number of newly hired pilots had been trained to fly them.

Both pilots of Faxi-21 underwent and successfully completed an ICAA approved ground course held in Reykjavik in the spring 1997 and subsequently completed flight training on the SA-227-AC with the ICAA approved company training/check pilot. Both pilots then completed a differences ground school and flight training for the type AC-227-DC, with Merlin Express Inc. of San Antonio, Texas.

The AAIB surveyed the ICAA approved Flugfélag Islands hf. Operations Manual, the SA-227-AC Crew Training Manual, as well as the differences training requirements for the SA-227-DC. Also the AAIB surveyed the operator´s applicable training records. All these documents were considered by the ICAA to be in acceptable order.

The ICAA approved SA-227-DC training program, approved on the 26 February 1995, contains the policy statement on the approval page, that main emphasis shall be put on practical training in the aircraft and in the appropriate flight simulators approved by the Airworthiness Authority.

The use of flight simulators, however, had not been implemented at the time of the incident.

The training program did not include requirements for wind shear training and it seems that little emphasis had been put on this subject as it was deleted from the training and examination checklist. Similarly, there were no requirements for examination in specific flight characteristics of the aircraft.

1.18 Additional information.

1.18.1 Ísafjörður Airport.

The town of Ísafjörður is located on the northern side of Skutulsfjörður, a small fjord extending to the south-south-west from the southern side of the Ísafjarðardjúp bay. The Ísafjörður Airport is located (66°03´30´´ N 023°08´25´´W) on the southern shore of the Skutulsfjordur fjord. The airport has one runway, designation 09/27 and it´s elevation is 10 feet. The runway is 1400 meters long and 45 meters wide.

The last aircraft movement at Ísafjörður Airport prior to the landing of TF-JML was at 14:41 hrs. No other aircraft landed or took-off from the airport after TF-JML departed for this flight. At the same time Faxi-21 departed Ísafjörður, there was another Flugfélag Íslands hf. SA-227-DC aircraft, flight number Faxi 24, approaching RE-NDB, enroute to Ísafjörður airport. At 19:50 hrs after learning of the Faxi-21 incident, the Captain of Faxi-24 reported that he had turned back to Reykjavik.

1.18.2 The Bolafjall Radar Data.

The radar at the Bolafjall mountain, close to Bolungarvik covered the flight path of FAXI-21. The radar is a "Secondary Radar" type. It records the digital data information received from the aircraft radar transponder.

The transcript of the recorded information is attached in Appendix 5.4 and it was used to analyse this incident.

1.18.3 Weight and Balance of the aircraft.

The dry operating weight of the aircraft TF-JML is 4.442 kg. Prior to departure from Ísafjörður, the aircraft was loaded with 19 passengers and 590 kg of fuel. There are two baggage compartments in the aircraft, one is in the nose compartment and the second baggage compartment is located in the rear part of the fuselage, aft of the passenger compartment. There were 35 kg of passenger baggage in the nose compartment and 164 kg in the rear cargo compartment. There was no mail and no cargo aboard and there were no last minute changes made.

The calculations based on these information showed, that the aircraft was loaded within the allowed limits. The Centre of Gravity (CG) for the loaded aircraft must be located between 260.70 inches and 277.0 inches aft of the aircraft Datum line. Prior to the departure from Ísafjörður Airport, the CG was calculated to be at 272.14 inches aft of the Datum line.

2. ANALYSIS.

2.1 General considerations.

In the Part 1 of this Report, the events of the flight are covered step by step, based on information retrieved from the Digital Flight Data Recorder, the Bolafjall Radar coverage and the pilots' reports. This form of presentation was chosen in order to minimise the repetition of data and the complexity of the report. This was also considered necessary in order to simplify the text of this analysis, where the conclusions made in reference to the gusts encountered according to the DFDR, did generally correspond in magnitudes, directions and time to the gusts perceived by the pilots.

The different methods of analysing the DFDR data are contained in this report and reference is made to the ICAO Circular 186-AN/ 122, about wind shear. Attached, also, is page 57, figure 4-3 (Appendix 5.6), from this Circular, showing reduction of angle of attack (AOA) due to a sharp-edged downdraft, providing quick reference for general analysis of the combination of pitch and AOA changes found in the DFDR data. From this page, for instance, it can be seen that an AOA change of 12 degrees at IAS of 185 knots corresponds to a vertical draft of 4.000 feet per minute, or 40 knots.

2.2 The weather.

There was a very warm air mass in the Ísafjarðardjúp bay area during the day, but when a front approached from the east in the afternoon, cooler air began to flow into the bay area. The mountains north of the bay kept the cool airflow away while the wind was light, but the cooler air may to some extent have been flowing over the existing air mass and thus causing considerable local thermal turbulence.

At about 15:00 hrs, the wind speed became high enough to enable the airflow over the mountains (ref.: The wind observations at Æðey island). This initiated the formation of mountain waves and during the next hours the conditions were such that the waves were breaking slightly lower than at the level, where the wind speed started to decrease. Breaking waves are known to cause severe turbulence.

It is considered likely that areas of rising air and turbulence, formed by the two previously mentioned causes, did merge and therefore, the turbulence became much more severe than either cause would justify.

Initially, the mountain waves were formed by the mountain Drangajökull glacier and by the mountain ridge south of it and/or by the Snæfjallaströnd coastal mountains as well as by the mountains between the fjords Skötufjörður and Mjóifjörður.

Around 20:00 hrs the wind speed had increased enough to prevent the waves from breaking. After that, the mountain waves in the area were of a "conventional form", probably with minor rotors at mountain height.

2.3 Mountain Waves / Breaking waves.

It is evident, that the aircraft was a subject to turbulence, exceeding the classification "severe", considering the reports given by the pilots and the passengers and the data extracted from the aircraft DFDR.

Quoting reference material contained in this report, intense rotor flows (associated with mountain waves) may contain downdrafts/updrafts as strong as 50 kts (5.000 ft per minute). Also various references on mountain waves, indicate that breaking mountain waves form typical vortices with diameters of the order of 1.200 feet, with tangential wind velocities of 40 to 50 kts.

From the DFDR and Radar data it is considered likely, that the wind speed was increasing up to 5.000 feet altitude and that the wind speed was at maximum between 5.000 and 6.000 feet or at 50-60 kts. Then it decreased rapidly above 6.000 feet altitude.

It seems, that the energy in the mountain waves over the Ísafjarðardjúp bay was "returned" close to where the waves were being created, either in the form of rotors or "breaking waves".

2.4 Human performance/pilots input.

The human performance in an encounter with vertical gusts of the severity experienced by the crew of Faxi 21 depends primarily on the awareness that the situation might occur or is imminent. The weather radar, which might have given indications of the adverse weather phenomenon, was not in use during this incident. The pilots had, however, noticed several weather phenomena in the area during the approach that was along the normal approach path, but the flight segment had been uneventful. If the weather conditions are known and severe wind shears are expected, the universal procedure is strict avoidance of the area involved. The capacity to handle the situation, once encountered, depends mainly on education and training and the familiarity with the aircraft type involved, how it behaves and responds to disturbances and control inputs. Situational awareness and the location of the event such as proximity to ground or mountains will also seriously affect the net result.

From the pilots' reports, it seems that the severity of the first updraft encountered was unexpected by the pilots. The aircraft was at that moment in a relatively steep climb (20 degrees) and banking. The pilots responded by reducing the pitch without altering the trimmed position of the horizontal stabiliser. The sequence that followed involved the pilots´ sensation, that the aircraft was not responding as expected, which might have resulted from the stabiliser trimmed 20° pitch up.

The Co-pilot was the FP but the Captain cautioned him to watch the speed and later he did not formally take command of the aircraft but assisted the FP such that both of them were pushing the stick resulting in reduction in pitch below a positive angle. Thus the aircraft was already pitching down when it entered a severe downdraft, aggravating the effect of the downdraft and resulting in excessive nose down attitude and rapid loss of altitude, necessitating a quick pullout due to the perceived proximity to mountains.

Thus the aircraft appears to have been in unstable pitch excursions when the second and the worst of the gust waves was encountered. The sequence of pitch, AOA, altitude, speed and "g-load" excursions of the first wave encounter was repeated and on a larger scale. It also appears that in between the two major dives and after the second one, that gust reversals took place, but as the aircraft was flying with a positive pitch during these, the only significant changes were in the "g-load". During the event the aircraft went through several vertical gust reversals as well as "g-load" reversals with the maximums of minus 1.25 g and plus 4.25 g.

Looking at the training program and experience of the pilots on the aircraft type involved, it seems that little emphasis had been put on turbulence and wind shear training, and the specific flight characteristics of the aircraft. Also flight training in full flight simulators for the SA-227-DC type of aircraft had not been applied, even though it was a matter of training policy in the approved training program.

Encounters with vertical gusts of the severity experienced in this incident are very rare. The phenomenon is very localized and does not last very long. The breaking mountain waves are also hard to forecast without substantial increase in weather observations above mountains, at locations and altitudes where they are likely to form.

2.5 Analysing the data.

The IMO Study-Analysis report, as well as the aircraft DFDR data and the Bolafjall Radar data indicate that the wind speeds below and above the altitude envelope where the incident occurred, were of the order of 20 to 30 kts. At the altitude of the incident, or between 4.500 feet and 6.500 feet, the wind velocities were higher or of the order 40 to 60 kts. The IMO Study-Analysis report concludes that there was indeed substantial evidence that breaking mountain waves could have been involved.

By analysing the DFDR data with regard to the changes in AOA and pitch changes, estimates of the sharp-edged up/down draft speeds were made. Also by looking for reversals of AOA with regard to pitch changes, approximate timing of the up or down drafts were made.

The analysis of the DFDR data by this method indicated that the aircraft encountered severe, if not extreme, velocities of up and down drafts of 35 to 57 kts, with periods of wind direction reversals averaging 7.5 seconds.

Considering the average IAS of the aircraft of 180 kts, and that the above 7,5 seconds would correspond to the time taken to cross the diameter of the wind eddy (rotor or wave), this gives the average diameter of the eddy as 2.300 feet or 700 meters.

Looking at the DFDR data covering the second dive, which was the worst one, the aircraft lost 2.244 feet in 13 seconds. There were critical 7 seconds where the altitude loss was 1.866 feet. Of these 1.866 feet, 1.365 feet could be attributed to the average IAS and the average down pitch of the aircraft, leaving 501 feet, being due to the effects of down draft with the average speed of approximately 42 knots.

Comparing this with the previous estimate of the size of the breaking wave vortices, and the estimated velocities, it seems that the altitude loss of the aircraft and the velocities experienced were such as if the aircraft had been flying on the tangent around a vortice.

2.6 Preventive Considerations.

For the purpose of learning from this incident and developing recommendations to deal with this phenomenon, questions arises about aircraft and human performance and if there was a question of instability of the pilot-aircraft combination. Generally, if there is a marked phase difference between the pilot´s action and the corresponding aircraft motion, an unstable oscillation can occur if a high frequency mode is excited.

When the aircraft encountered the gusts about 100 seconds after take-off, it had reached 4.200 ft altitude. At this point the aircraft was probably at a higher altitude than normally experienced by most passenger aircraft after departure from Ísafjörður airport. This might explain why this localised phenomenon has not been experienced or reported before.

As previously mentioned, encounters with vertical gusts of the severity experienced in this incident are very rare. The phenomenon is very localized and does not last very long. The breaking mountain waves are also hard to forecast without substantial increase in weather observations above mountains, at locations and altitudes where they are likely to form. In this particular area, the phenomenon observed by the IMO weather observer at Æðey island, might be an indication for the IMO forecaster to expect moderate to severe localised turbulence in the Ísafjarðardjúp bay area.

This particular incident indicates that more emphasis should be put on training. Especially the training in detection and avoidance of adverse weather phenomena is essential and the use of full flight simulators could provide training in handling and recovery.

3. CONCLUSIONS. Probable contributing factors are marked with an asterisk *.

3.1 The flight crew was properly licensed, rated and medically fit to carry out their duties during this flight.

3.2 The aircraft was fully airworthy prior to the incident and maintained in accordance with the ICAA approved maintenance schedule.

3.3 The aircraft was correctly loaded and it´s documentation was in order.

3.4 During the approach in the Isafjörður Bay, the pilots had noticed several weather phenomena in the area, but the flight segment had been uneventful.

* 3.5 The ICAA approved SA-227-DC training program contains the operator´s policy statement on the approval page, that main emphasis shall be put on practical training in the aircraft and in the appropriate flight simulators approved by the ICAA. The use of flight simulators for practical training had not been implemented at the time of the incident. The training program did not include requirements for turbulence and wind shear training.

3.6 The conclusions of the IMO Study – Analysis Report are detailed on page 6 of this report. They support the existence of breaking mountain waves and severe vertical gusts in the area of the incident.

3.7 Encounters with vertical gusts of the severity experienced in this incident are very rare. The phenomenon is very localized and does not last very long. The breaking mountain waves are also hard to forecast without substantial increase in weather observations above mountains, at locations and altitudes where they are likely to form.

* 3.8 The aircraft encountered severe up - and downdrafts, exceeding the classification "severe turbulence". The turbulence involved up - and downdrafts with the speeds of 35 to 57 knots, with reversals of wind directions in periods averaging 7.5 seconds.

* 3.9 From the pilots' reports, it seems that the severity of the first updraft encountered was unexpected by them. The aircraft was at that moment in a relatively steep climb (20 degrees) and banking. The pilots responded in reducing the pitch without altering the trimmed position of the horizontal stabiliser. The sequence that followed involved the pilot´s sensation, that the aircraft was not responding as expected, which probably resulted from the stabiliser being trimmed for approximately 20° nose up climb attitude.

* 3.10 The Captain cautioned the copilot who was the flying pilot to watch the speed and subsequently and without formally taking over the command, he assisted the FP such that both of them were pushing the stick resulting in reduction in pitch below a positive angle. Thus the aircraft was already in negative pitch when it entered a severe downdraft, aggravating the effect of the downdraft and resulting in excessive nose down attitude and rapid loss of altitude, necessitating a quick pullout due to the perceived proximity to mountains.

* 3.11 It was difficult to handle the aircraft in the extreme vertical gusts as the two pilots were both on the controls, using force to counteract the effect of the horizontal stabiliser trim. Also both engines had a "climb power" setting throughout the whole sequence.

3.12 The aircraft made three dives and lost 2.244 feet of height in 13 seconds of which 1.866 feet were lost only in 7 seconds during the second dive. Of these about 500 feet were estimated to be due to the effects of severe down draft with the average speed of 42 knots. The aircraft also went through several vertical gust reversals as well as "g" load reversals in the range from minus 1.25 g to plus 4.23 g.

3.13 The total time elapsed from the beginning of the irregularity until the aircraft resumed normal flight, was 1 minute and 30 seconds.

3.14 The aircraft suffered structural damage to the wings, but there were no injuries to the passengers or to the crew. A hydraulic pressure line cracked in the right engine nacelle where it connects aft of the firewall, due to the distortion between the wing and the nacelle during the high "g" load excursions. This caused loss of hydraulic pressure and subsequent loss of flap operation during landing. The landing gear was extended with the alternate system.

3.15 The importance of the use of a full flight simulator is emphasised, for training pilots in handling the aircraft in adverse weather phenomena, such as windshear and turbulence.

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4. SAFETY RECOMMENDATIONS.

4.1 Action already taken:

4.1.1 The AAIB briefed the director of flight operations of Flugfélag Íslands hf, on the IMO study-analysis report, when it was received by the AAIB.

4.1.2 Flugfélag Íslands hf has already implemented the use of SA-227 full flight simulator in the training program for SA-227-AC/DC pilots.

4.2 It is recommended that:

4.2.1 The Icelandic Civil Aviation Administration should require all Commercial Operators of "Performance Class A" aircraft to implement the use of full flight simulators in the initial and recurrent flight training of their pilots.

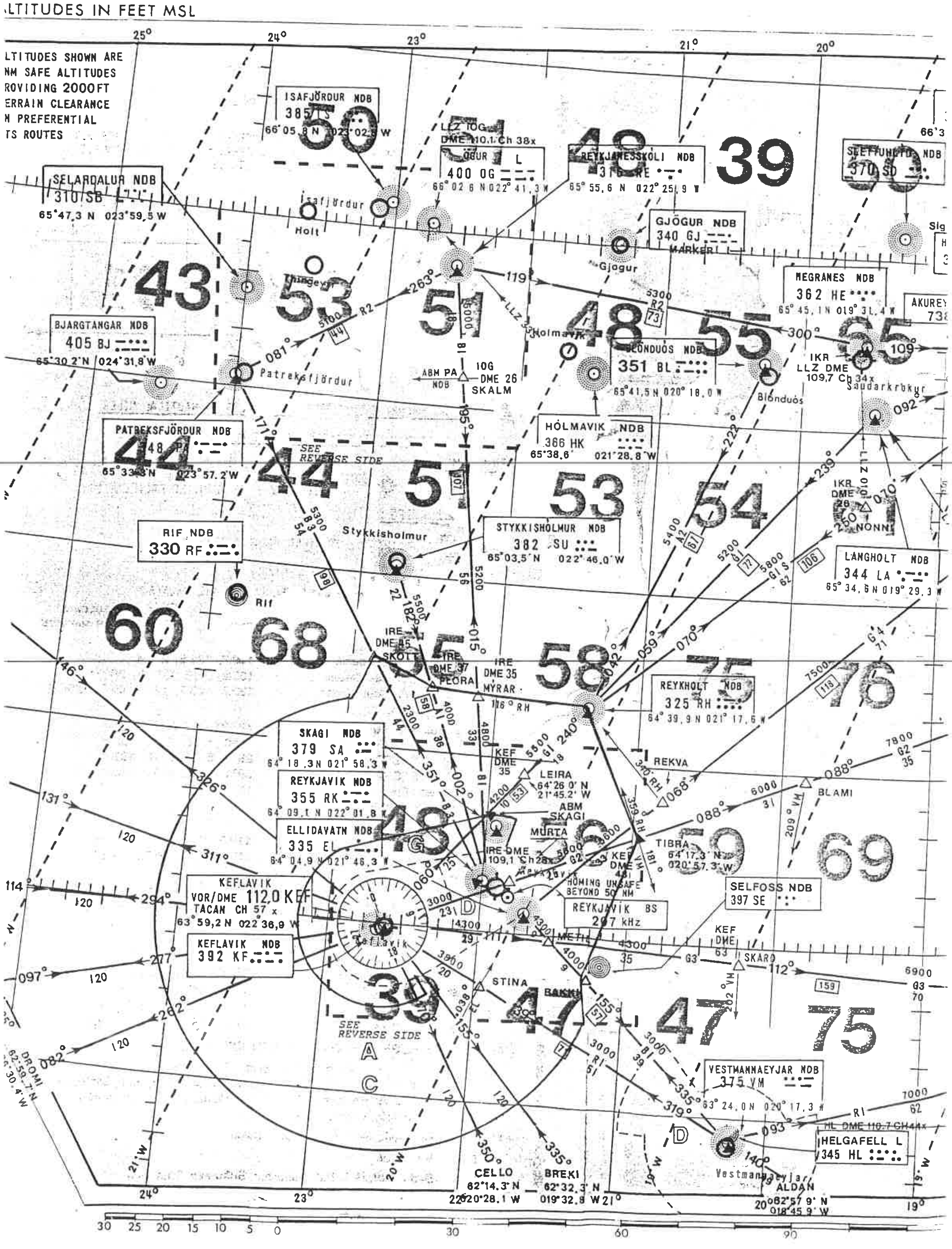
4.2.2 The Icelandic Meteorological Office should consider modifying the reporting code used by weather observers at stations such as the Æðey island, to include phenomena when observed, that are likely to produce wind shears.

Reykjavík, 30 December 1997

Aircraft Accident Investigation Board,
Iceland

5 APPENDICES.

5.1 A Radio Navigation Map – Iceland



5.2 A Map showing the Isafjarðardjúp Bay ar

5.3 Isafjordur Approach Charts

AIP Iceland
FLUGMÁLAHANDBÓK

INSTRUMENT APPROACH
CHART-ICAO
SCALE 1:400 000

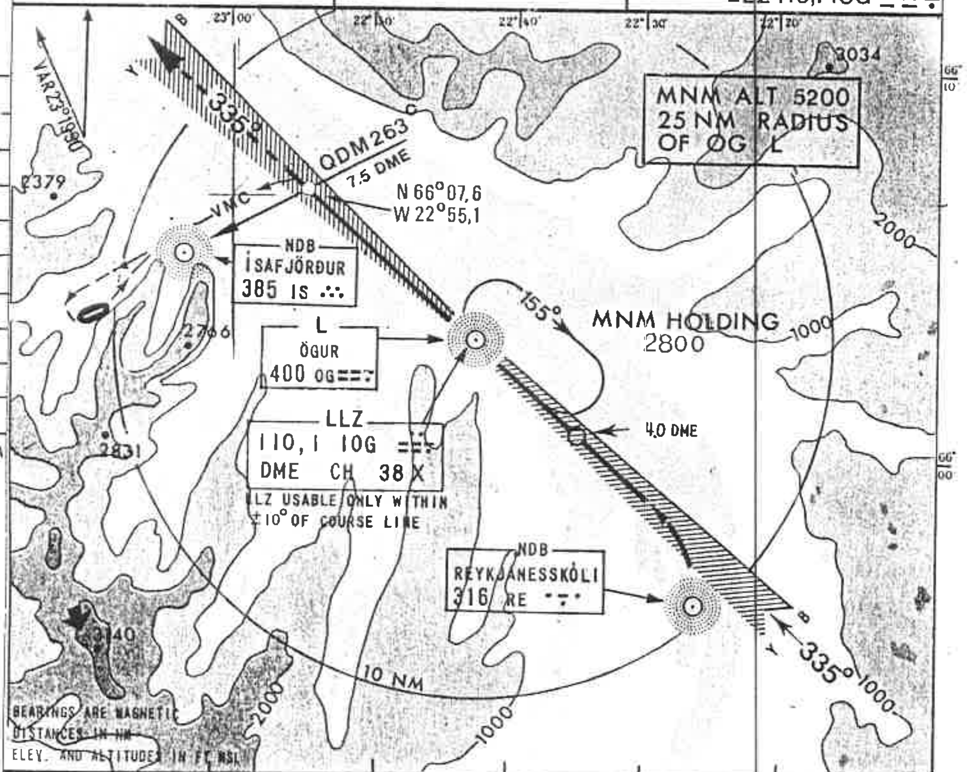
ELEV. 10

IS AFIS 118,8
ACC 119,7

BIIS
4 OCT 1990

ÍSAFJÖRDUR, ICELAND
LLZ 335°

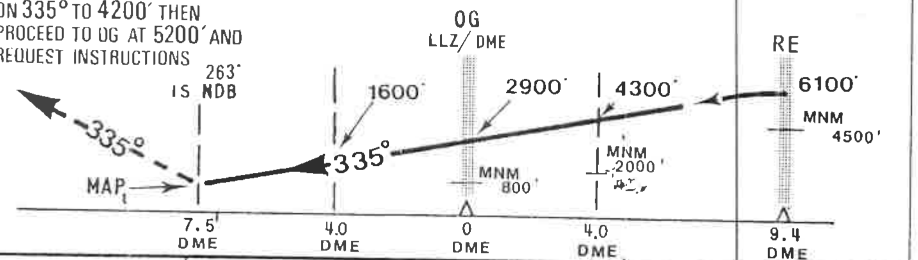
LLZ 110,1 IOG



TRANS LEVEL BY ATC
TRANS ALT 7000'

OCL 500

MISSED APPROACH CLIMB ON 335° TO 4200' THEN PROCEED TO OG AT 5200' AND REQUEST INSTRUCTIONS



LANDING MINIMA	STRAIGHT-IN LANDING RWY				CIRCLE TO LAND
ACFT TYPE					DAY
MNM WEATHER					
DECISION HEIGHT (QNH)					NIGHT
RADIO ALT. SET					

GND SPEED KTS	80	100	120	140	160	180	ADD.
OG TO MAP 7.5NM	5:37	4:30	3:45	3:13	2:48	2:30	

FLUGMÁLASTJÓRN
CHANGES: VARIATION - SECT ALT
CIVIL AVIATION ADMINISTRATION

AIP Iceland
FLUGMÁLAHANDBÓK

INSTRUMENT APPROACH
CHART-ICAO
SCALE 1:400 000

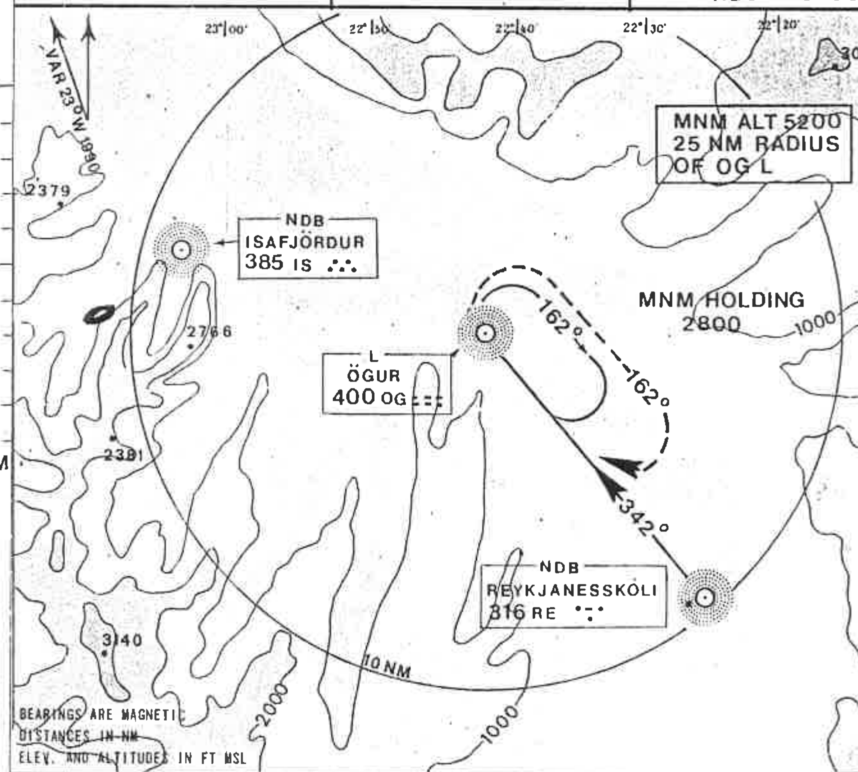
ELEV. 10

IS RADIO 118.8
ACC 119.7

B
4 OCT 19

ÍSAFJÖRDUR, ICELA
NDB 3

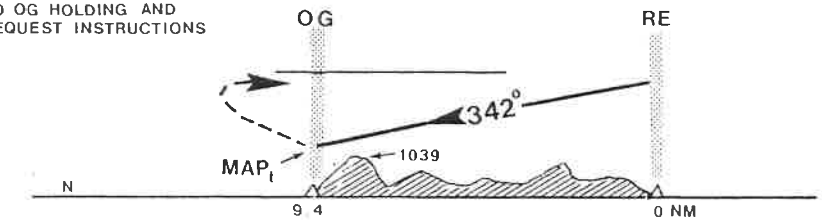
NDB 400 OG



OCL 1340

TRANS LEVEL B
TRANS ALT 700

MISSED APPROACH RIGHT TURN CLIMB ON 162° TO 2800 PROCEED TO OG HOLDING AND REQUEST INSTRUCTIONS

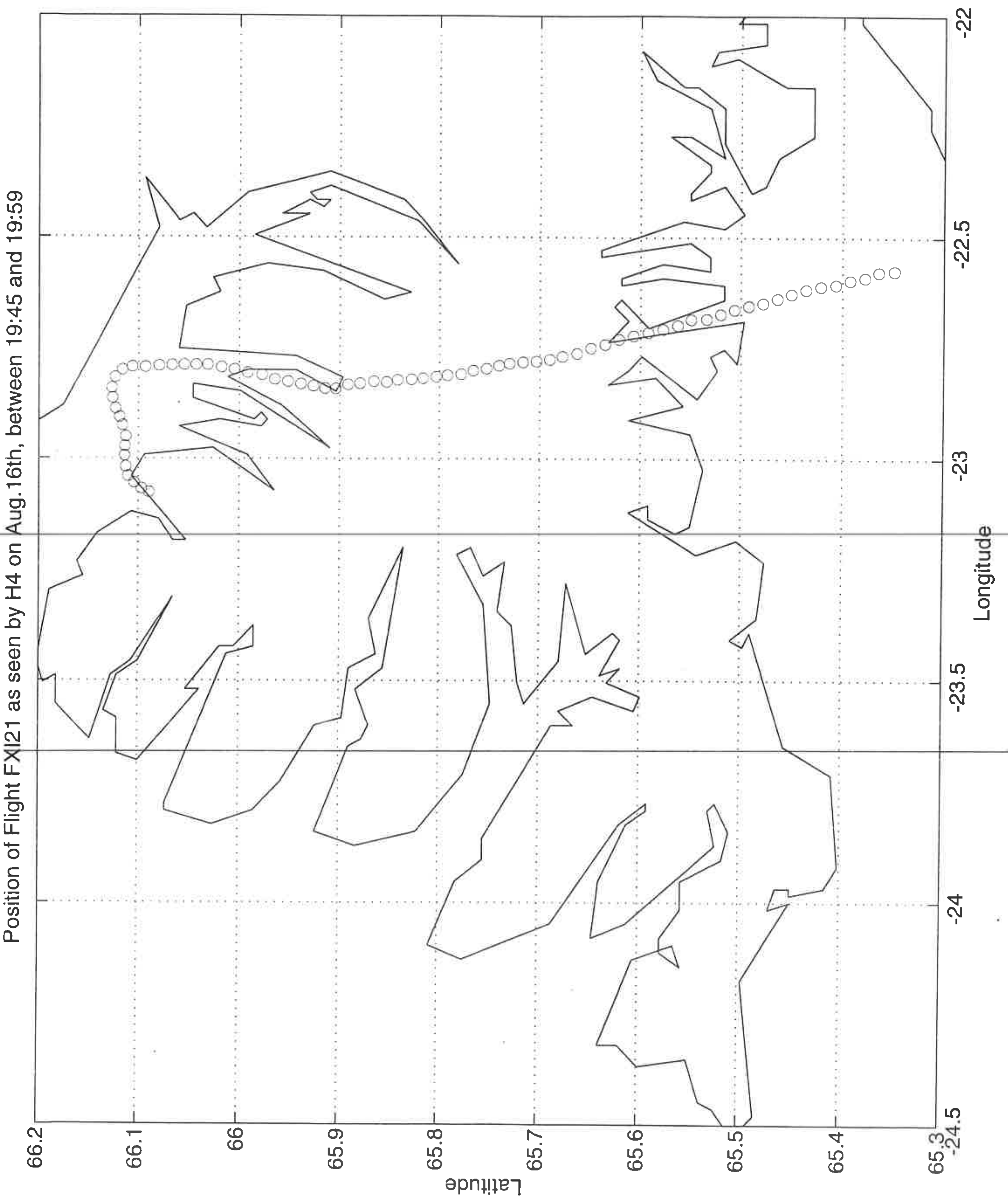


LANDING MINIMA	STRAIGHT-IN LANDING RWY				CIRCLE T
ACFT TYPE					DAY
MNM WEATHER					
DECISION HEIGHT (QNH)					NIGH
RADIO ALT. SET					

GND SPEED KTS	80	100	120	140	160	180	ADD.

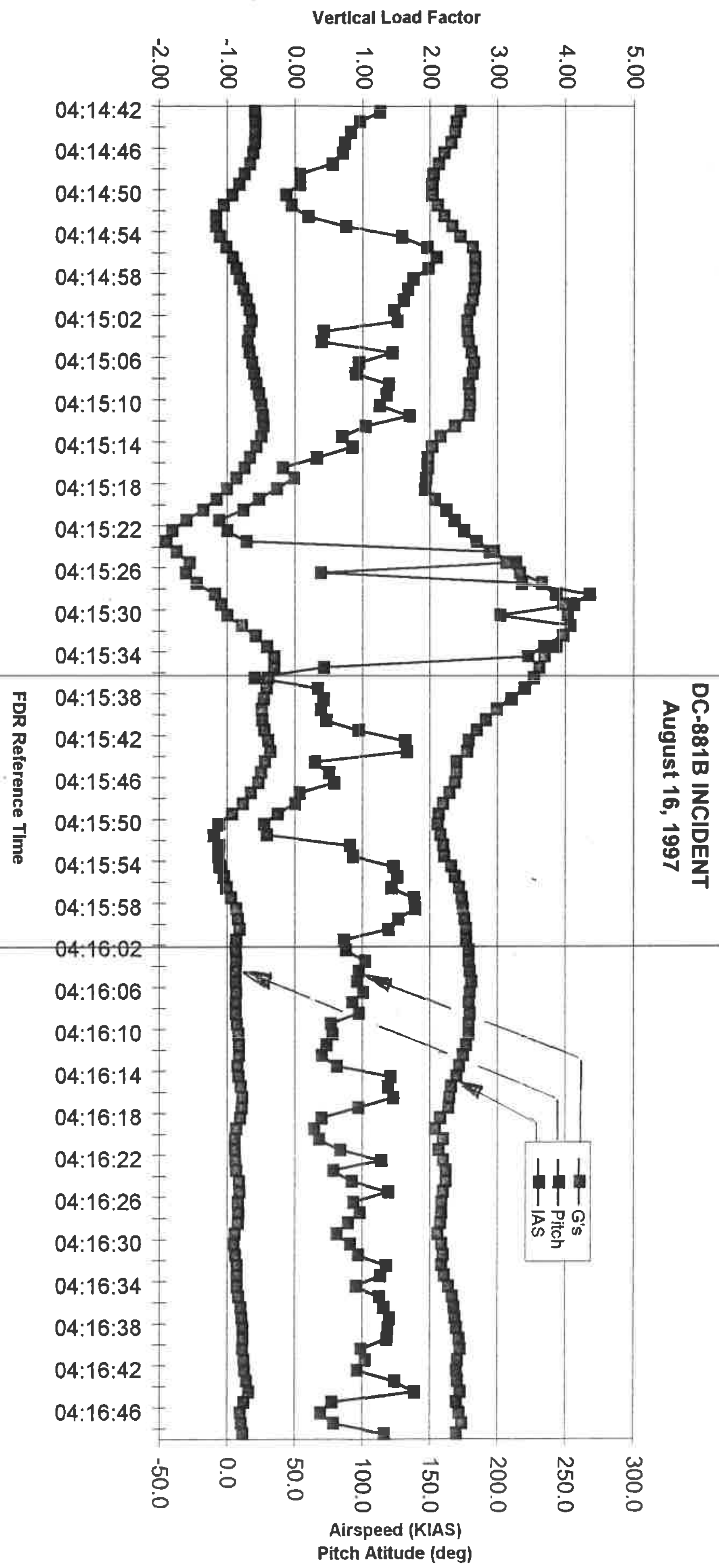
FLUGMÁLASTJÓRN
CHANGES: VARIATION - SECT ALT
CIVIL AVIATION ADMIN

5.4 Map transcripts of the Bolafjall Radar data.

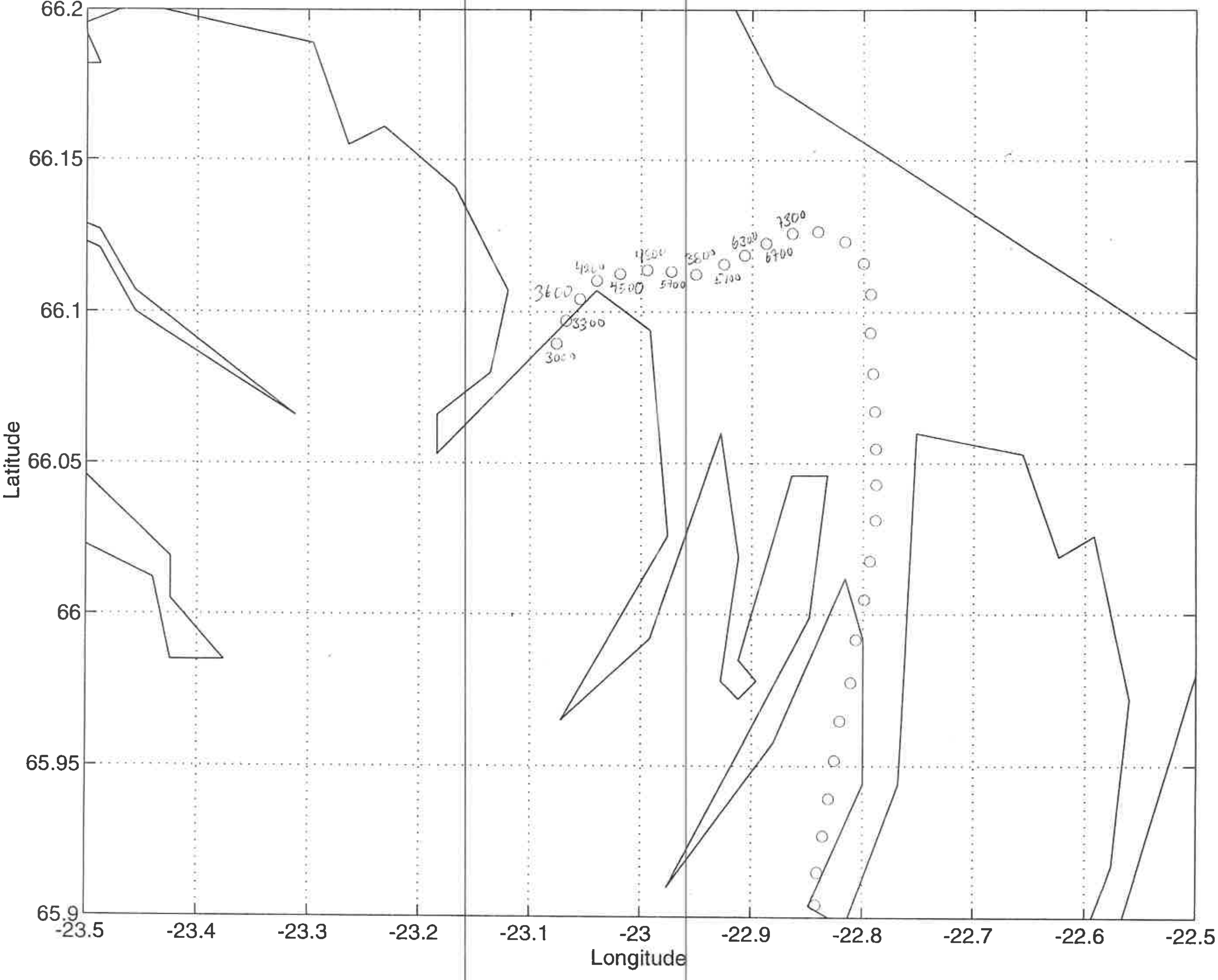


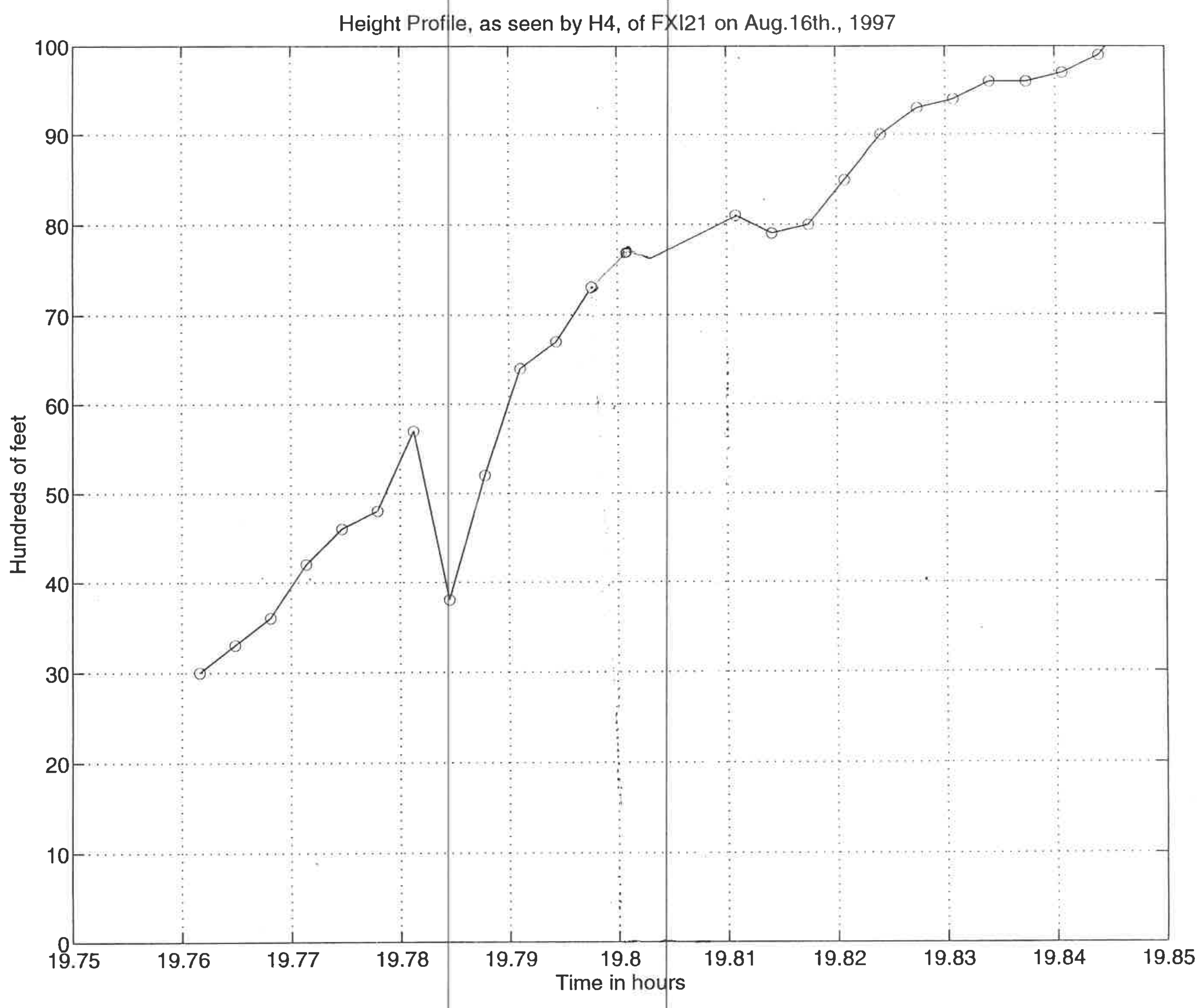
12 seconds between sweeps

5.5 Transcripts of the aircraft DFDR data.

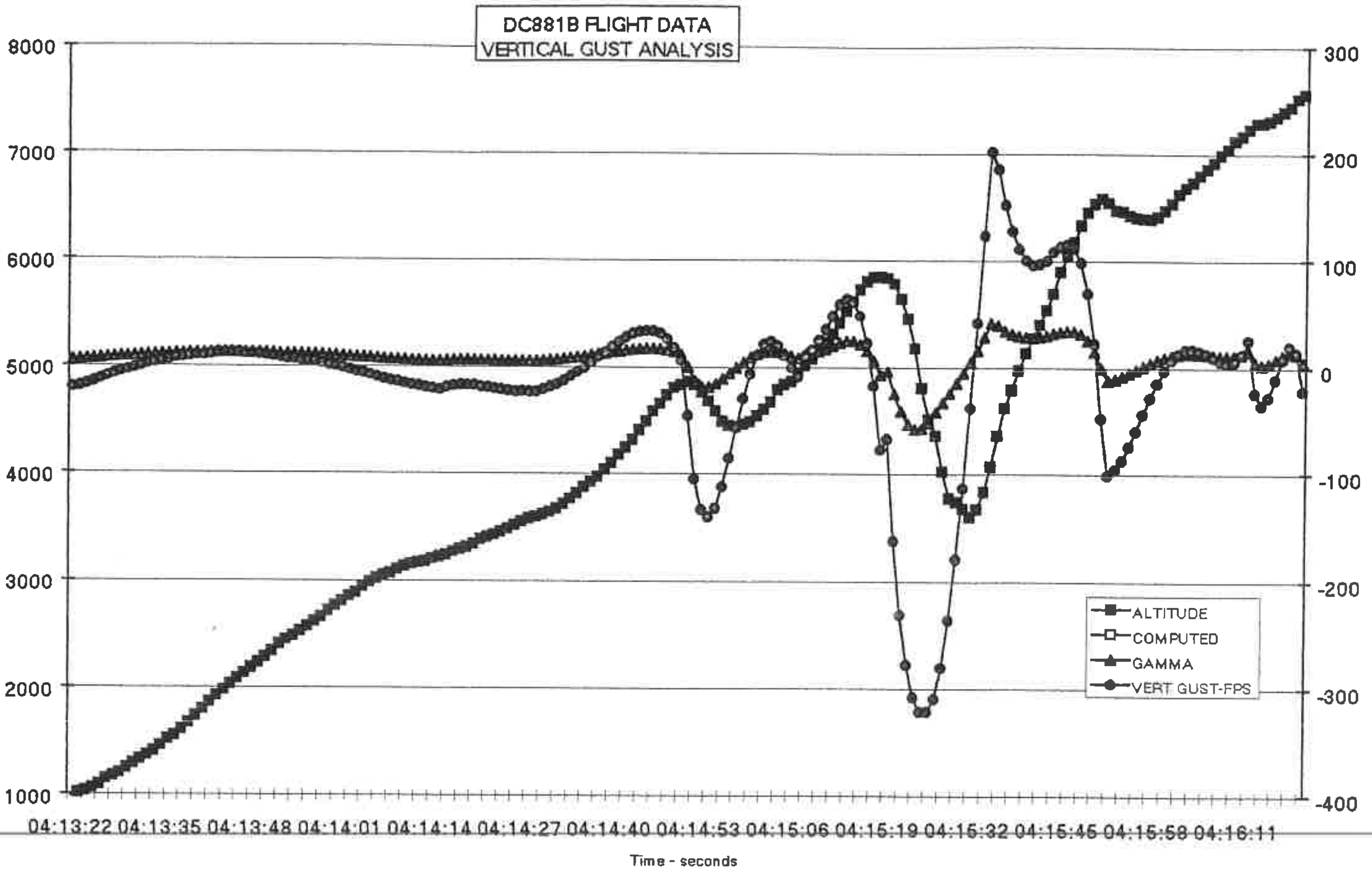


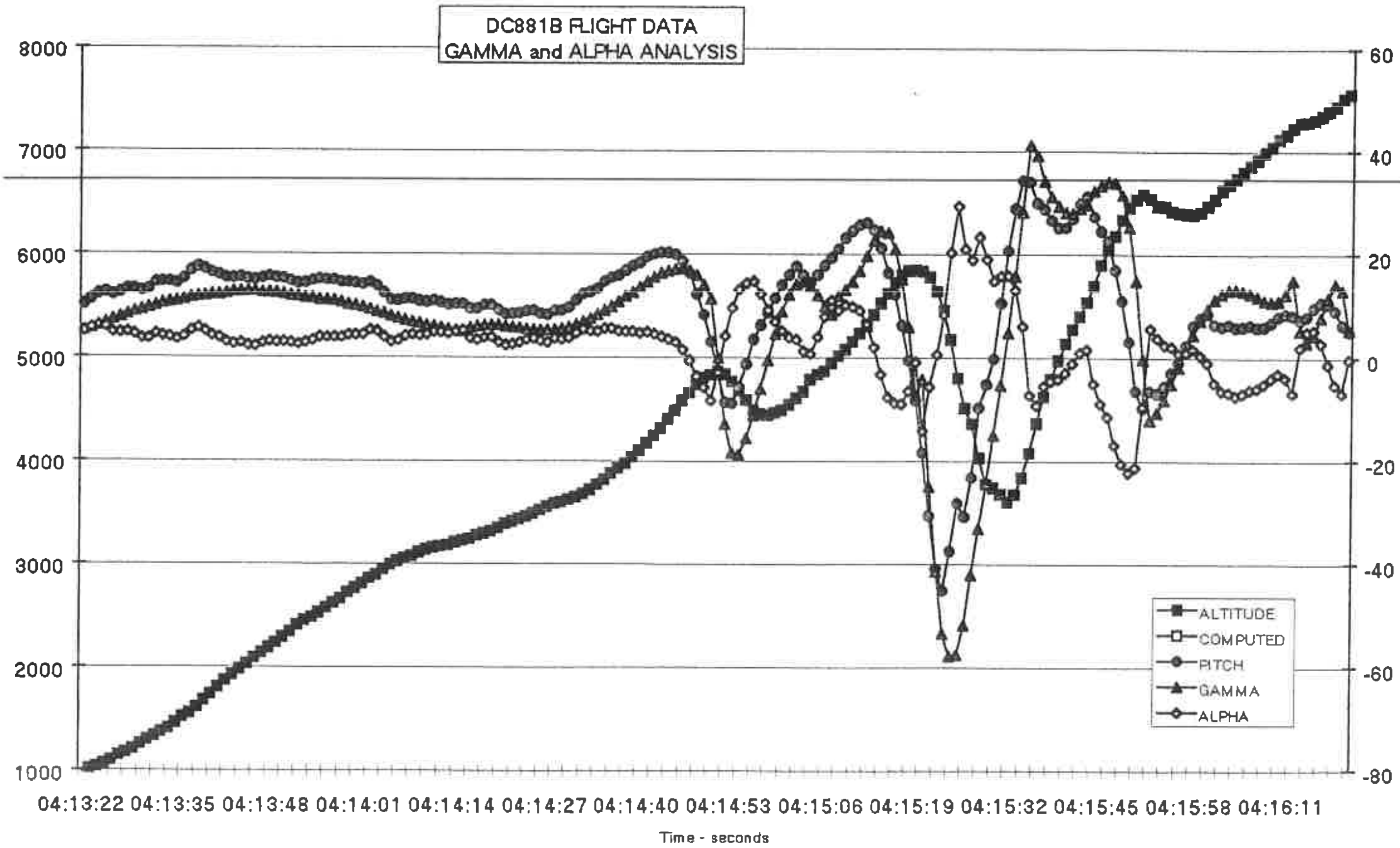
Position of Flight FX121 as seen by H4 on Aug.16th, between 19:45 and 19:59



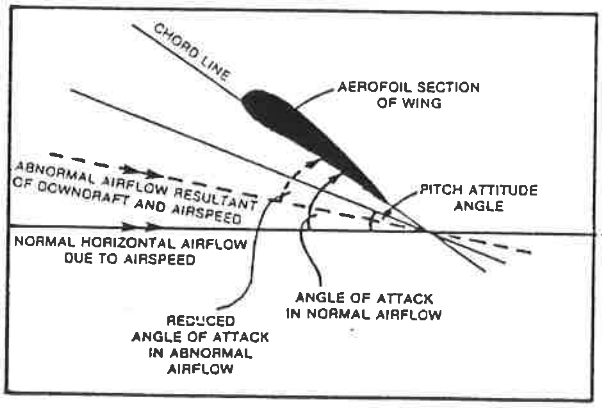

Height Profile, as seen by H4, of FXI21 on Aug.16th., 1997
Hundreds of feet
0
10
20
30
40
50
60
70
80
90
100
19.75
19.76
19.77
19.78
19.79
19.8
19.81
19.82
19.83
19.84
19.85
Time in hours

5.6 Fairchild Aircraft Inc. analysis of the DFDR data.

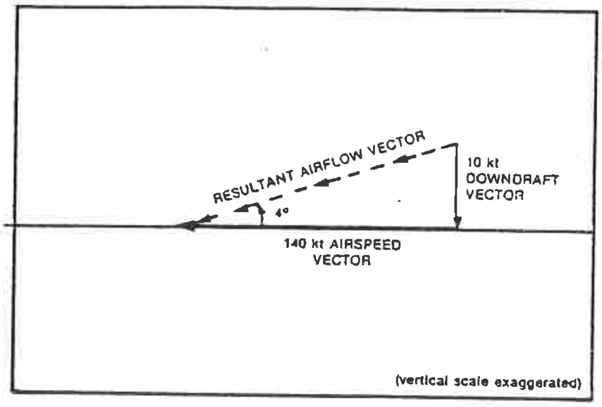




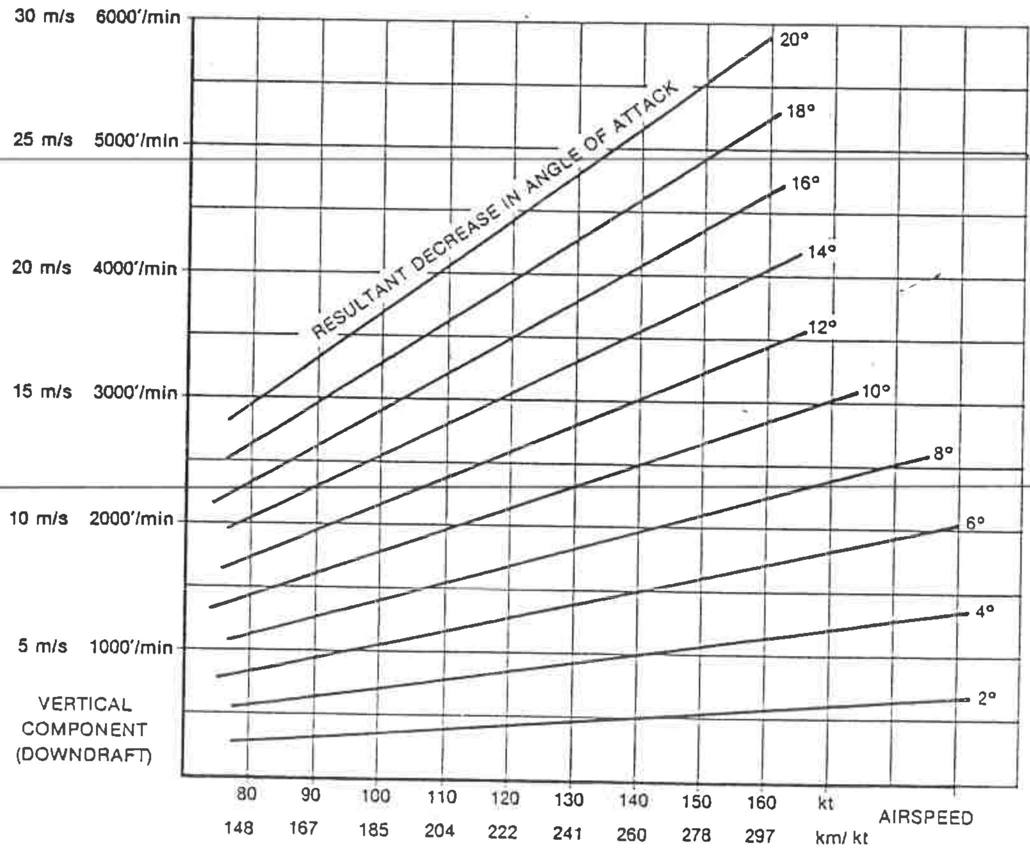
5.7 From ICAO Circular 186-AN/122.



a) Angle of attack reduced due to downdraft but pitch attitude angle remains unchanged



b) 4° reduction in angle of attack due to 10 kt downdraft at airspeed of 140 kt

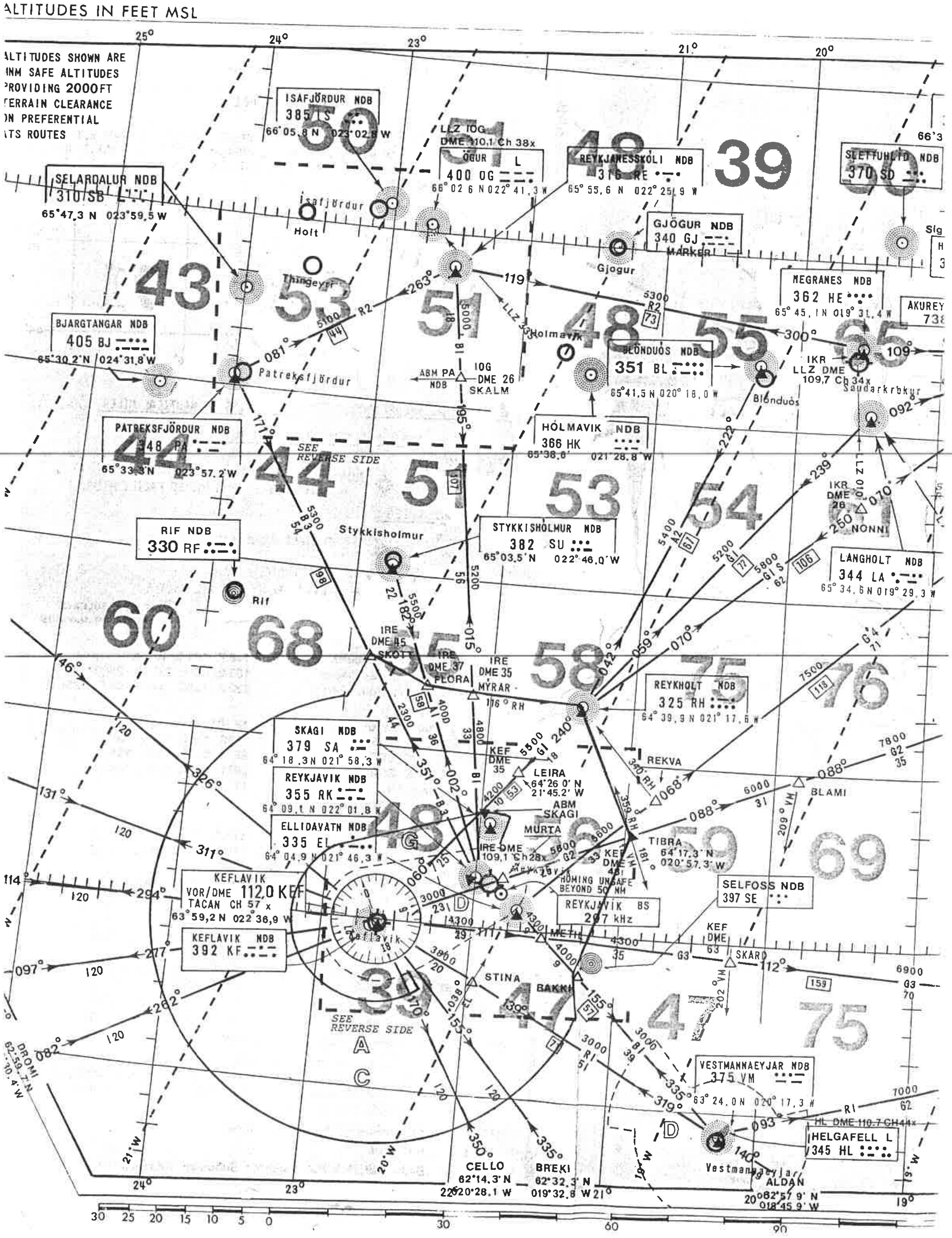


c) Decrease in angle of attack resulting from various combinations of airspeed and vertical component of the wind (downdraft)

Figure 4-3. Reduction of angle of attack due to sharp-edged downdraft

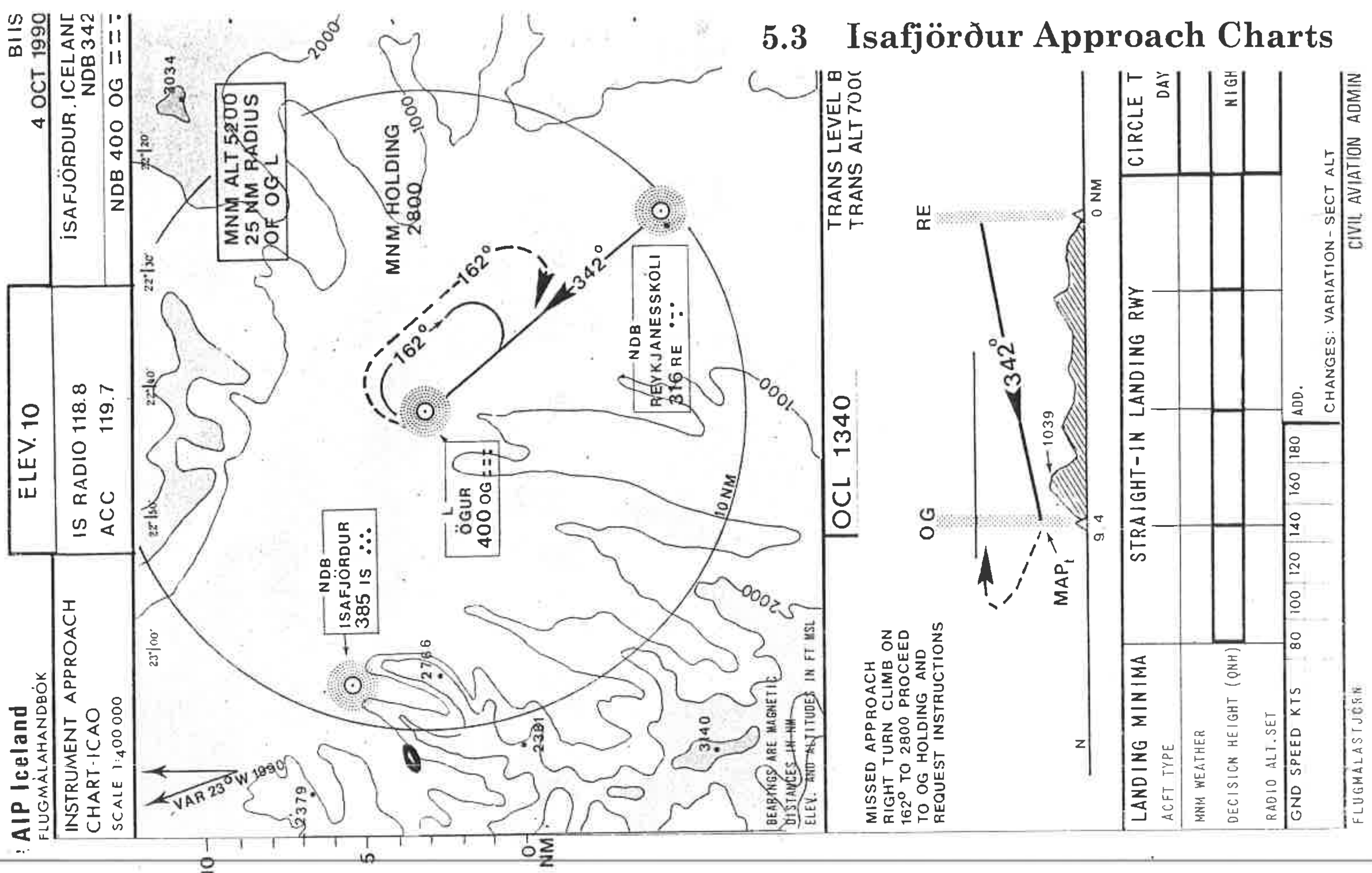
5 APPENDICES.

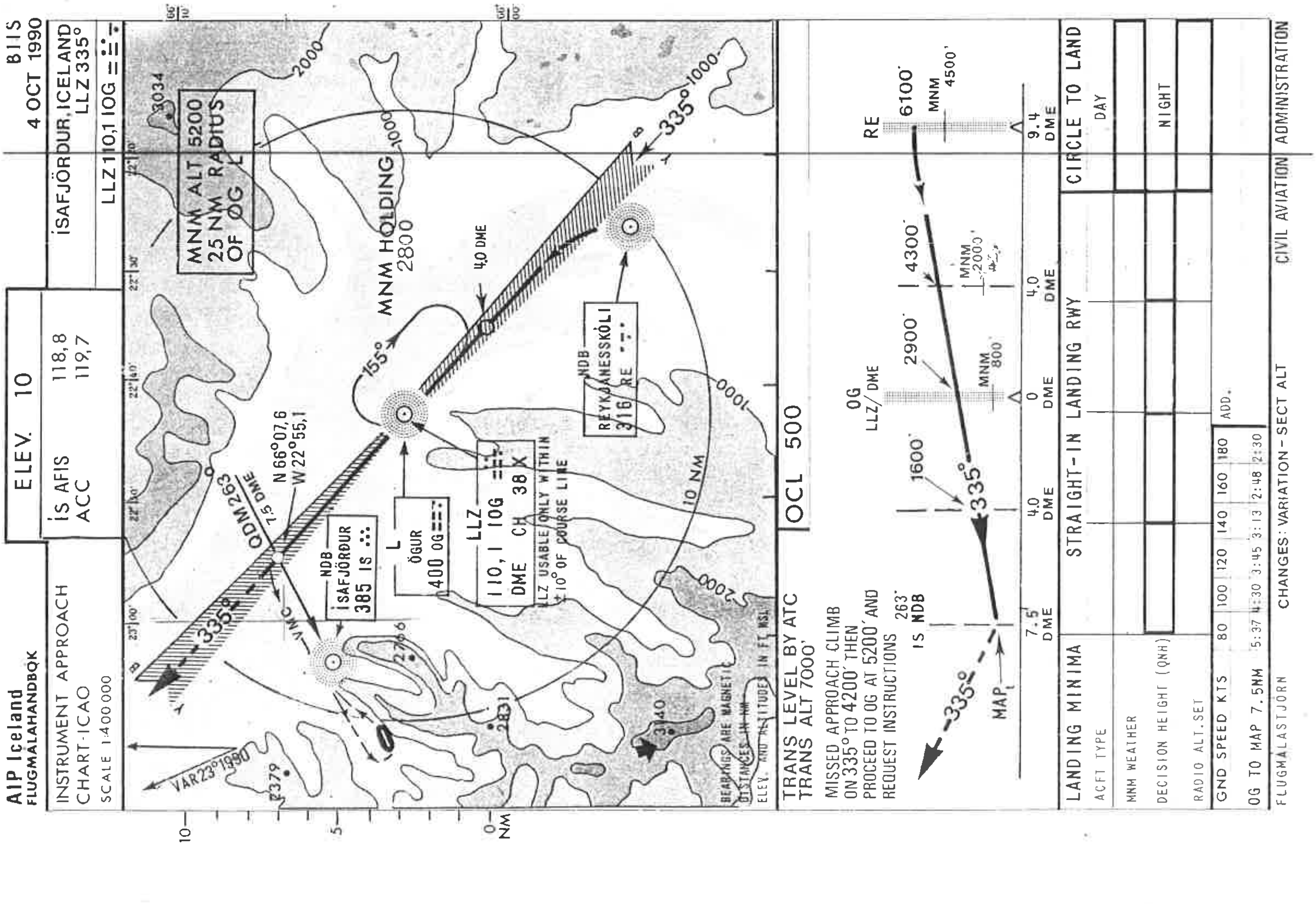
5.1 A Radio Navigation Map – Iceland



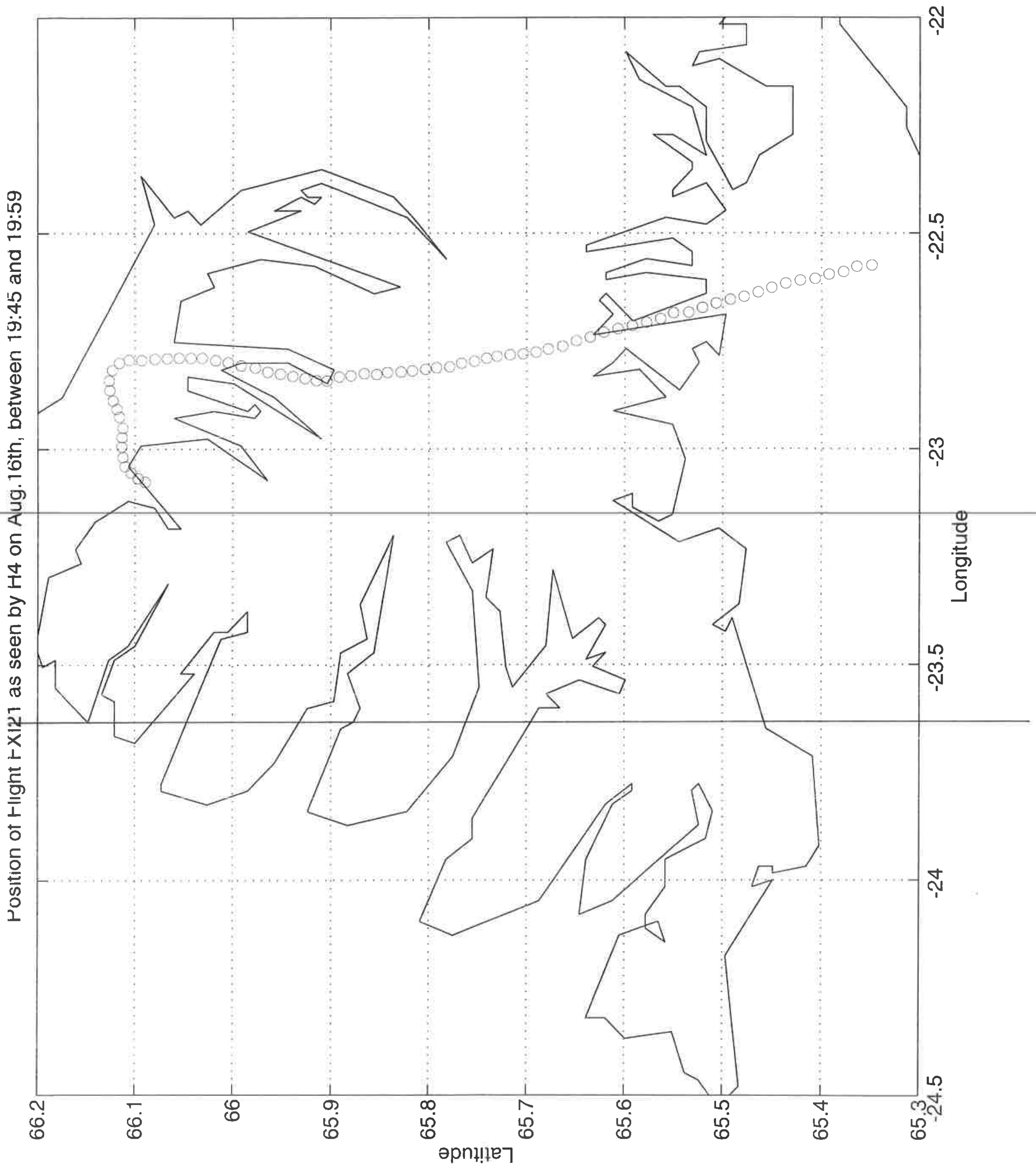
5.2 A Map showing the Isafjarðardjúp Bay ar

5.3 Isafjörður Approach Charts



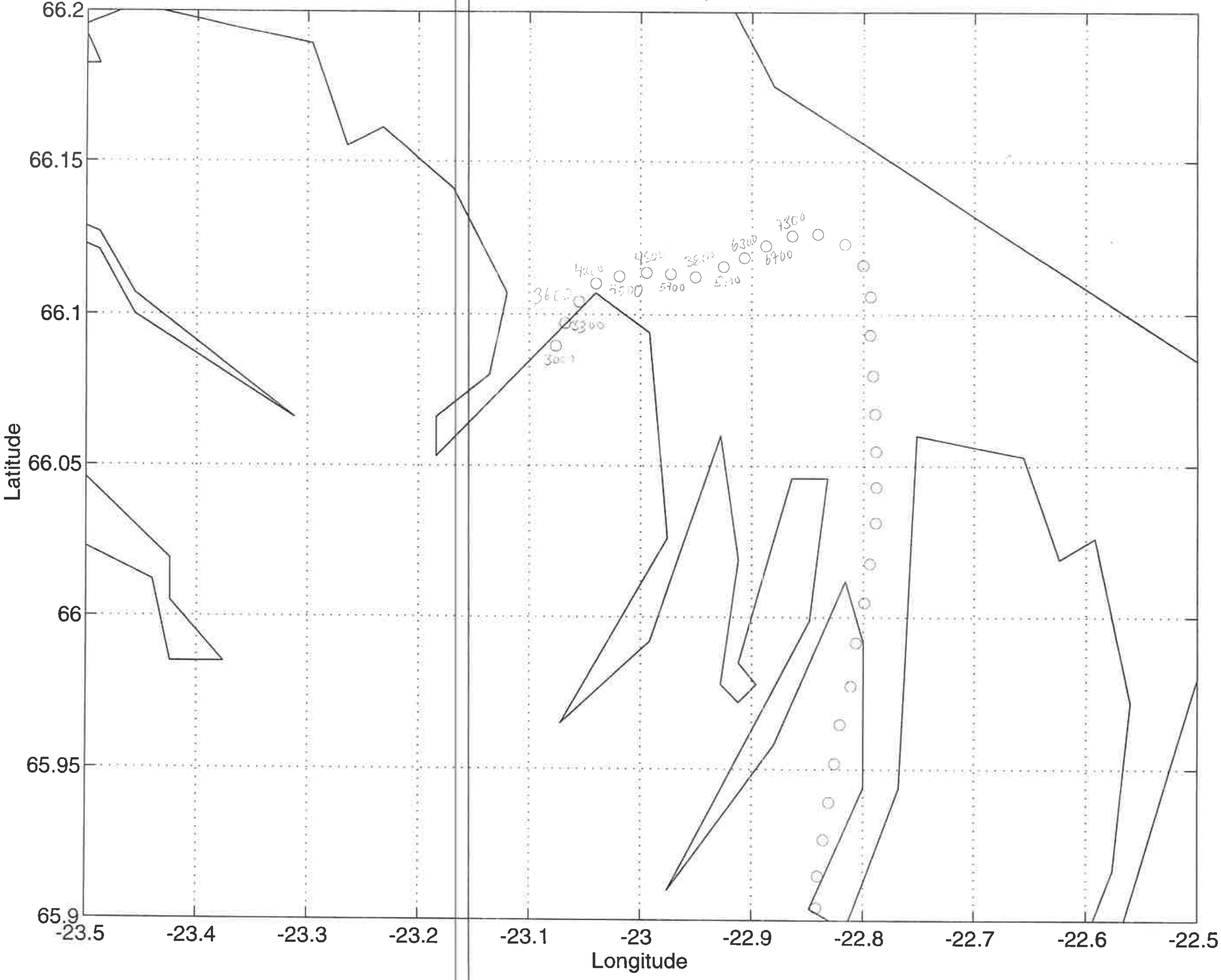


5.4 Map transcripts of the Bolafjall Radar data.

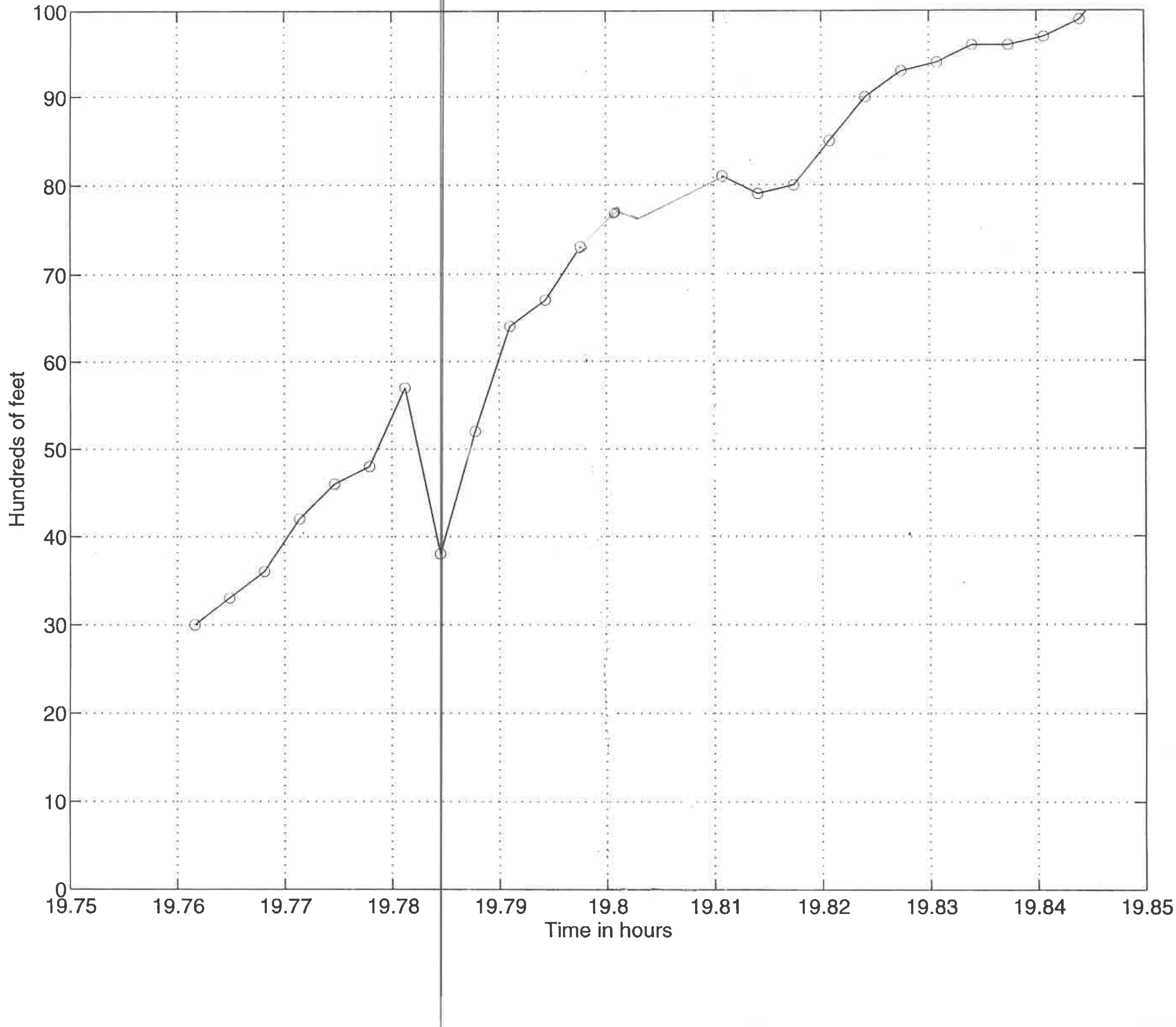


12 seconds between sweeps

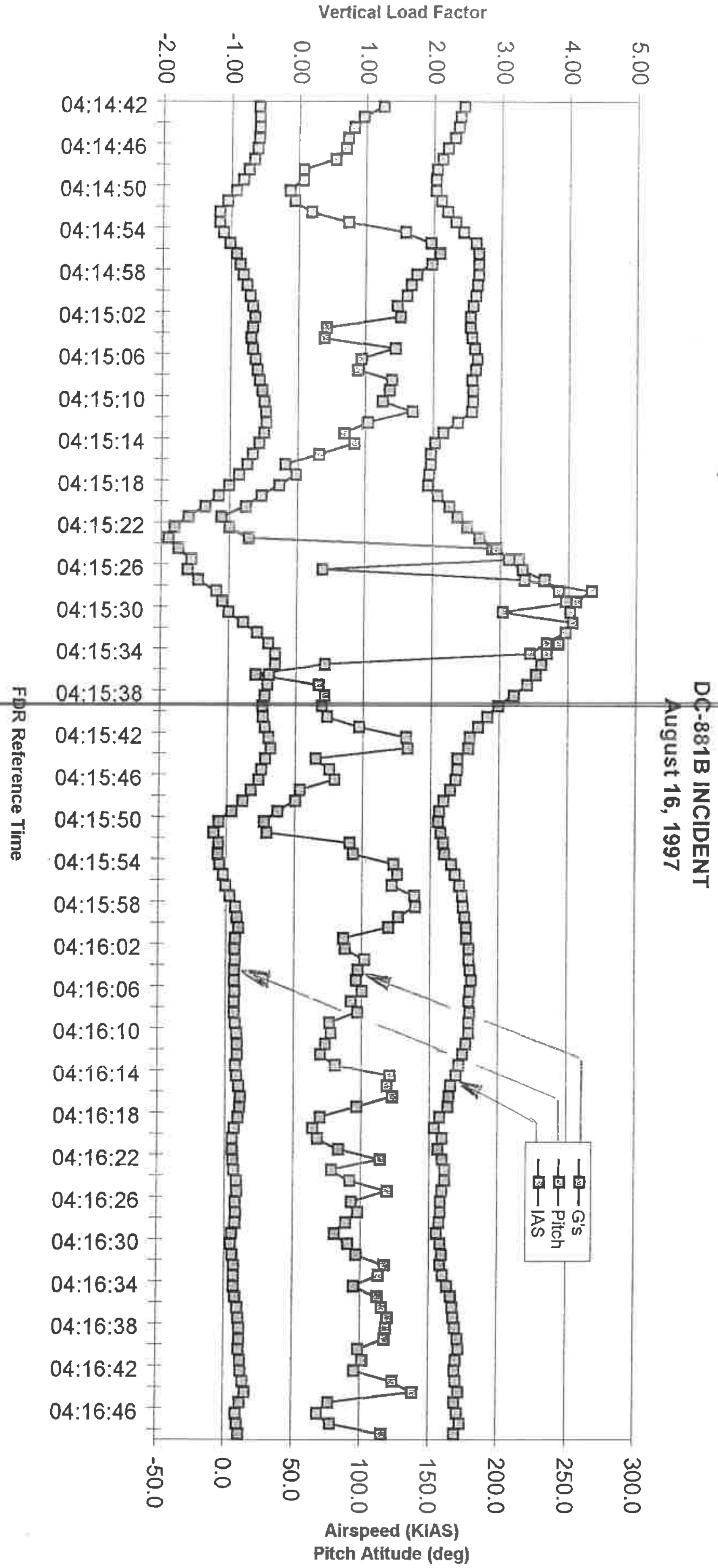
Position of Flight FXI21 as seen by H4 on Aug.16th, between 19:45 and 19:59



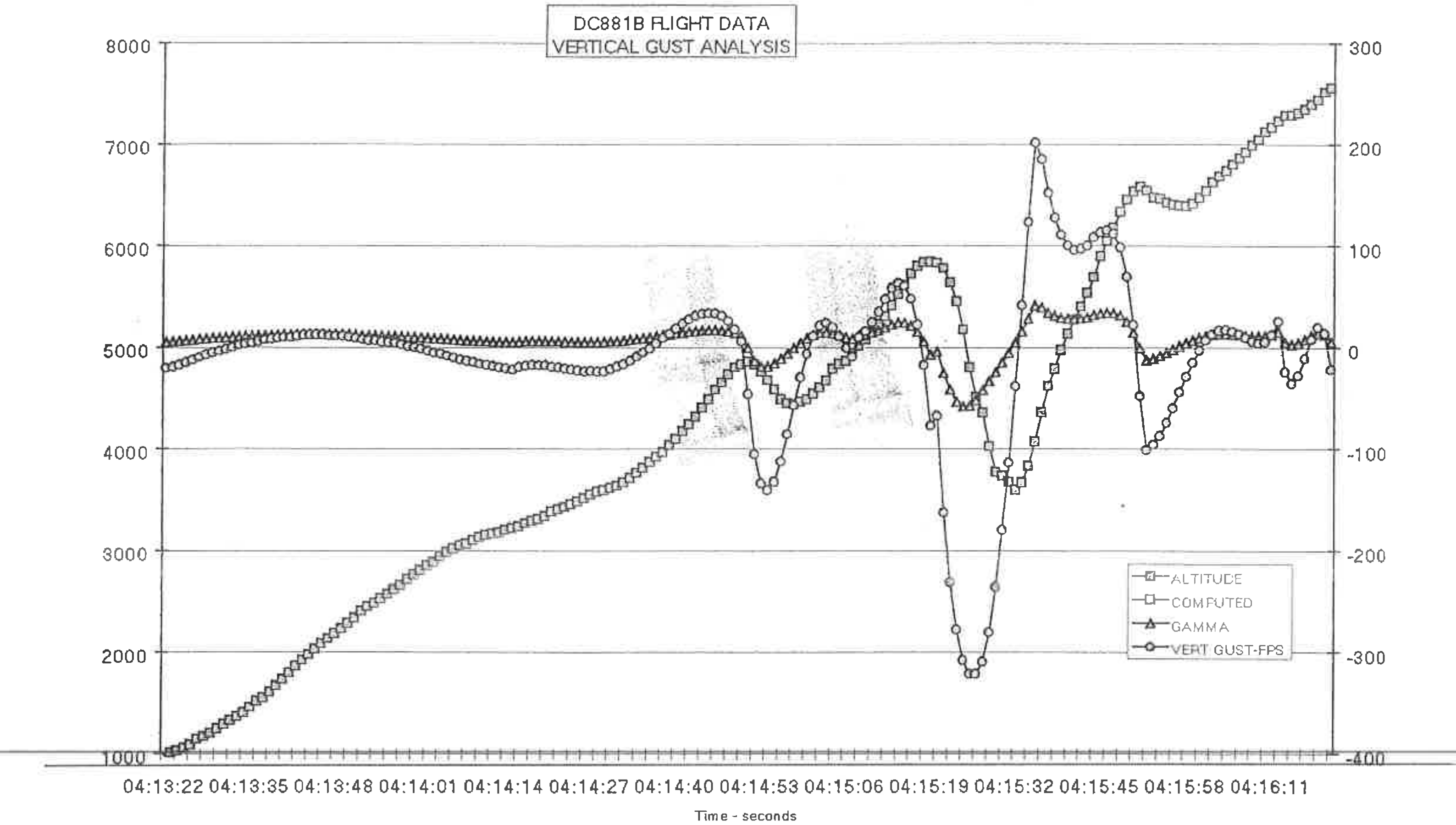
Height Profile, as seen by H4, of FXi21 on Aug.16th., 1997

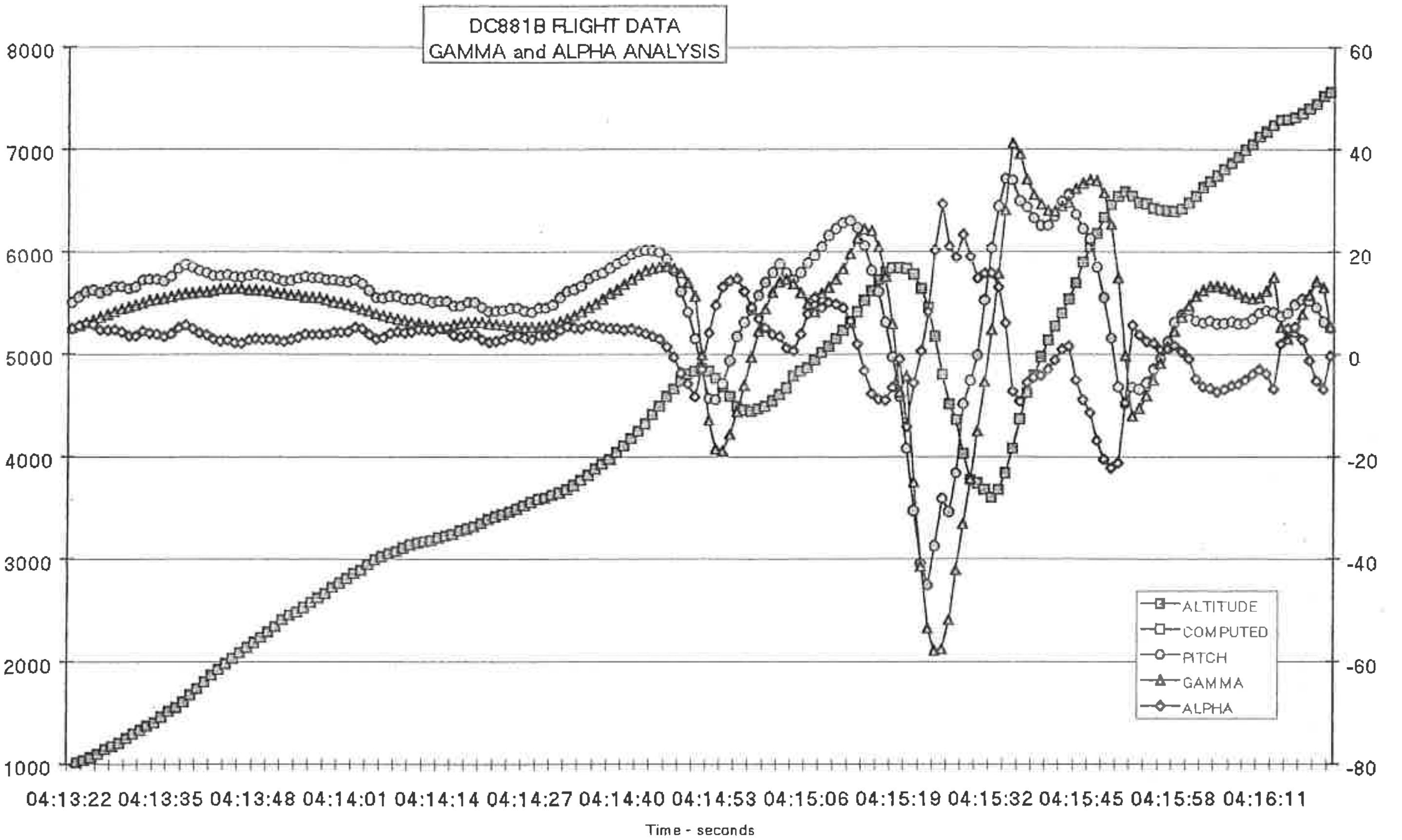


5.5 Transcripts of the aircraft DFDR data.

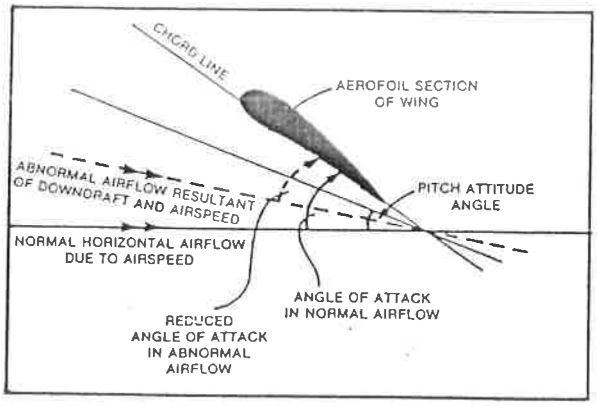


5.6 Fairchild Aircraft Inc. analysis of the DFDR data.

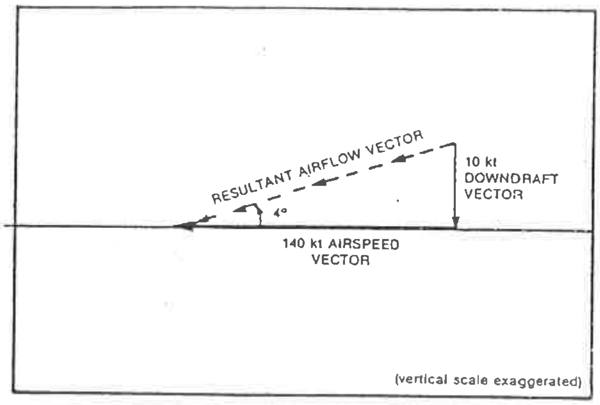




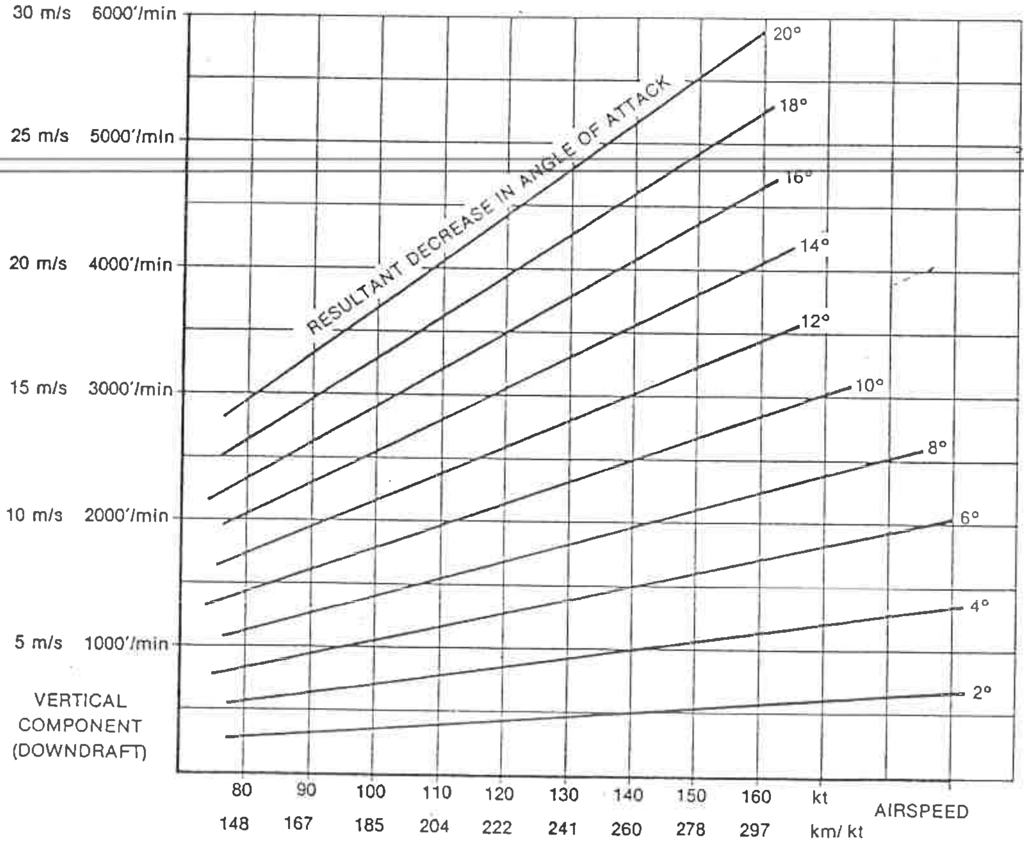
5.7 From ICAO Circular 186-AN/122.



a) Angle of attack reduced due to downdraft but pitch attitude angle remains unchanged



b) 4° reduction in angle of attack due to 10 kt downdraft at airspeed of 140 kt



c) Decrease in angle of attack resulting from various combinations of airspeed and vertical component of the wind (downdraft)

Figure 4-3. Reduction of angle of attack due to sharp-edged downdraft