RNSA

Rannsóknarnefnd samgönguslysa

Final Report on aircraft accident

Case no: **2015-075-F-021**

Date: **9. August 2015**

Location: **The valley of Barkárdalur, Iceland**

Description: **Aircraft crashed in a narrow valley with a low cloud base, while attempting to turn around**

Contents

Samantekt (Icelandic synopsis)

Klukkan 14:01 þann 9. ágúst 2015 flaug flugmaður ásamt félaga sínum, ferjuflugmanni, flugvél N610LC, sem er af gerðinni De Havilland DHC-2 Beaver, í sjónflugi frá flugvellinum á Akureyri áleiðis til Keflavíkurflugvallar. Tilgangur flugsins var að ferja flugvélina frá Akureyri til Bandaríkjanna þar sem að selja átti flugvélina.

Var flugvélinni flogið út Eyjafjörð frá Akureyri, yfir Þelamörk og inn Öxnadal. Lágskýjað var og ekki reyndist unnt af fljúga yfir Öxnadalsheiði. Var flugvélinni því snúið við innarlega í Öxnadal og flogið út í átt að Staðartunguhálsi þar sem stefnan var svo tekin í átt að botni Hörgárdals. Inni í Hörgárdal reyndist einnig ófært yfir Hörgárdalsheiði vegna lágra skýja. Var flugvélinni því aftur snúið við. Hugðust flugmennirnir þá fljúga í kringum Tröllaskagann samkvæmt varaplani sínu, en þegar þeir komu aftur að Staðartunguhálsi sýndist þeim þeir sjá gat í skýjunum innst inni í Barkárdal. Var því sú skyndiákvörðun tekin af báðum flugmönnunum að fljúga inn Barkárdal.

Barkárdalur er langur og þröngur dalur með 3000-4500 feta háum fjöllum beggja vegna. Innst inni í Barkárdal er fjallaskarð sem liggur lægst í um 3900 feta hæð.

Um þremur korterum eftir flugtak brotlenti flugvélin innarlega í Barkárdal í um 2260 feta hæð. Flugmaðurinn komst lífs af, en ferjuflugmaðurinn fórst í eldi sem kviknaði í flakinu eftir brotlendinguna.

Við rannsóknina kom í ljós að flugvélin var ofhlaðin og var afkastageta hennar talsvert skert af þeim sökum. Rannsóknin leiddi í ljós að ekki voru sjónflugsskilyrði á flugleiðinni yfir Tröllaskaga. RNSA telur að mannlegir þættir[1] hafi átt stóran þátt í flugslysinu og þá er einnig talið að blöndungsísing hafi haft áhrif í flugslysinu.

Rannsóknarnefnd samgönguslysa gefur út eina tillögu í öryggisátt og þrenn tilmæli í tengslum við rannsóknina.

Skýrslan er skrifuð á ensku þar sem málsaðilar eru bæði íslenskir og erlendir, en slíkt er heimilt samkvæmt 32. grein laga [18/2013] um rannsókn samgönguslysa.

[1] human factors

Synopsis

At 14:01 on August 9th, 2015, a pilot along with a friend, a contracted ferry flight pilot, planned to fly airplane N610LC, which is of the type De Havilland DHC-2 Beaver, under Visual Flight Rules (VFR) from Akureyri Airport to Keflavik Airport in Iceland. The purpose of the flight was to ferry the airplane from Akureyri to Minneapolis/St. Paul in the United States, where the airplane was to be sold.

The airplane was initially flown in Eyjafjörður in a northernly direction from Akureyri, over Þelamörk and then towards and into the valley of Öxnadalur. The cloud ceiling was low and it was not possible to fly VFR flight over the heath/ridge of Öxnadalsheiði. The airplane was turned around in the head of the valley of Öxnadalur and flown towards the ridge of Staðartunguháls, where it was then flown towards the heath/ridge of Hörgárdalsheiði at the head of the valley of Hörgárdalur. In the valley of Hörgárdalur it became apparent that the cloud base was blocking off the heath/ridge of Hörgárdalsheiði, so the airplane was turned around again. The pilots then decided to fly around the peninsula of Tröllaskagi per their original backup plan, but when they reached the ridge of Staðartunguháls again the pilots noticed what looked like a break in the cloud cover over the head of the valley of Barkárdalur. A spontaneous decision was made by the pilots to fly into the valley of Barkárdalur.

The valley of Barkárdalur is a long narrow valley with 3000 – 4500 feet high mountain ranges extending on either side. At the head of the valley of Barkárdalur there is a mountain passage at an elevation of approximately 3900 ft.

About 45 minutes after takeoff the airplane crashed in the head of the valley of Barkárdalur at an elevation of 2260 feet. The pilot was severely injured and the ferry flight pilot was fatally injured in a post crash fire.

The investigation revealed that the airplane was over the maximum weight limit and its performance considerably degraded as of result of the overweight condition. The ITSB also believes carburetor icing contributed to the accident. Furthermore, the investigation revealed that VMC did not exist on the intended flight route across the peninsula of Tröllaskagi. Finally, multiple human factors issues were identified.

The ITSB issues one safety recommendation and three safety actions as a result of this investigation.

1. Factual information

Location and time	
Location:	The valley of Barkárdalur, Iceland (65° 39′ 46.2″ N, 018° 46′ 40.9″ W)
Date:	9. August 2015
Time[2]:	Approximately 14:45

Aircraft	
Type:	De Havilland DHC-2 Beaver
Register:	N610LC
Year of manufacture:	1960
Serial number:	1446
CoA:	Valid
Engines:	Pratt & Whitney R985-AN-14B, S/N JP206812

Other information	
Persons on board:	Two
Injury:	One fatally injured and one seriously injured
Damage:	Destroyed
Short description:	Aircraft crashed in a narrow valley with a low cloud base, while attempting to turn around.
Weather:	The cloud ceiling was low and visibility across the peninsula of Tröllaskagi was limited due to fog and/or precipitation
Meteorological conditions:	VMC during takeoff, but IMC on the intended flight route across the peninsula of Tröllaskagi
Type of flight:	Ferry flight

[2] All times in the report are Icelandic local times (UTC+0), unless otherwise stated

1.1. History of the flight

At 14:01 on August 9th 2015 airplane N610LC, which was of the type De Havilland DHC-2 Beaver, took off from Akureyri Airport with two pilots on board. The purpose of the flight was to ferry the airplane from Akureyri in Iceland to Minneapolis/St Paul in the United States, where it was to be sold. The lengthy ferry flight would require multiple stops for rest and refueling. The first stop was planned at Keflavik Airport in Iceland, with an ETA[3] at 16:00. The plan was to stay overnight in the area around Keflavik Airport and then continue to Greenland the next day. For the first leg of the flight, the pilot flying (PF) was a pilot who was also the registered trustor of the airplane. The second pilot, a contracted ferry flight pilot, operated as a pilot not flying (PNF).

Before departure, both pilots inspected the airplane and prepared for the ferry flight. The PF checked the weather on the internet[4], performed weight and balance calculations and filed a flight plan with ATC[5] at Akureyri Airport. The PNF finished the loading of the airplane, including installing the aircraft documents in a cargo hold within the forward section of the right landing gear float. Then the PNF fueled the airplane, including a ferry fuel tank that had been installed inside the cabin of the airplane several days earlier.

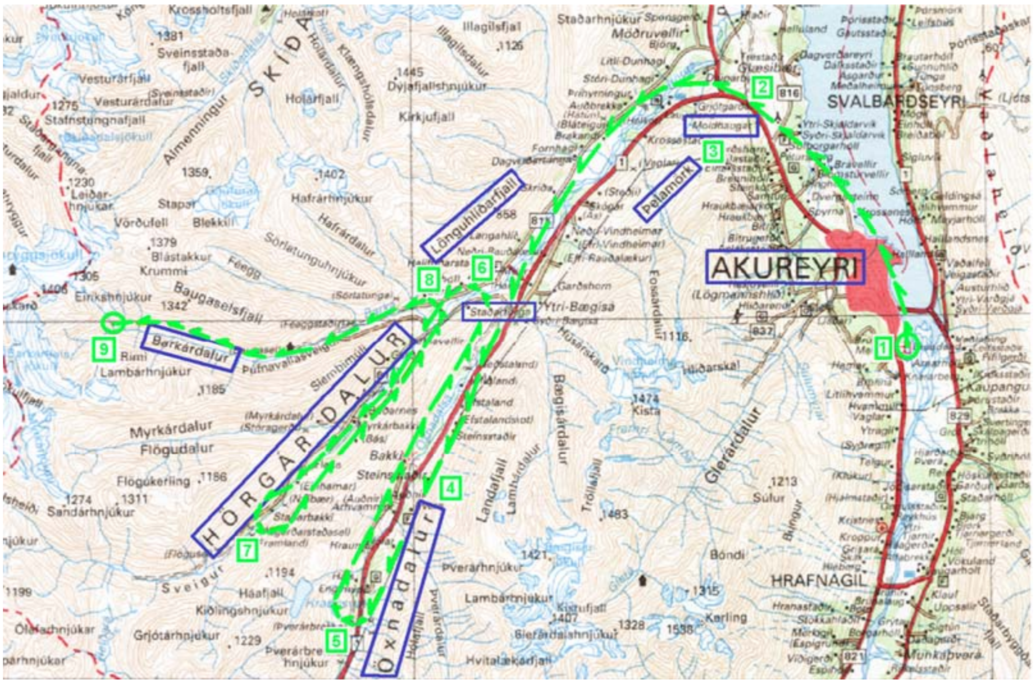


Figure 1: Map of the route flown (Landmælingar Íslands / National Land Survey of Iceland, 1999)

---

[3] Estimated Time of Arrival
[4] The official website of Icelandic Meterological Office, http://www.vedur.is/vedur/flugvedur/
[5] Air Traffic Control

After takeoff from Akureyri Airport [Item 1 on Figure 1], the heading was set to where Route 1[6] crosses over the ridge of Moldhaugaháls [Item 2 on Figure 1] in Þelamörk. Six minutes after takeoff the PF contacted ATC at Akureyri airport and advised that they were over Þelamörk [Item 3 on Figure 1]. According to multiple witnesses' statements and photos taken, the airplane passed over Route 1 across the ridge of Moldhaugaháls in Þelamörk at a low altitude and then turned left, heading towards the valley of Öxnadalur [Item 4 on Figure 1]. The dashed green arrow line in Figure 1 is a rough estimate of the airplane's track based on witnesses' statements. The pictures shown in Figure 2 and Figure 3 were taken by a front seat passenger of a car driving on Route 1 in Þelamörk. The airplane is highlighted with a red circle on the pictures.

As can be seen on Figure 3, there were clouds present at a lower altitude than the mountain tops in the mouth of the valley of Hörgárdalur on the way towards the valley of Öxnadalur. According to witnesses' statements, this cloud cover got thicker towards the head of the valley of Öxnadalur and the head of the valley of Hörgárdalur. According to the pilot flying, the plan was to fly into the valley of Öxnadalur to see if there was a break in the cloud cover at the valley head [Item 5 on Figure 1], where they could fly over the heath/ridge of Öxnadalsheiði[7] and then towards Keflavik Airport.

Figure 2: Airplane N610LC (in red circle) passed over Route 1 in Þelamörk

[6] The main road around Iceland
[7] A passage between the mountains at the head of the valley of Öxnadalur and towards the fjord of Skagafjörður

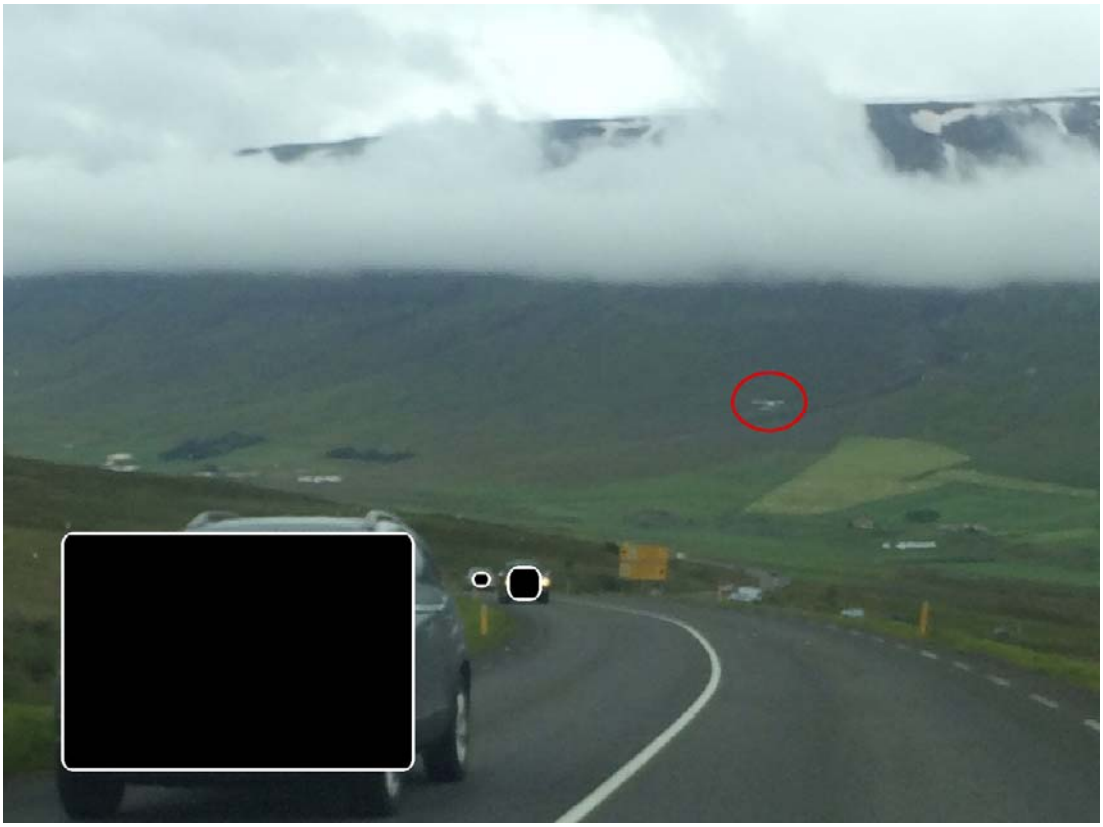


Figure 3: Airplane N610LC (in red circle) in Þelamörk over the junction between Route 1 and Route 82

As the airplane flew towards the head of the valley of Öxnadalur, it became apparent that the cloud cover got thicker overhead, blocking off the valley head and the top of the mountain range. The pilots therefore decided to turn around and try the next valley, Hörgárdalur. Multiple witnesses confirmed the flight path of the airplane towards the head of the valley of Öxnadalur and then back towards the valley of Hörgárdalur.

When the airplane was about to fly out of the valley of Öxnadalur, at 14:24, the pilot flying contacted ATC at Akureyri Airport and requested their flight plan to be lengthened by 20 minutes. The ATCO[8] complied and changed their ETA at Keflavik Airport to 16:20. At 14:26 the PF contacted the ATCO again and advised that they would go over the heath/ridge of Hörgárdalsheiði[9] instead of the heath/ridge of Öxnadalsheiði. According to the PF, the airspeed was 95 - 105 mph when they flew in the valley of Öxnadalur and the valley of Hörgárdalur.

[8] Air Traffic Control Officer
[9] A passage between the mountains at the head of the valley of Hörgárdalur and towards the fjord of Skagafjörður

The airplane was flown past the end of the mountain ridge Staðartunguháls [Item 6 on Figure 1], which separates the mouth of the valley of Öxnadalur from the valley of Hörgárdalur. There were witnesses that noticed the airplane flying in front of the ridge of Staðartunguháls and based on their statements the altitude of the airplane when it passed in front of the ridge was estimated to have been around 900 ft MSL[10] (500-600 AGL[11]).

The airplane was then flown towards the heath/ridge of Hörgárdalsheiði at the head of the valley of Hörgárdalur [Item 7 on Figure 1]. According to the PF the cloud base was blocking off the heath/ridge of Hörgárdalsheiði, so they turned around again. According to the PF they had the option of flying around the whole mountainous pensula of Tröllaskagi[12], but that would result in an hour being added to the flight time. When they reached the ridge of Staðartunguháls again, the pilots noticed what looked like a break in the cloud cover above the head of the valley of Barkárdalur out the left window (Figure 4). They therefore decided to make the 3rd attempt to fly across the pensula of Tröllaskagi, now via the valley of Barkárdalur. Various landmarks and locations being mentioned in this chapter are shown in Figure 5 and Figure 6.

Figure 4: Red circles indicates area of suspected break in clouds in Barkárdalur

[10] Mean Sea Level
[11] Above Ground Level
[12] A mountainous peninsula located between Eyjafjörður and Skagafjörður which includes the valleys of Öxnadalur, Hörgárdalur and Barkárdalur amongst many other.

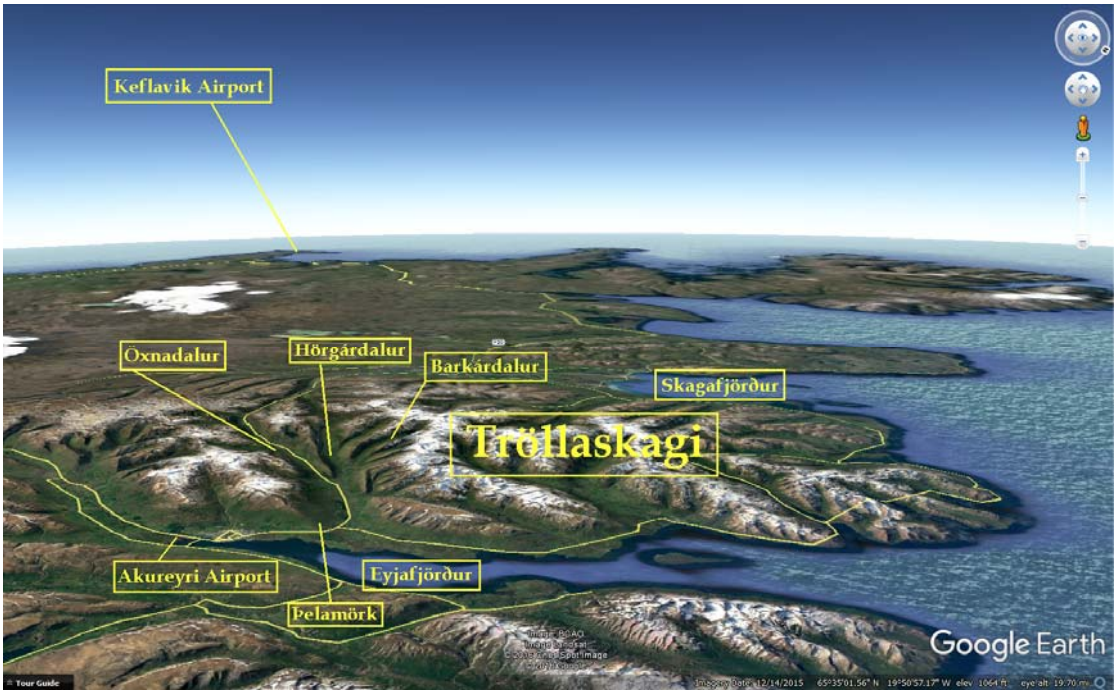


Figure 5: Overview picture explaining the various locations

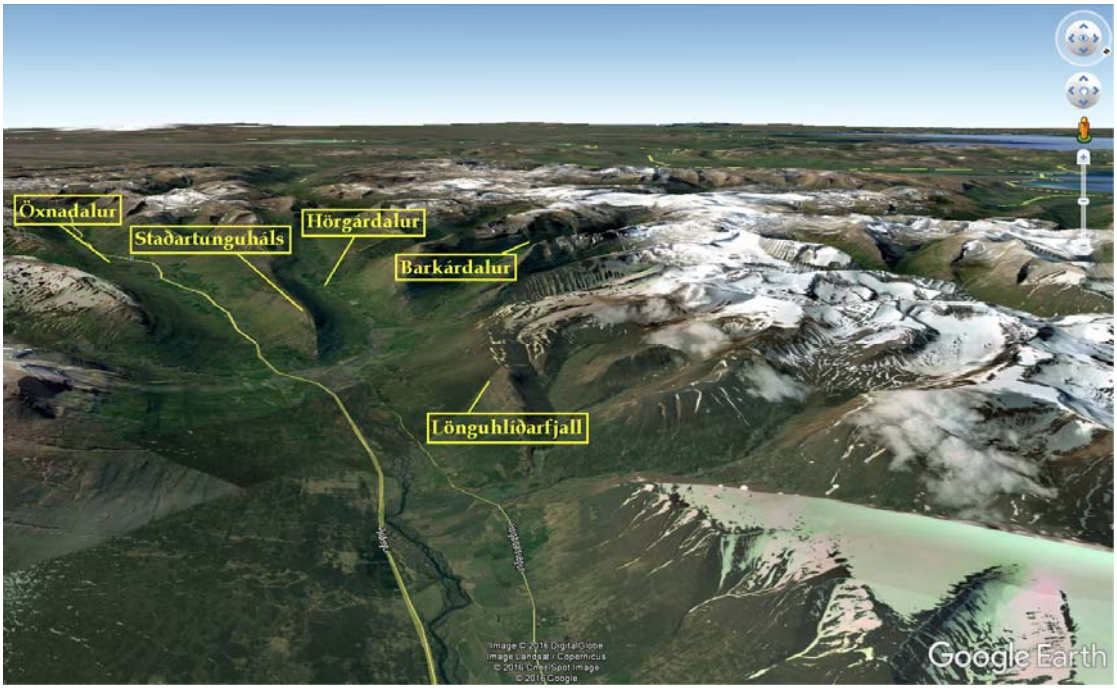


Figure 6: Overview picture of the valley of Hörgárdalur and the surrounding area

The PF changed the heading towards the valley of Barkárdalur. There was a witness in the valley of Hörgárdalur that noticed the airplane flying towards and into the valley of Barkárdalur. Based on a statement taken from this witness, the airplane was estimated to be climbing between the altitude of 1200 ft and 1400 ft MSL when it

passed the mountain Lönguhlíðarfjall [Item 8 on Figure 1] and into the valley of Barkárdalur.

There are no witnesses to the flight, except the PF, after the airplane entered the valley of Barkárdalur.

According to the PF the atmosphere in the airplane was relaxed and the airplane was climbing while flying into the valley of Barkárdalur at an airspeed of 80 - 90 mph. The PF had flown through the valley of Barkárdalur before (although never on a DHC-2 Beaver), and was aware of that the ridge/passage towards the fjord of Skagafjörður over the head of the valley of Barkárdalur required a higher altitude.

According to the PF, in the valley of Barkárdalur when the airplane was at an altitude well above 2000 feet[13] MSL (flying at an altitude approximately half way up the mountain slopes), the pilots noticed a reduction in engine power.

At this time, the airplane was located at the northern side of the valley (flying towards the valley head), climbing and at an airspeed of 75 - 80 mph.

The PNF ensured that the fuel pressure was sufficient, turned on the carburetor heat, as the pilots suspected carburetor icing, and started leaning the fuel mixture to increase the exhaust temperature, while the PF flew the airplane. The pilots then experienced the airplane starting to lose altitude. At this time the pilots also realized that they were not going to make it over the ridge at the head of the valley, because of their loss of altitude and also as they realized that the ridge was blocked with clouds.

The pilots became aware that they were flying much closer to the valley floor than they had expected. The pilots subsequently decided to turn around.

According to the PF, he estimated the altitude loss to have been around 100-200 ft before they decided to turn around.

The flaps were in the TAKEOFF position. The PF reduced the airspeed to less than 60 mph. His aim was to make the turn as steep as possible with a minimum turn radius. The PF then rolled the airplane left, with a bank angle of 30° – 40°.

[13] According to PF statement

When the airplane reached a bank angle between 30° and 40°, it lost altitude rapidly and the PF became aware that they were about to collide with the ground. The PF quickly leveled off the airplane and further reduced the airspeed to less than 50 mph. About 5 seconds later one of the floats hit the top of a large rock on the ground [Item 9 on Figure 1].

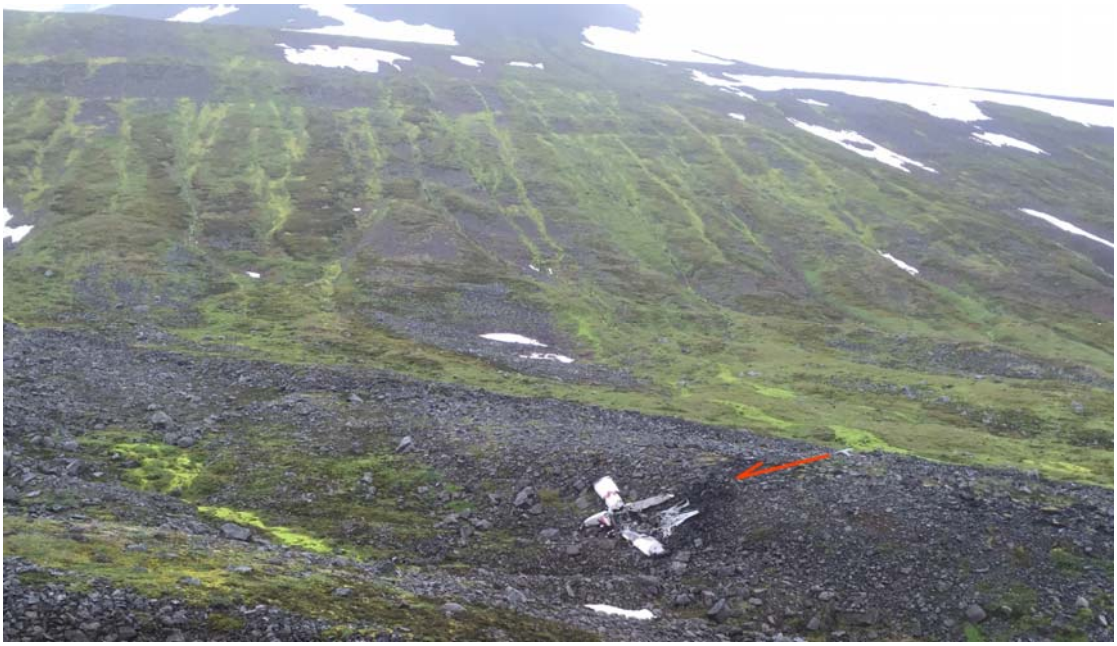


Figure 7: The accident site (the arrow showing the direction of the crash)

The airplane skidded across a rock covered ridge, see arrow in Figure 7. Parts broke off the airplane and the wing tips hit the ridge, tearing up the wing tip fuel tanks, causing fires. The floats broke from underneath the airplane fuselage, causing the fuselage bottom to tear up and fire to start when the airplane skidded off the ridge and then came to rest on the other side of the rocky ridge.

Both pilots had their seatbelts on, survived the crash and were alive inside the airplane at this point. The fuselage was resting on the ground on its left side with the right forward door facing up and the left forward door blocked off by the rocky ground. The forward cockpit window was intact. At this point, there was a fire burning as well as smoke inside the airplane cabin.

Both pilots released their seat belts and shouted at each other to get out. The right door was stuck and would not open. The PNF decided to climb into the back of the cabin, which was partly blocked off by the ferry fuel tank, most likely to try to exit via

the cabin area. The PF noticed a crack in the window on the right forward door. While standing on the inside of the left forward door he thrust himself upwards, putting his head into the cracked window, breaking it.

The PF squeezed out the broken right door window and pushed himself backwards in a sitting position away from the burning airplane.

According to the PF the airplane fuselage was engulfed in fire within 2 - 3 minutes from the crash. When he had pushed himself 10 - 15 meters away, explosions occurred in the airplane wreckage.

The PNF was unable to evacuate the airplane.

1.2. Injuries to persons

The PNF was fatally injured during the post accident fire. The PF was severely injured, with extensive burn wounds.

1.3. Damage to aircraft

The airplane was destroyed.

1.4. Personnel information

According to the pilot flying, both pilots were well rested before the flight.

Pilot Flying		
Age:	75 years	
Certificate:	ATPL/A	
Ratings:	SEP (land), valid SEP (sea), valid MEP (land), valid IR, valid DC3, valid	
Medical Certificate:	Class 2, valid	
Experience:	Total flight hours:	~ 22,000
	Total flight hours on type:	~ 250
	Last 90 days on type:	Unknown[14]
	Last 24 hours on type:	0.75

During the investigation, it was considered whether to classify the ferry flight pilot solely as a passenger or as a pilot not flying (PNF). The moment the ferry flight pilot took part in the preparation of the accident flight, this stopped being a flight with a single pilot crew. Instead the pilots, reverted to their familiar work career roles of PF and PNF.

Based on the fact that the ferry flight pilot was contracted for the ferry flight and took on tasks both during the preparation of first flight leg, as well as during the emergency phase, the ITSB[15] decided to classify the ferry flight pilot as a PNF.

1.5. Aircraft information

The airplane, DHC-2 Beaver with S/N 1446 was manufactured in October 1960. In December 1963 the airplane crashed in Kenya under the registration XP-776, where it remained un-airworthy for close to four decades. In October 2002 the airplane was transported to Canada, where it was repaired and re-registered as C-GPAB and then returned to service. In 2006 the airplane was re-registered as N610LC. In 2007 it was temporarily re-registered as C-FPWH and various STCs[16] were installed to upgrade and modernize the airplane. Amongst the most significant of those STCs (with regards

[14] Pilot log book was lost in the accident fire
[15] Icelandic Transportation Safety Board
[16] Supplemental Type Certificates

to this investigation), were changes that modified the airplane from landplane to seaplane, changed its maximum gross weight from 5090 lbs to 5370 lbs and upgraded its propeller to increase the airplane's performance for the increased maximum gross weight. The airplane was then re-registered again as N610LC by the end of 2007.

Figure 8: Airplane N610LC one day prior to the accident

On May 2nd 2008, the airplane received FAA special flight permit on a special airworthiness certificate, valid until June 1st 2008, for operation in excess of the maximum certified takeoff weight during a ferry flight to Akureyri in Iceland. For this ferry flight to Iceland a 10% increase in the gross weight was temporarily permitted, bringing the gross weight from 5370 lbs up to 5907 lbs. The special airworthiness certificate was based on FAA major alteration that was also issued on May 2nd 2008. That alteration required removal of all passengers' seats and the co-pilot's seat, installation of a ferry fuel tank into the cabin, updated weight and balance report and an airworthiness limitation that all weights above 5100 lbs would be fuel in the airplane's wing tip tanks and the ferry fuel tank. See Figure 9 for the re-installation of ferry fuel tank few days before the accident flight in 2015, which is similar to its installation when it was transported to Iceland in 2008.

After the airplane arrived in Iceland, the ferry fuel tank was removed and the airplane returned to the configuration prior to the FAA major alteration approved on May 2nd 2008.

Figure 9: Ferry fuel tank installed in cabin, seen through left cabin door

In 2009 a trust agreement was signed, allowing for the airplane to be operated on a United States registry in Iceland by an Icelandic citizen.

The airplane received its annual/100 hour inspections as required, while still being operated on United States registry N610LC, in Iceland between 2008 and 2015. The last scheduled maintenance (annual/100 hour inspection) on the airplane was performed in March 2015. That inspection resulted in the propeller being removed, sent for overhaul and then reinstalled.

1.6. Meteorological information

Following is the METAR at Akureyri Airport around the time of the accident:

METAR BIAR 091200Z 34008KT 9999 FEW009 OVC041 10/08 Q0993
METAR BIAR 091300Z 36010KT 9999 FEW010 BKN040 10/08 Q0993
METAR BIAR 091400Z 35011KT 9999 FEW012 BKN037 10/08 Q0993
METAR BIAR 091500Z 33011KT 9999 SCT009 OVC039 10/08 Q0992

According to the PF, he checked the weather on the Icelandic Meterological Office (IMO) website before the flight. He was aware of low cloud ceiling in the northern part of Iceland, but believed the visibility to be good below the mountains tops. He also noted that the weather at Keflavik Airport and in the southwestern part of Iceland was good. The plan was to fly into the valley of Öxnadalur and see if there was a break in the cloud cover at the valley head, where they could fly over the heath/ridge of Öxnadalsheiði and then towards Keflavik Airport. The plan was to stay in the Keflavik area overnight and then to continue the journey to Greenland early in the morning the day after (August 10th). Figure 10 shows that a low pressure area was moving over Iceland during the flight from Akureyri.

According to Figure 11, the low pressure area had passed when they planned to fly to Greenland the day after.

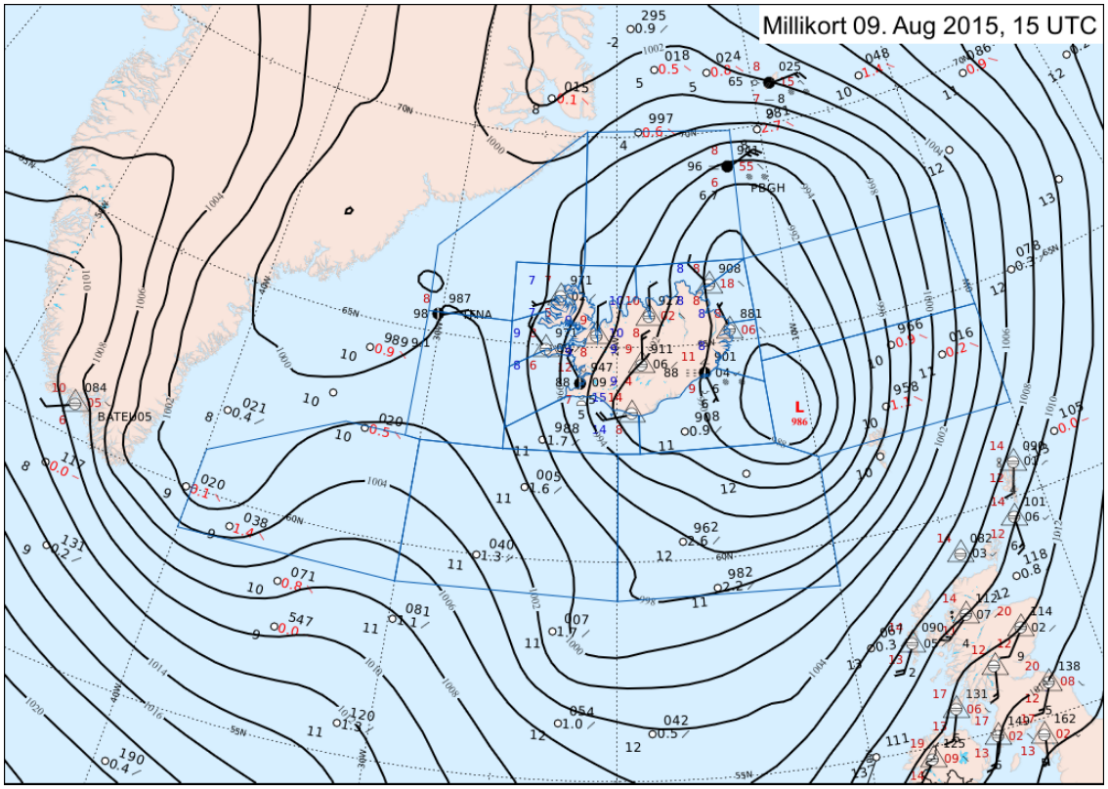


Figure 10: Low pressure area over Iceland on August 9th 2015 at 15:00 UTC [time of accident 14:45]

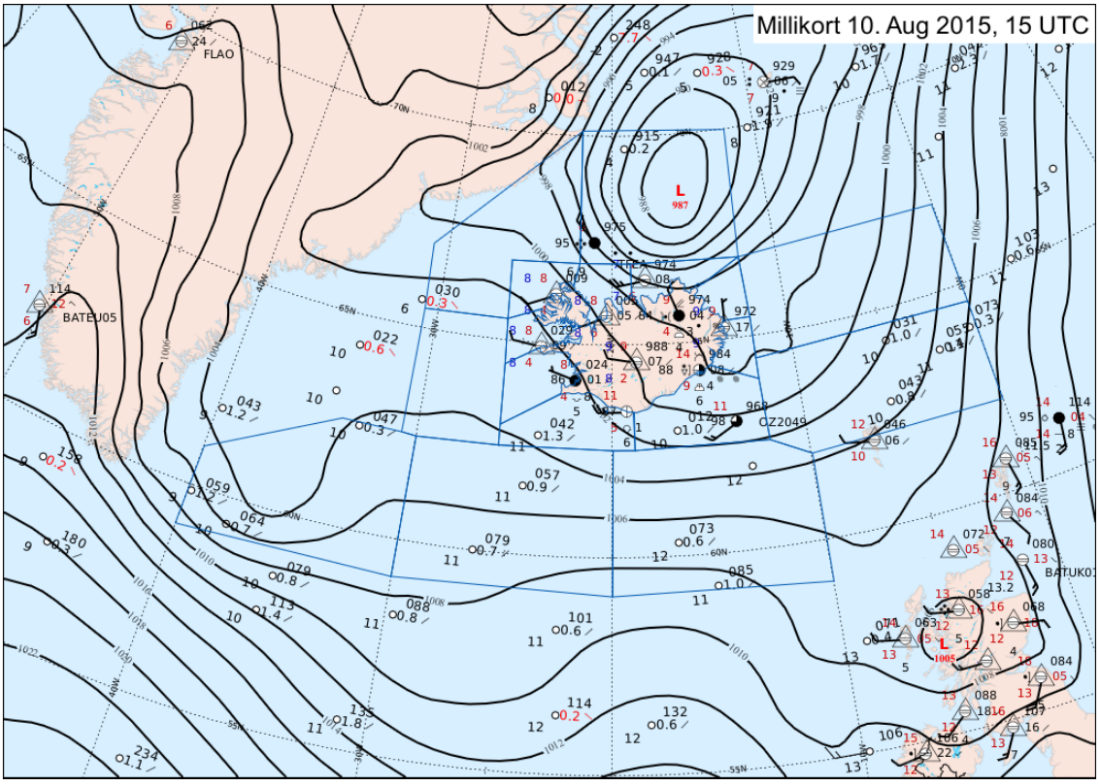


Figure 11: Low pressure area has moved north of Iceland on August 10th 2015 at 15:00 UTC

The valley of Barkárdalur, where the accident occurred, is uninhabited and no weather observations are recorded in that valley. The valley of Barkárdalur is long and narrow, with 3000 – 4500 feet high mountain ranges extending on either side. The ITSB compared SYNOP measurements taken at the towns of Akureyri, Dalvík and Sauðárkrókur around the Tröllaskagi peninsula. The temperature was between 9°C and 10°C, the dew point was between 8°C and 9°C and the air pressure was between 992 hPa and 994 hPa, at these three locations around the time of the accident. This data was used to estimate the temperature, dew point and air pressure at the accident site at the time of the accident, taking into account the changes due to the accident site's elevation.

According to a witness in the valley of Hörgárdalur, the cloud cover in the area around the mouth of the valley of Barkárdalur, at and around the mountain of Lönguhlíðarfjall, was below the mountain tops. The mountain of Lönguhlíðarfjall is between 2000 feet and 2800 feet high. Furthermore, for the tallest mountain tops the cloud cover was down to the middle of the mountain sides and in some cases there were fog patches. The mountain tops at the valley head of Hörgárdalur were covered in clouds. There was almost no wind and shortly after 15:00 it started raining.

The Icelandic Meteorology Office (IMO) compiled a weather report for the ITSB in relation to the investigation. According to the weather report there are several automatic weather observation stations located on the eastern part of Tröllaskagi peninsula. Most of these weather stations recorded high humidity around the time of the accident. The closest weather station to the valley of Barkárdalur is located at Möðruvellir in the valley of Hörgárdalur. It recorded 80 – 85 % humidity around the time of the accident. Such high humidity indicates that the cloud ceiling was low and that either fog or rain was occurring nearby. Pictures from traffic cameras on Öxnadalsheiði taken around the time of the accident showed fog.

The IMO also compiled an HARMONIE high resolution weather model, which gave a good indication of the wind and the weather in the area at 15:00 at the day of the accident. According to the model, in Eyjafjörður and on Tröllaskagi, there was slow breeze from northerly direction, rain and mild weather. See Figure 12.

The HARMONIE model from the Icelandic Meteorology Office also indicated minor mountain waves on Tröllaskagi, in the area of the valley of Hörgárdalur and also in the valley of Barkárdalur. According to the data, a minor downdraft of 0.8 m/s, or 157 fpm, was estimated in the valley of Barkárdalur. See Figure 13.

In its weather report, the IMO concluded that in the valley of Barkárdalur and the surrounding area there was a slow breeze and minimal amount of vertical movement of the air around the mountains. The IMO estimated the cloud ceiling in and around the valley of Barkárdalur to be very low and visibility limited due to fog or precipitation. The IMO also estimated that the weather conditions would not support VFR flight.

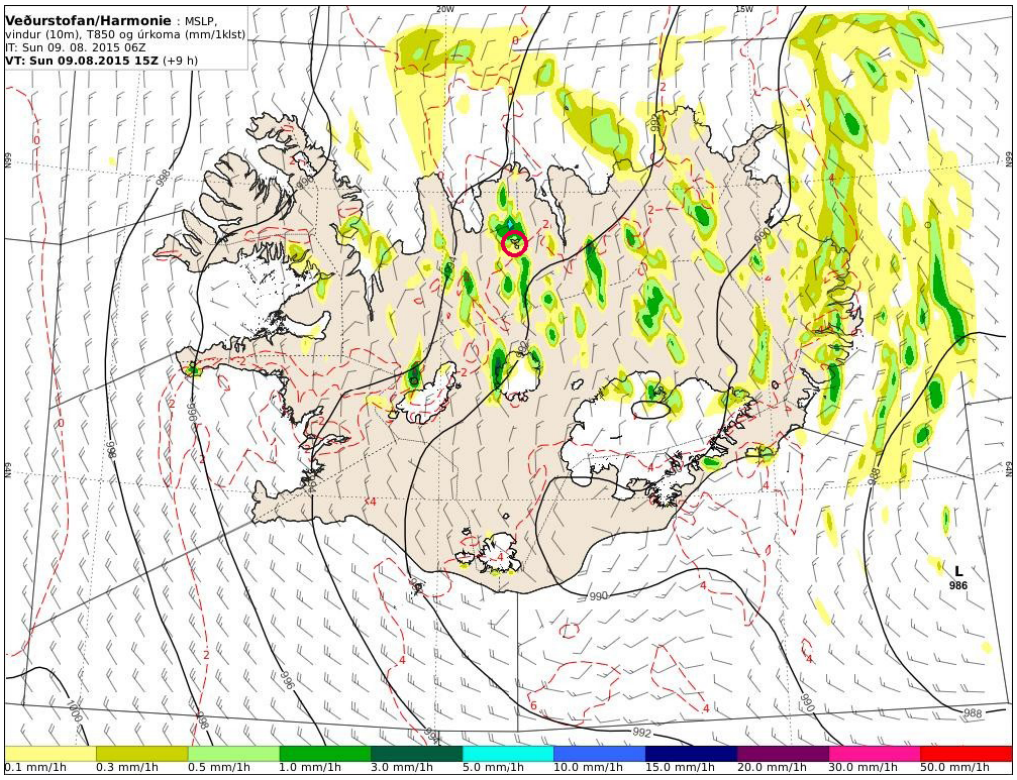


Figure 12: Wind and rain over Iceland at 15:00 on the day of the accident (red circle indicates Barkárdalur)

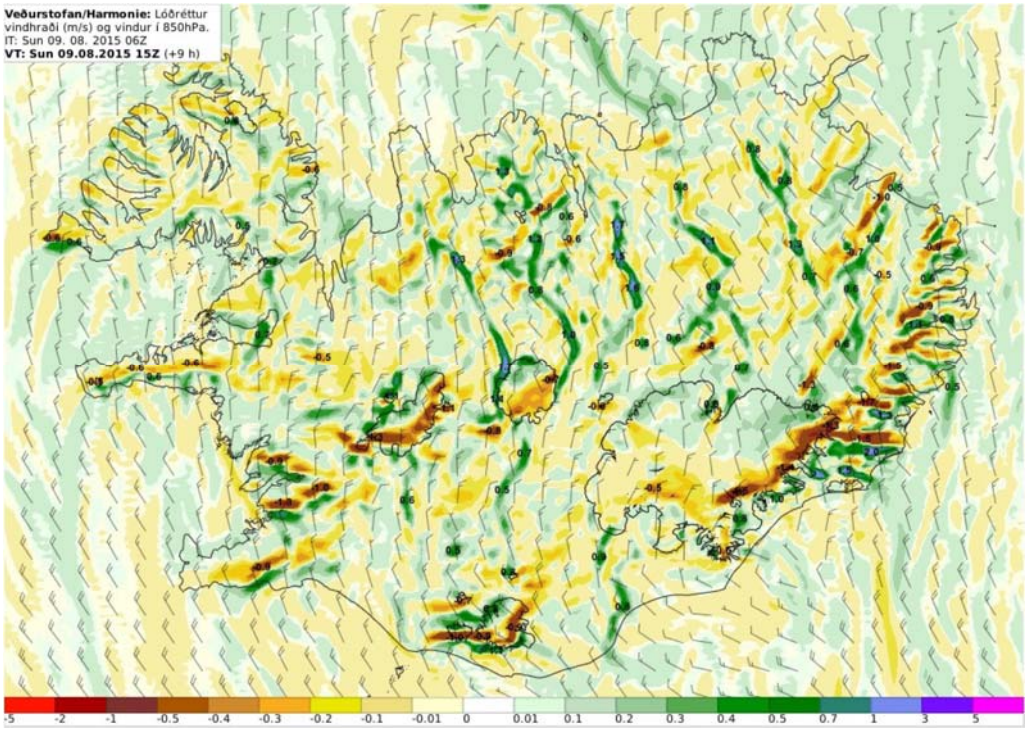


Figure 13: Mountain waves over Iceland at 15:00 on the day of the accident

1.7. Aids to navigation

Airplane N610LC was equipped with all the necessary instruments for IFR flight. The accident flight was nevertheless executed as VFR flight, in conditions that, according to the Icelandic Meterologicaly Office, did not support VFR flight on the planned flight route over Tröllaskagi.

The investigation revealed that the PF did not like flying this particular airplane in clouds due to possible icing, as the airplane did not have de-icing equipment.

1.8. Medical and pathological information

The autopsy of the PNF states that the cause of death was traced to traumatic injuries to the inner organs or because of hyper-thermal trauma.

1.9. Fire

The wing tips hit the ground as the aircraft skidded across a ridge. The fuel tanks in the wing tips ruptured and several fires started on the ridge that the airplane skidded across. The main fuel tanks in the airplane fuselage also ruptured and fuselage fire started when the airplane came to rest on the other side of the ridge. The complete fuselage section of the airplane was on fire within 2-3 minutes after the crash and there were indications of explosions of the fuel tanks.

The fire reached such a temperature that the aluminum in the fuselage and tail section of the airplane, as well as the complete interior, burned to such an extent that molten aluminum[17] was found on the rock under the wreckage. There were mostly steel[18] parts such as control cables and components that remained. From this the ITSB estimates the fuselage cabin fire temperature to have been between 700°C and 1500°C. The fuselage cabin fire self-extinguished within 25 minutes.

Fire also started in the aft section of the engine casing which was made out of magnesium. The magnesium fire was to the extent that the complete aft portion of the engine casing was burnt away. This engine fire lasted approximately 2-3 hours.

[17] Aluminum alloys have a melting point of about 700°C
[18] Steel has a melting point of about 1500°C

1.10. Test and research

The engine and propeller were sent for teardown analysis in the United States.

Detailed analysis was performed to photos, such as the one shown in Figure 2, to estimate the airplane's track and altitude.

1.11. Additional information

The ITSB was not notified of the missing airplane, neither by Isavia ATC nor by the Emergency Services.

2. Analysis

2.1. General

The valley of Barkárdalur (see Figure 14) is a long narrow valley with 3000 – 4500 feet high mountain ranges extending on either side. In the aft third of the valley the valley floor rises rapidly. Along the track of the last 2 miles before the accident site, the valley floor rises from 1320 ft up to 2260 ft, or by 940 ft. The accident site was located at an elevation of 2260 ft, at 65° 39′ 46.2″ N, 018° 46′ 40.9″ W. The elevation of the mountain passage at the head of the the valley of Barkárdalur is approximately 3900 ft.

Figure 14: The valley of Barkárdalur (Accident site marked with X inside red circle)

2.1.1. Weather

According to the PF, he checked the weather on the the IMO website before the flight. According to the PF, they were not under any pressure to fly to Keflavik Airport at the day of the accident.

The flight conditions over Iceland, that were available on the IMO website before the flight for the period of the flight, can be seen on the next page in a text format.

Flugskilyrðin yfir Íslandi
09.08.2015

HORFUR 1200 - 1700 GMT.

Háloftavindar/hiti:
FL050: 360/10-20KT, +02
FL100: VRB07KT A-til, annars 330/05-15KT, -04
FL180: 250/10-20KT, en VRB05KT A-til, -19

Yfirlit:
300 km S af Hornafirði er víðáttumikil 985 mb lægð sem fer NNA.

Vindar nærri yfirborði:
N-læg átt 5 til 25 hnútar, hvassast SV-til.

Skýjahæð/skyggni/veður:
BKN/OVC í 0800 til 2500 fetum N- og A-til og lélegt skyggni í rigningu eða súld. SCT/BKN í 2500 til 5000 fetum S- og V-lands. Toppar yfir 20.000 fet S-til en lagskipt í um 12 til 20 þúsund fetum N-lands.

Sjónflugsskilyrði milli landshluta:
Ófært N- og A-til, annars yfirleitt sæmileg.

Frostmarkshæð:
Um 5000 til 7000 fet, hæst S-til.

Ísing:
LGT/MOD N- og A-til. Annars óveruleg.

Kvika:
LGT SV-til og A-ast, annars NIL.

Annað:
NIL

Flight conditions over Iceland[19]
9. 08.2015

Forecast valid 1200 – 1700 GMT.

High altitude winds / temperature:
FL050: 360/10-20KT, +02
FL100: VRB07KT East 330/05-15KT other, -04
FL180: 250/10-20KT, but VRB05KT East, -19

Overview:
300 km S of Hornafjordur there is a vast 985 mb low pressure area moving NNE

Winds near surface:
Northerly 5-25 knots, highest in SW Iceland.

Cloud ceiling/visibility/weather:
BKN/OVC between 800 and 2500 ft in northern and eastern parts of Iceland and poor visibility in rain or drizzle. SCT/BKN between 2500 and 5000 ft in southern and western parts of Iceland. Cloud tops over 20,000 ft in southern Iceland, but layered in and in between 12,000 and 20,000 in northern Iceland.

Visual flight conditions between parts of Iceland:
Not VMC in northern and eastern parts of Iceland, otherwise ok.

Freezing altitude:
About 5000-7000 ft, highest in southern Iceland.

Icing:
LGT/MOD in northern and easter parts of Iceland. Otherwise insignificant.

Turbulence:
LGT in southwestern and eastern Iceland. Otherwise NIL.

Other:
NIL

[19] English translation made by the ITSB

The ITSB collected the weather data that was available on the IMO website, before the flight. Figure 15 shows the low cloud cover forecasted over Iceland at 14:00[20] on the day of the accident. The low cloud ceiling forcast issued at 12:00 on the day of the accident for the time period around 14:00 which is shown in Figure 15 is based on the "HARMONIE" high resolution weather model from the IMO. According to the model, the weather conditions did not support VFR flight from Akureyri to Keflavik, across the peninsula of Tröllaskagi.

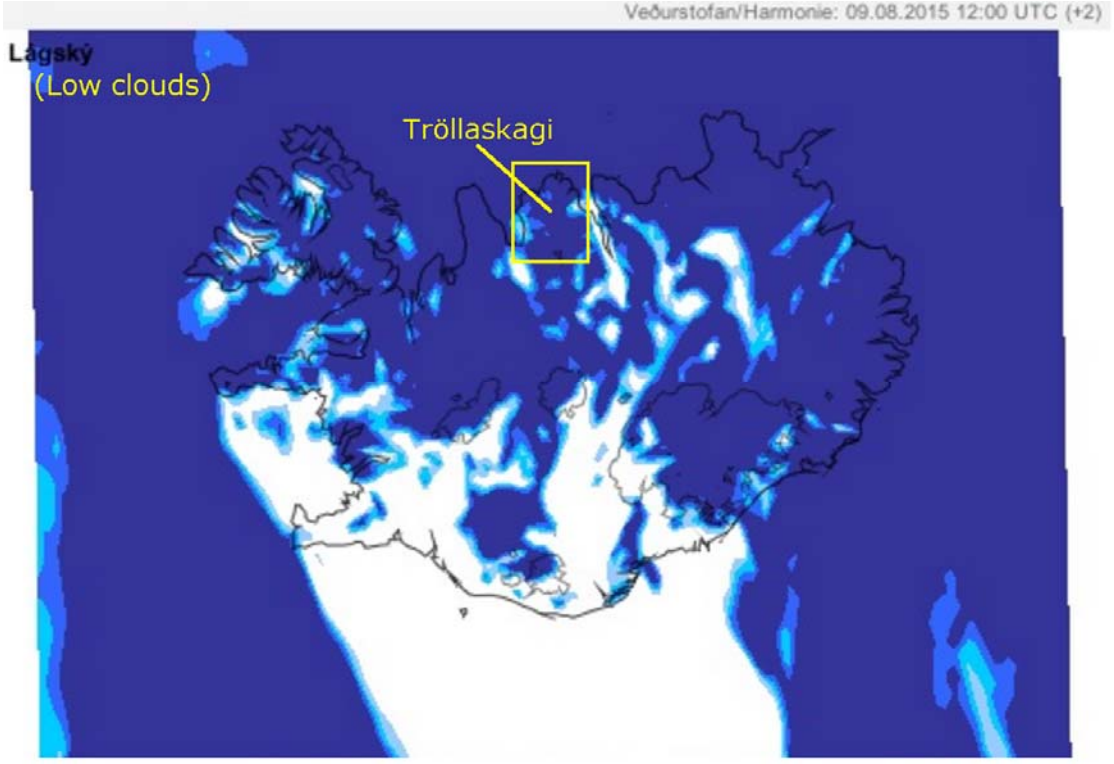


Figure 15 Low clouds (shown in blue) forecasted over Iceland at 14:00 on the day of the accident

According to the report that the IMO compiled for the ITSB, in the valley of Barkárdalur the cloud ceiling was estimated to be low and visibility limited due to fog or precipitation. The weather conditions most likely did not support VFR flights.

From photos taken by the PF at the accident site, the ITSB estimated the cloud ceiling around the accident site to be approximately 2700 feet. The ITSB also calculated the temperature, dew point and the air pressure at the accident site in the valley of Barkárdalur based on the SYNOP measurements taken at the towns of Akureyri, Dalvík and Sauðárkrókur, around the Tröllaskagi peninsula. According to these

[20] The takeoff from Akureyri Airport was at 14:01

calculations, the temperature at the accident site in the valley of Barkárdalur was found to be 5°C, the dew point 4°C and the air pressure 918 hPa. These conditions were then used in the performance calculations and carburator icing estimation for the investigation.

The investigation revealed that on August 7th the flight crew was committed to fly out of Keflavik Airport early on August 10th, due to the weather forecast, and planned to arrive in Minneapolis/St Paul (United States) on August 13th. The weather forecast from 12:00 on August 7th valid at 18:00 on August 7th – 12th can be seen in Figure 16. At this time the weather forecast on the route between Akureyri Airport and Keflavik Airport did not support VFR flight until August 10th.

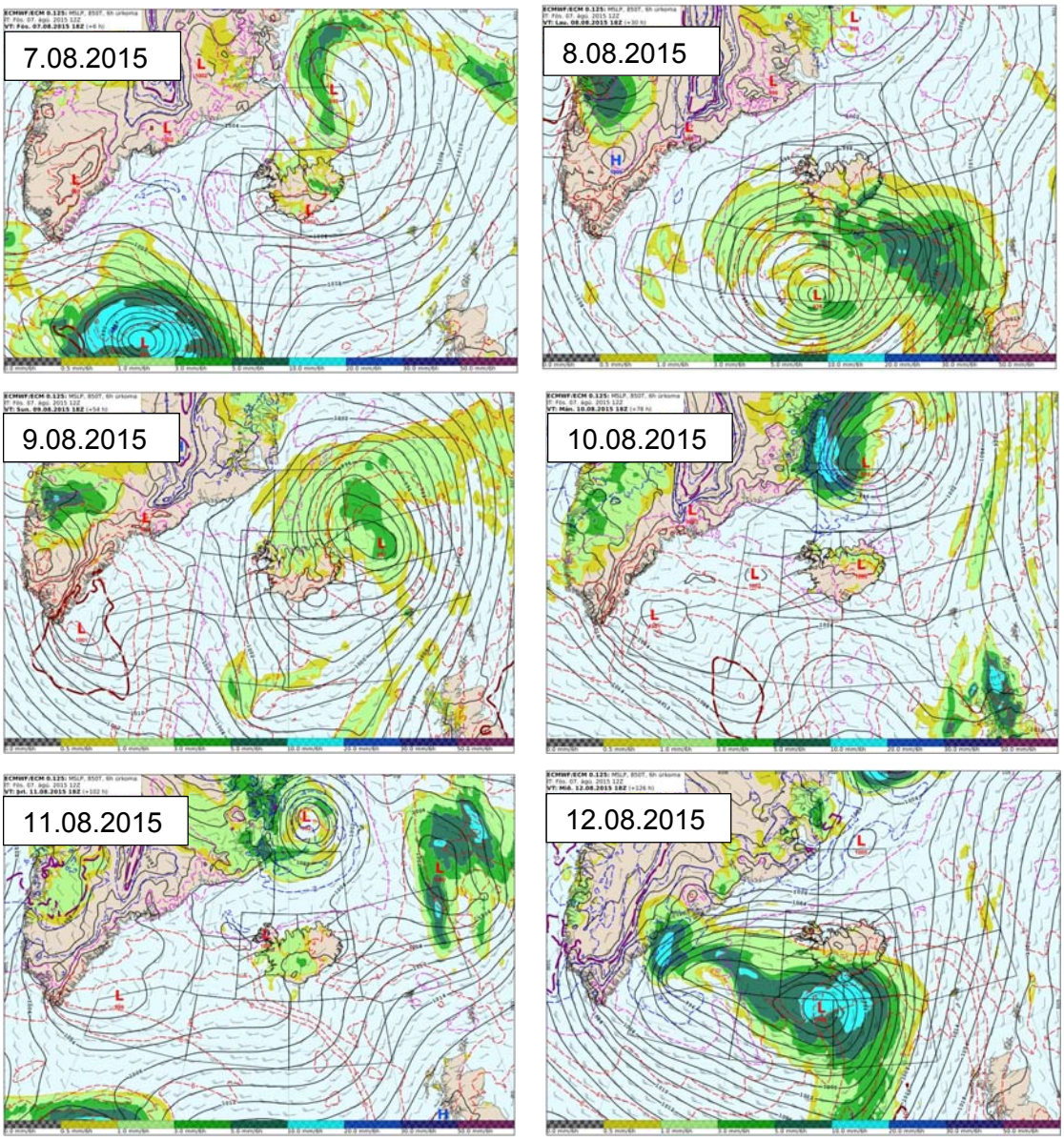
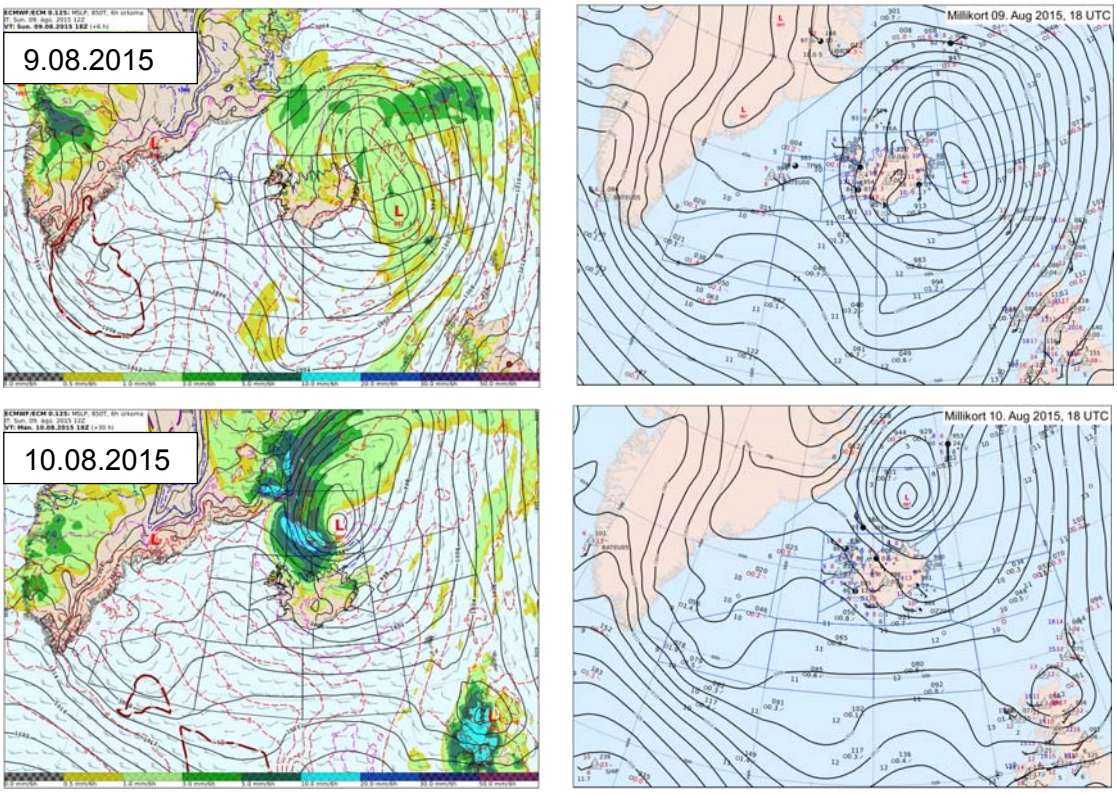


Figure 16: Weather forecast from 12:00 on August 7th 2015, for 18:00 on August 7th – 12th

According to the weather forecast prior to the departure on August 9th for the following days, low pressure areas were forecasted on the flight route between Iceland and Greenland in all periods between August 10th and August 16, except on August 10th. The best “window” for visual flight between Iceland and Greenland therefore existed on August 10th. Prior to departure on August 9th, the weather forecast on the route between Akureyri Airport and Keflavik Airport did not support VFR flight until August 11th. Figure 17 shows the weather forecast from 12:00 on August 9th valid at 18:00 on August 9th – 14th on the left side and the actual SYNOP weather observations on the right side.

The ITSB belives that this may have placed pressure on the pilots to fly to Keflavik Airport on August 9th, regardless of the poor weather conditions for VFR flight during that flight leg.



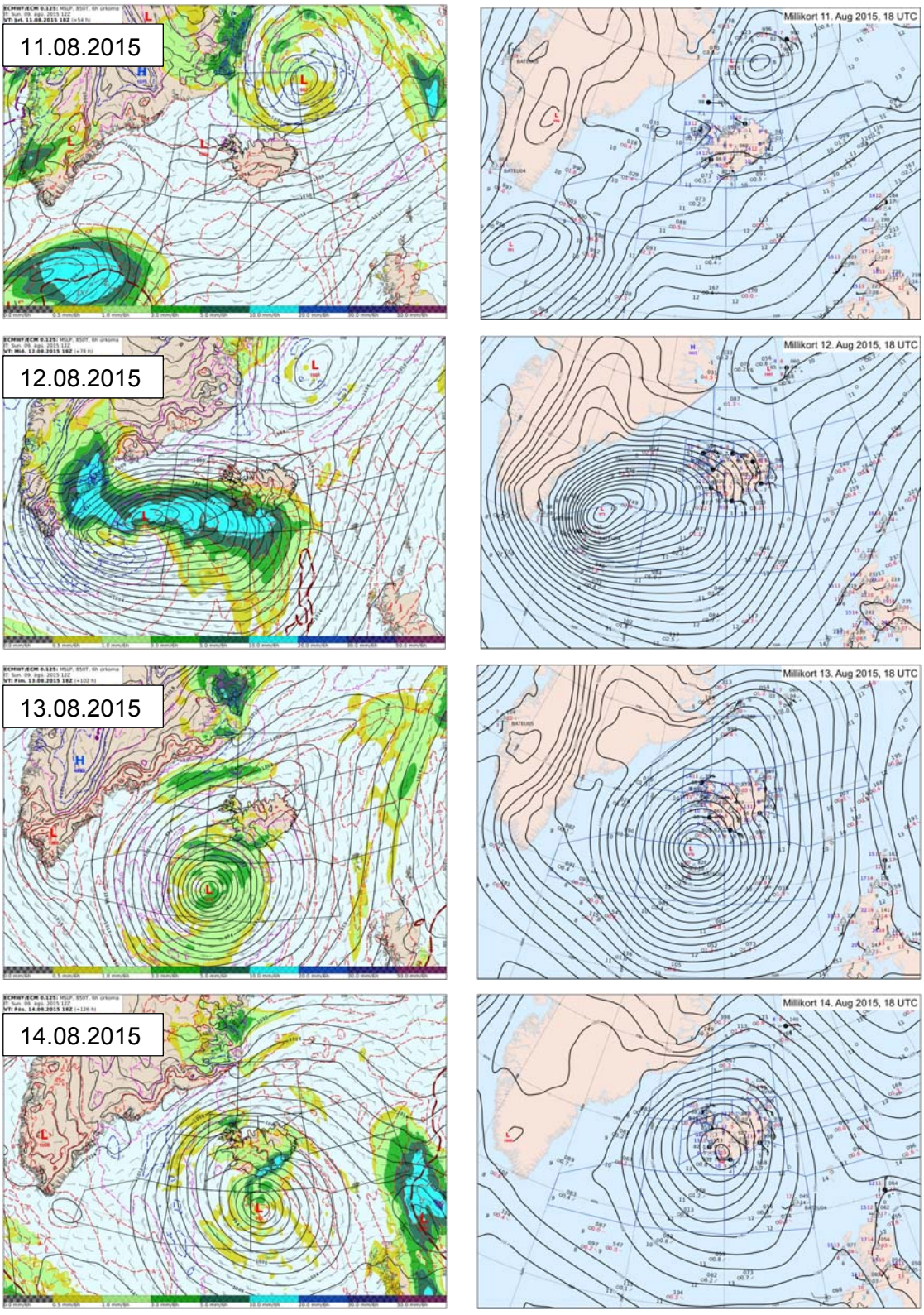


Figure 17: Weather in between and over Iceland and Greenland (forecast from 12:00 on August 9th 2015 valid at 18:00 on August 9th – 14th on left side and SYNOP observations on right side)

2.1.2. Fueling

The last fueling of the airplane before departure of the accident flight was accomplished by the PNF, while the PF was inside the hangar finishing the paperwork for the flight.

The airplane was equipped with three main tanks under the cabin floor, which together could hold 360 liters of fuel. The airplane was also equipped with fuel tanks in the wing tips, which together could hold 164 liters of fuel. Several days prior to the accident a ferry fuel tank was also installed in the cabin, behind the pilot seats, which could hold 284 liters of fuel. In total the fuel capability of the airplane was therefore 808 liters.

As the airplane was completely destroyed during the accident, it was not possible to measure the fuel on board at the accident site. It was therefore necessary to perform analysis to determine the fuel on board.Two different methods were used to determine the fuel quantity on board the airplane. According to the first method, there were about 641 liters of Avgas 100LL fuel in the airplane's fuel tanks prior to the accident flight's takeoff. According to the second method, there were about 742 liters of Avgas 100LL fuel in the airplane's fuel tanks prior to takeoff for the accident flight. Based on these methods the ITSB concludes that the airplane's fuel load was between 79.3% and 91.8% of total fuel capacity, including the ferry fuel tank in the cabin. Assuming that the main fuel tanks and the wing tip tanks were full, then based on the two methods used to calculated the fuel, the fuel quantity in the cabin ferry fuel tank was:

- Method #1 – About 118 liters of fuel or 41% full of fuel
- Method #2 – About 219 liters of fuel or 77% full of fuel

According to the PF, he believed that there were only about 20 liters of fuel in the ferry fuel tank. This suggests that the PNF did not update the PF with the correct fuel information[21] before the flight.

Details on the fuel analysis can been seen in Appendix A.

[21] The fuel quantity indicators on the instrument panel only provided details about the fuel in the three main tanks under the cabin floor (fwd, center and the aft fuel tanks), but no information about the fuel in the wing tip tanks nor the ferry flight fuel tank.

2.1.3. Weight and balance

In 2007, when the airplane was upgraded and modernized with several STC's, the total gross weight of the airplane was increased from 5090 lbs up to 5370 lbs. Due to the multiple modifications, the empty weight of the airplane changed to 4270 lbs. This left 1100 lbs for useful load, which included pilots, passengers, cargo and fuel.

The upgraded weights can be seen in Figure 18, which is a Weight and Balance Report issued for the airplane on November 17th 2007.


[redacted]

11/17/2007

Weight and Balance Report
C-FPWH DHC-2 MK-1 SN 1446

Amphibian Empty Weight	Weight	Arm	Moment
	4346	0.0	0.0
Items Installed 6100A Floats & Assoc. Equipment			
Ballast Removed	-76.0	-228.0	+1732.8
Totals	4270.0	4.05	+ 1732.8

Sea Plane

Gross Weight:	5370.00
Empty Weight	4270.0
E.W.C.G.	4.05
Useful Load	1,100.00

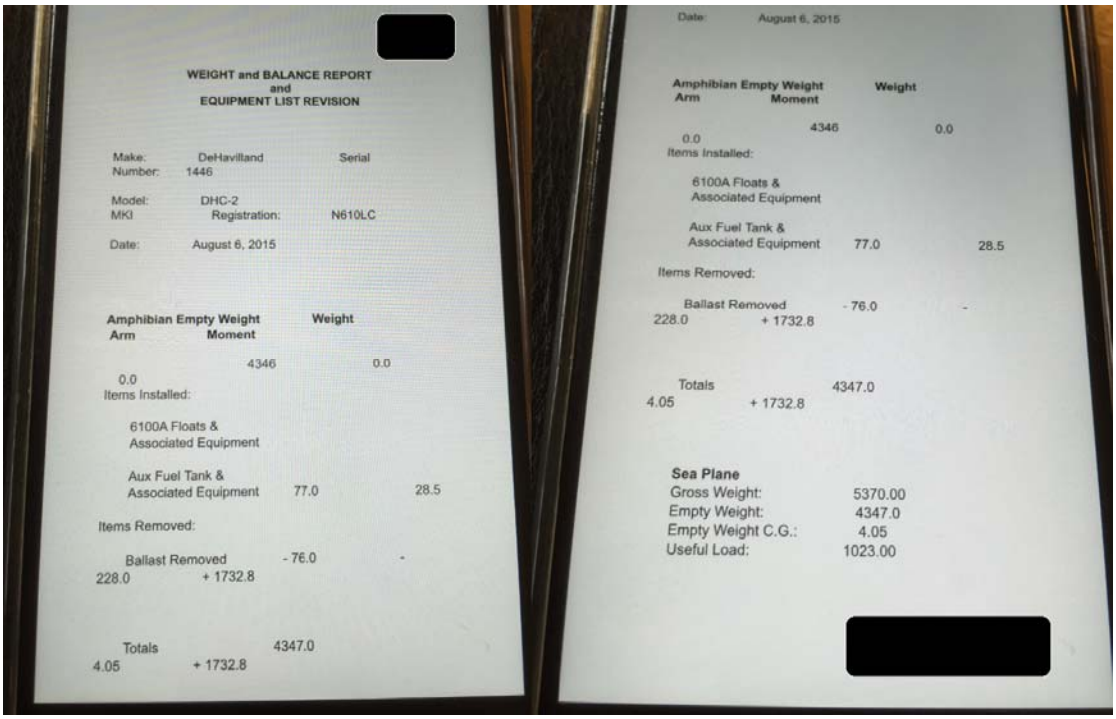
[redacted]

Figure 18: W&B Report issued in 2007

On May 2nd 2008, prior to its ferry flight to Iceland, the airplane received a FAA major alteration which required removal of all passengers' seats, the co-pilot's seat and the installation of a ferry fuel tank. This alteration changed the empty weight of the airplane to 4237 lbs, increasing the useful load to 1133 lbs. The aircraft also received on May 2nd 2008 a FAA special flight permit on a special airworthiness certificate, valid until June 1st 2008, for operation in excess of the maximum certified takeoff weight during a ferry flight to Akureyri in Iceland. For this ferry flight to Iceland a 10% increase in the gross weight was temporarily permitted, bringing the gross weight from 5370 lbs up to 5907 lbs. This special flight permit increased the allowable useful load by 537 lbs, bringing it up to 1670 lbs.

The investigation revealed that the initial intention for the ferry flight back to the USA from Akureyri in Iceland was to re-install this major alteration and the special airworthiness certificate. The investigation also revealed that when it became apparent that it would take several weeks to procure the necessary overflight permits and special airworthiness certificate for temporarily permitting the gross weight exceeding the maximum gross weight of the airplane, this effort was discontinued.

The flight crew then installed the ferry fuel tank into the airplane as cargo few days before the accident and the flight was planned in accordance to a new Weight and Balance Report that had been issued on August 6th 2015. In this new Weight and Balance Report the maximum gross weight allowed for the airplane remained at 5370 lbs for the ferry flight back to the USA (see Figure 19). According to the airplane's Weight and Balance Report the airplane's useful load was 1023 lbs.



WEIGHT and BALANCE REPORT
and
EQUIPMENT LIST REVISION

Make: DeHavilland Serial Number: 1446
Model: DHC-2 MKI Registration: N610LC
Date: August 6, 2015

Amphibian Empty Weight Arm	Moment	Weight
	4346	0.0
0.0		
Items Installed:		
6100A Floats & Associated Equipment		
Aux Fuel Tank & Associated Equipment	77.0	28.5
Items Removed:		
Ballast Removed	- 76.0	-
228.0	+ 1732.8	
Totals	4347.0	
4.05	+ 1732.8	

Date: August 6, 2015

Amphibian Empty Weight Arm	Moment	Weight
	4346	0.0
0.0		
Items Installed:		
6100A Floats & Associated Equipment		
Aux Fuel Tank & Associated Equipment	77.0	28.5
Items Removed:		
Ballast Removed	- 76.0	-
228.0	+ 1732.8	
Totals	4347.0	
4.05	+ 1732.8	

Sea Plane

Gross Weight:	5370.00
Empty Weight:	4347.0
Empty Weight C.G.:	4.05
Useful Load:	1023.00

Figure 19: W&B Report issued on August 6th 2015

The PF had prepared weight and balance calculations for the airplane prior to the accident flight. The weight and balance sheet was brought on board the airplane, in an aluminum folder, without a copy being left behind at the departure point as that is not a requirement. The ITSB could not review and verify the pilot's W&B calculations, as the aluminum folder containing them was destroyed in the accident fire.

The ITSB therefore performed weight and balance calculations for the airplane on data collected, both for the takeoff from Akureyri Airport and also for its estimated status at the time of the accident in the valley of Barkárdalur.

As mentioned in the chapter 2.1.2. Fueling, the investigation revealed that the ferry fuel tank contained 118 – 219 liters of fuel before takeoff. The investigation also revealed that a fuel line was connected to the ferry fuel tank on the tank side (see

Figure 20). The ITSB could however not verify whether this fuel line was connected to the airplane's fuel system due to the severe damage from the fire. The ITSB investigation also revealed that prior to the accident flight, the co-pilot's seat remained installed and the seats that had been removed to fit the ferry fuel tank in the 2nd seat row were stored in the aft most section of the cabin, behind the ferry fuel tank and on top of the third seat row. See Figure 20, taken during the preparation of the flight on August 8th, 2015.

Figure 20: Picture showing the installed ferry fuel tank and the 2nd seat row in the aft part of the cabin

The ITSB calculated the weight of the airplane (including crew and cargo), before the 298.91 liters of AVGAS 100LL fueling of the airplane by the PNF on August 9th, to have been between 5410 lbs and 5569 lbs. This was 40 lbs – 199 lbs above the maximum gross weight limit[22].

The ITSB fuel calculations also revealed the actual weight of the airplane at takeoff from BIAR (after the PNF fueling) to be between 5882 lbs and 6041 lbs, based on the lower or upper limit of the calculated fuel on board. This was between 512 lbs and 671

[22] Uncertainty due to lower and upper limit of estimated fuel on board (method #1 & #2)

lbs over the airplane's maximum gross weight. The airplane was therefore found to be well outside the maximum gross weight limit during takeoff from BIAR.

At the time of the accident, the airplane had been flown for about 45 minutes. The calculations revealed that at the time of the accident the weight of the airplane was between 5760 lbs. and 5919 lbs. This was between 390 lbs and 549 lbs over the airplane's maximum gross weight. The airplane was therefore found to be outside its allowable weight limits when the accident occurred.

The weight of the airplane, in relation to its weight and balance envelope can be seen in Figure 21. Details on the weight & balance calculations can be seen in Appendix B.

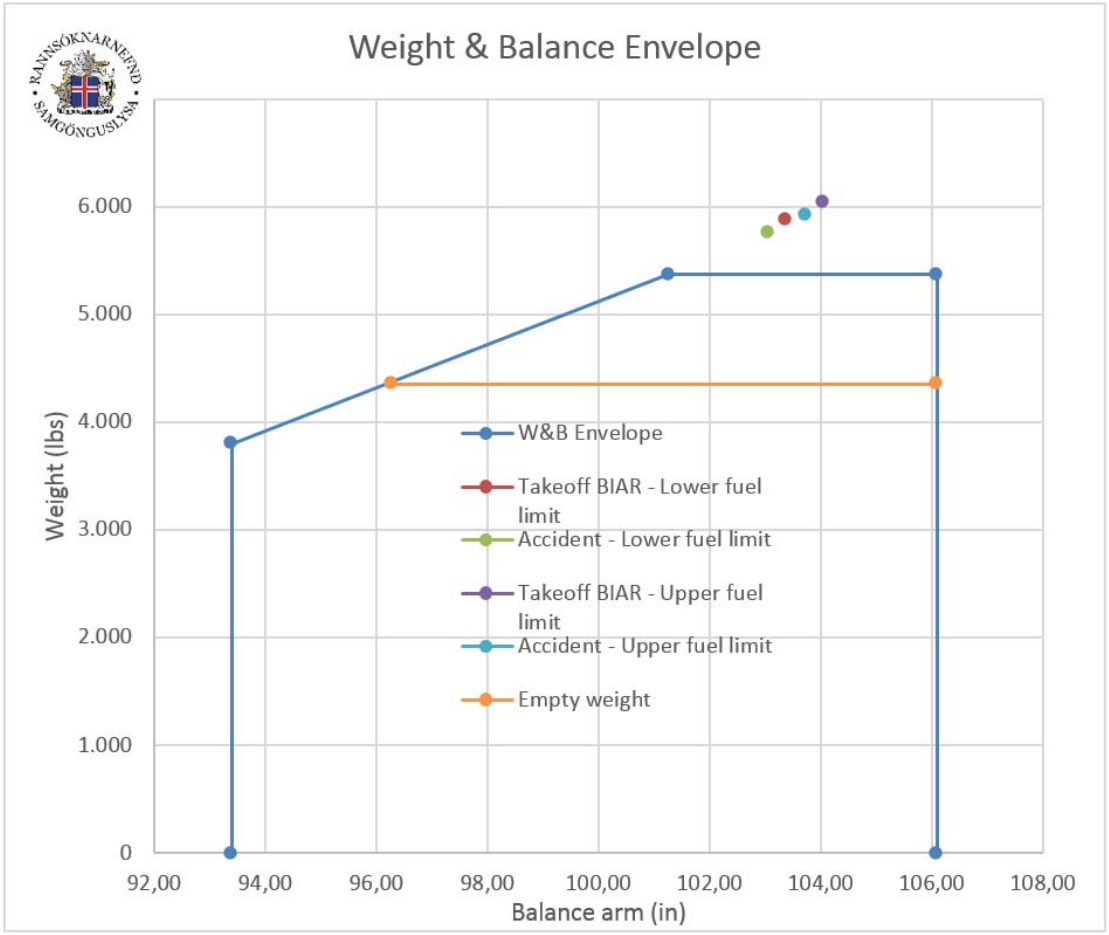


Figure 21: Calculated Weight & Balance for airplane N610LC at the time of the accident

2.2. Aircraft

The engine and the propeller were sent for a teardown inspection (see Figure 22) at a facility in the United States of America, specializing in overhauling and rebuilding Pratt & Whitney R985 series engines. Present for the teardown inspection, in addition to the facility's specialists performing the inspection, was the IIC[23] from the ITSB, the ACCREP[24] from the NTSB, two representatives from the FAA and a propeller specialist from the propeller manufacturer.

The overall condition of the engine at the time of flight could not be determined, due to the absence of the engine's rear accessory case, blower assembly and critical accessories such as the magnetos and carburetor. These parts in the aft section of the engine were manufactured out of magnesium and had burned away during the post accident fire. The teardown inspection of the engine parts that had survived the fire did however conclude that no internal mode of failures had occurred to those parts prior to the accident and no possible cause of the lack of engine performance was found.

Figure 22: The engine and propeller from airplane N610LC shipped for teardown inspection

[23] Investigator-In-Charge
[24] Accredited Representatives, selected by the nations involved in the investigation per ICAO Annex 13

The teardown inspection of the propeller indicated a rotation of the propeller at high power in the normal blade angle range of operation at the time of impact. There were no discrepancies noted that would preclude normal operation. All the damage to the propeller blades was consistent with high impact forces into rocky terrain.

2.2.1. Carburetor icing

The ITSB analyzed the weather in the valley of Barkárdalur at the time of the accident with regards to possible carburetor icing. According to the analysis, as shown in Figure 23, it is highly likely that carburetor icing occurred before the accident.

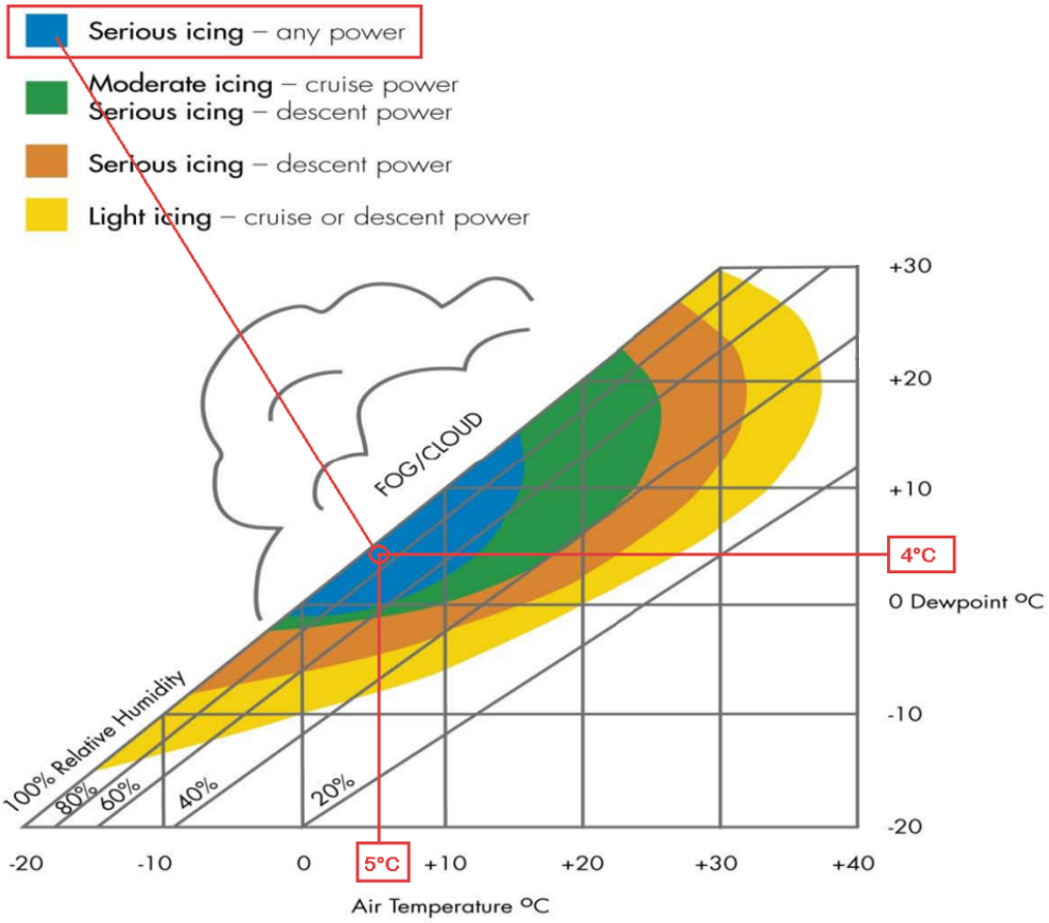


Figure 23: Carburetor icing conditions at the accident site at the time of the accident[25]

[25] UK CAA Safety Sense Leaflet 14, Piston Engine Icing, see http://publicapps.caa.co.uk/docs/33/20130121SSL14.pdf

2.2.2. Aircraft maintenance

On March 26th 2015 the last annual/100 hour inspection of the aircraft airframe, engine, propeller and appliances was performed. The aircraft was found to be un-airworthy due to a damaged propeller. The propeller was removed and sent for repair/overhaul. On May 27th 2015, a transponder test was completed for the airplane. The propeller that had been removed due to damage in March 2015 was then returned after overhaul and re-installed on June 1st 2015, making the airplane airworthy again. The last maintenance on the airplane was an engine differential compression check, performed on August 6th 2015.

The investigation did not reveal any open maintenance issues with the airplane at the time of the accident.

2.2.3. Aircraft performance

The ITSB performed detailed performance calculations for the airplane and found its performance to be considerably degraded due to its overweight condition. Details on the performance calculations can be seen in Appendix C.

According to the ITSB performance calculations, it would only have been theoretically possible to turn the airplane around in the valley of Barkárdalur in the area where the accident occurred under and in between the following conditions:

Lower weight limit at Barkárdalur of 5760 lbs:

- 30° bank angle at 60-65 mph, flaps TAKEOFF
- 40° bank angle at 65-75 mph, flaps TAKEOFF
- 50° bank angle at 90-95 mph, flaps UP

Upper weight limit at Barkárdalur of 5919 lbs:

- 30° bank angle at 60-65 mph, flaps TAKEOFF
- 40° bank angle at 70-75 mph, flaps TAKEOFF
- 50° bank angle at 95 mph, flaps UP

All other bank angles (in increments of +/- 10°) and airspeed values (in increments of +/-5 mph) would have resulted in too large turn diameter for the area in the valley of Barkárdalur, the airplane stalling, the airplane exceeding its structural speed limit or

the power required exceeding the power available (insufficient power) from the propeller/engine combination, resulting in the airplane losing altitude.

As can be seen in Figure 24, performing a 30° turn at an airspeed just below 60 mph (the airspeed at which the turn was attempted) would have been fine with regards to the airplane's type certificate MTOW of 5090 lbs or its STC SA610GL MTOW of 5370 lbs. However, when taking into consideration the upper and lower limits for the airplane's actual weight, a 30° turn at an airspeed just below 60 mph resulted in the power available just barely exceeding the power required.

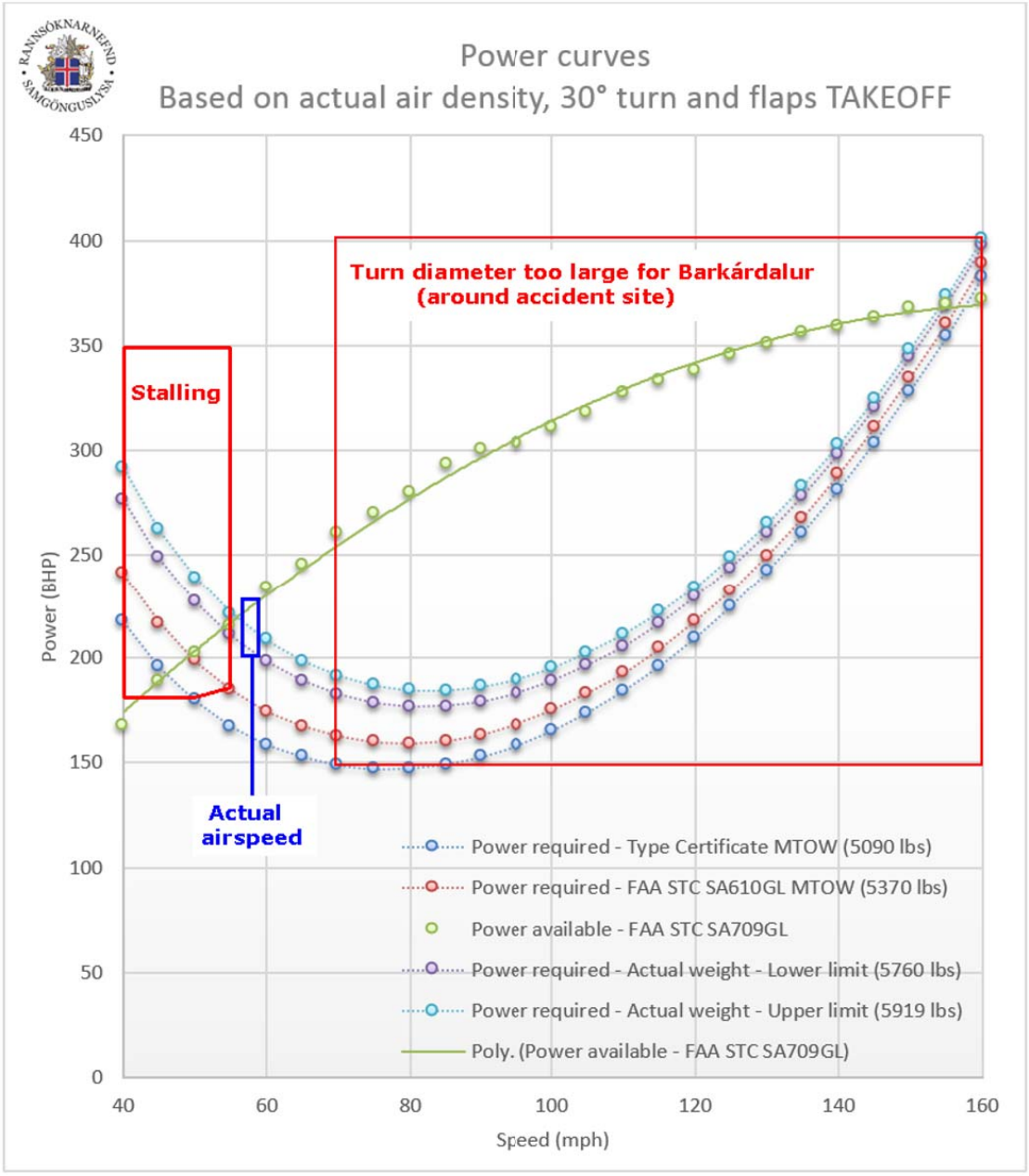


Figure 24: Power curves for 30° turn – Power available barely meets power required

When the bank angle was then increased to 40°, the performance became insufficient. As can be seen in Figure 25, a 40° turn at an airspeed just below 60 mph resulted in the power required exceeding the power available, while at the same time the airplane was about to stall due to its overweight condition. The PF states that the airplane did not reach this stall condition during the turn. The ITSB believes he reason why the airplane lost altitude when the turn was executed can be explaned by the fact that the power required exceeded the power available.

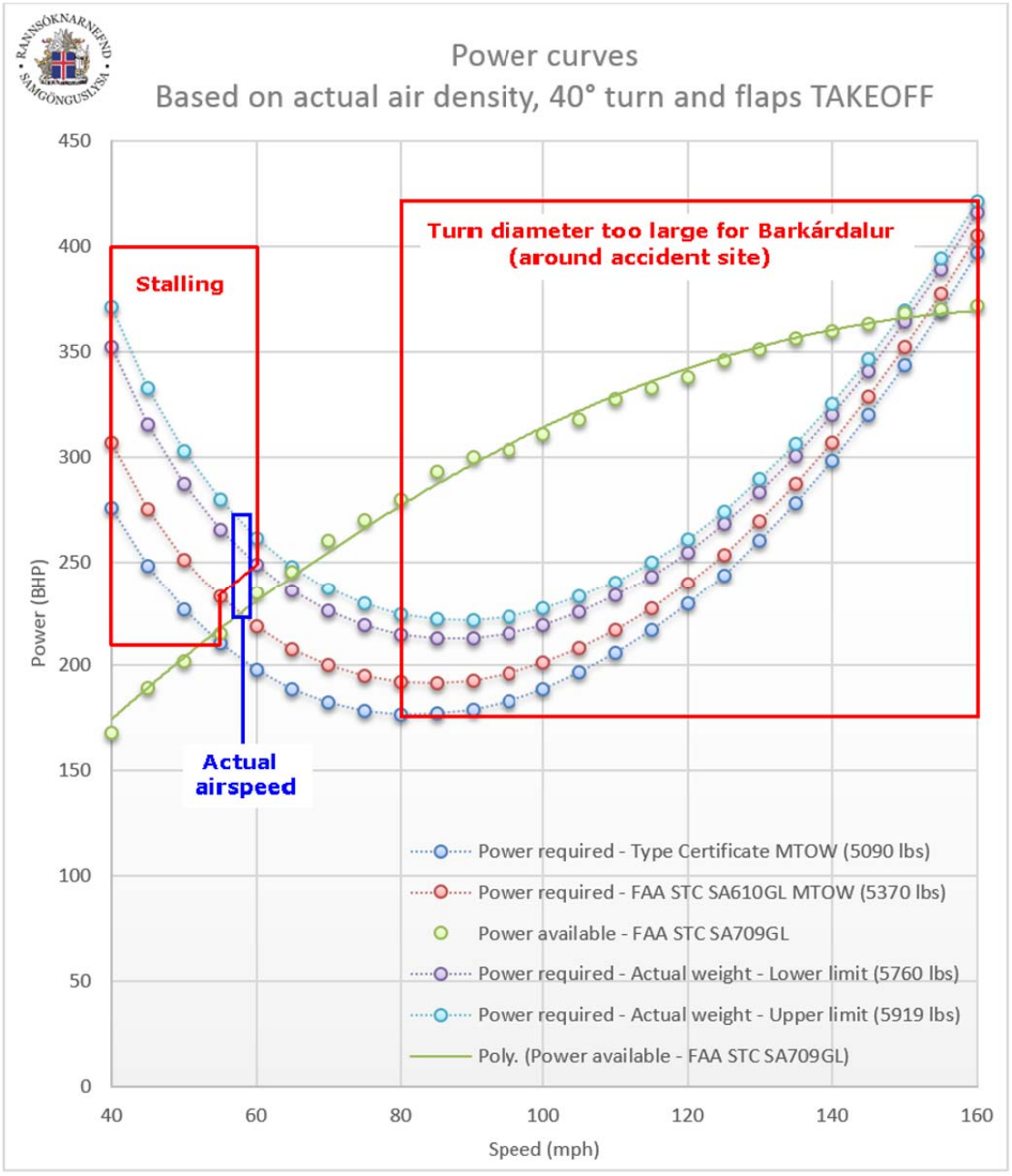


Figure 25: Power curves for 40° turn – Airspeed too low, stalling and power required excceds power available

2.3. Human Factors

The investigation revealed multiple human factor issues. These were analysed using HFACS[26] where preconditions for unsafe acts and unsafe acts were identified.

2.3.1. Preconditions for unsafe acts

The following preconditions for unsafe acts were identified:

Environmental Factors - Physical Environment

- Weather
- Altitude
- Terrain

Conditions of Operators – Adverse Mental States

- Loss of situational awareness
- Overconfidence
- Continuation bias

Personnel Factors – Crew Resource Management (CRM)

- Inadequate planning
- Failed to conduct adequate briefing

2.3.1.1. Weather

Two days prior to the departure, on August 7th, it became apparent that the weather for the flight between Keflavik Airport and Greenland, which was perhaps the most critical leg of the ferry flight between Akureyri in Iceland and Minneapolis/St Paul in the United States, was only favourable for VFR flight on August 10th.

The first leg of the flight was from Akureyri Airport in northern part of Iceland and to Keflavik Airport in the southwestern part of Iceland.

On August 7th the weather forecast on the route between Akureyri Airport and Keflavik Airport did not look good for VFR flight until August 10th. On August 9th, before takeoff

[26] Human Factors Analysis and Classification System

for the accident flight, the weather forecast on the route between Akureyri Airport and Keflavik Airport had detoriated further and did not justify VFR flight until August 11th.

This may have motivated the pilots to finish the first leg of the flight before August 10th, regardless of the poor weather conditions for the first leg of the flight.

2.3.1.2. Altitude

The investigation revealed that during the flight from Akureyri Airport and until the accident in the valley of Barkárdalur, airplane NC610LC was flown at low altitudes. An exception to this is when the PF increased the altitude in the valley of Hörgárdalur before entering the valley of Barkárdalur. This increase in altitude was however not sufficient due to the rise of the valley floor at the head of the valley of Barkárdalur.

The ITSB determined the reason for the low altitude to be that the pilots wanted to fly below the low cloud patches.

2.3.1.3. Terrain

Tröllaskagi is a mountainous peninsula located between Eyjafjörður and Skagafjörður in northern Iceland. It includes the valleys of Öxnadalur, Hörgárdalur and Barkárdalur amongst many other. The valley of Barkárdalur is a long and narrow valley with 3000 – 4500 feet high mountain ranges extending on either side. The mountain passage at the head of the valley of Barkárdalur is at an elevation of approximately 3900 ft. In the aft third of the valley the valley floor rises rapidly. Along the track of the last 2 miles before the accident site, the valley floor rises from 1320 ft up to 2260 ft, or by 940 ft.

The ITSB determined that the pilots failed to take note of the geometry of the valley of Barkárdalur, namely its narrow width and fast rising floor towards its head. This fact along with limited performance of the airplane would have indicated that clearing the passage at the head of the valley of Barkárdalur or turning around would have been almost impossible for this particular airplane in its overweight condition.

Why the pilots decided to fly into Barkárdalur could partly be explained by the fact that the PF had flown through the valley of Barkárdalur and the passage at its head on previous occasions. Those were however accomplished on both a smaller and lighter airplane of much greater performance (e.g. Piper Super Cub).

2.3.1.4. Loss of situational awareness

In the valley of Barkárdalur, shortly before the partially executed turn, the pilots became aware how close they were flying to the valley floor which did not add up with regards to their experienced altitude loss. In the aft third of the valley of Barkárdalur the valley floor rises rapidly towards its head. Over the last 2 miles before the accident site, the valley floor rises from 1320 ft up to 2260 ft, or by 940 ft.

The ITSB determined that the pilots were not activily managing the flight or planning ahead of the aircraft, taking into account various necessary factors including performance, weather and terrain. The ITSB believes that carburetor icing problem may have diverted the PF attention from the rising terrain.

2.3.1.5. Overconfidence

Both pilots had experience flying DHC-2 Beaver. They should therefore have been aware of its capability and limitations. On August 9th the flight differered from most of those flights with respect that the airplane had been loaded over its maximum weight limit. Based on their experiences they were in the position to be aware of the negative effect the overweight condition would have on the performance capability of the airplane for the flight.

The pilots initial intention was to re-install the major alteration and the special airworthiness certificate from 2008 (when the airplane was ferry flown to Iceland). This would have temporarily permitted the gross weight to exceed the maximum gross weight of the airplane by 10%. When it became apparent that it would take several weeks to procure the necessary permits, to ferry fly the airplane with its weight exceeding the maximum gross weight of the airplane, this work was discontinued.

The ITSB believes that the special ferry flight permit the pilots received for the flight in 2008 may have provided the pilots with a false assumption that such loading of the airplane on the way back in 2015 was also acceptable. For comparison the special flight permit in 2008 allowed a temporary maximum weight of 5907 lbs, which is very close to the 5919 lbs actual upper weight limit of the accident flight in 2015.

2.3.1.6. Continuation bias

Continuation bias is the unconscious cognitive bias to continue with the original plan in spite of changing conditions.

The plan was to look for an opening in the cloud cover at the head of the valley of Öxnadalur.

According to the PF, flying around the peninsula of Tröllaskagi was to be their next course of action, should they not be able to find an opening in the cloud cover. This was not preferred as it would have added an hour to their flight.

When it became apparent that there was no opening in the cloud cover at the head of the valley of Öxnadalur, they continued to try to find an opening to fly over the peninsula of Tröllaskagi, rather to revert to their backup plan of flying around it.

2.3.1.7. Inadequate planning

Inaquate planning is when a plan is not appropriate or incomplete.

Flight planning includes ensuring that the airplane has sufficient fuel available for the flight (including fuel reserves), the airplane being within its weight and balance limitations, the weather forecast at take off, planned flight route and landing being acceptable for the intended flight rules and that the airplane performance being sufficient for the flight.

The investigation showed the airplane having abundant fuel for the intended flight.

The investigation showed the W&B calculations performed by the PF prior to the flight to have been incorrect, as the airplane's weight was well over the maximum gross weight of the airplane.

The flight was planned in weather conditions that did not support VFR flight across the peninsula of Tröllaskagi.

The ITSB believes the decision to fly into the valley of Barkárdalur was taken spontaneously, when flying out of the valley of Hörgárdalur and the pilots noticed what looked like a break in the cloud cover over the head of the valley of Barkárdalur.

2.3.1.8. Failed to conduct adequate briefing

The moment the PNF took part in the preparation of the accident flight, this stopped being a flight with a single pilot crew. Instead the pilots, reverted to their familiar work career roles of PF and PNF.

For multi crew operations an effective CRM approach becomes important for ensuring a safe flight. Task planning and crew briefing are key CRM tasks.

A failure of CRM occurred when the PNF did not inform the PF of the amount of fuel he added to the airplane prior to the flight.

The ITSB estimated the fuel in the cabin ferry fuel tank to be between 118 and 219 liters. According to the PF, he believed that there were only about 20 liters of fuel in the ferry fuel tank and he did not check the content of the this fuel tank before flight.

This added fuel considerably degraded the airplane's performance.

2.3.2. Unsafe acts

The following unsafe acts were identified:

- Perceptual errors due to visual illusion
- Misjudged height above terrain due to failure to prioritise attention
- Poor decision
- Attempted VFR in marginal weather conditions across Tröllaskagi
- Exceedance of limits of aircraft

2.3.2.1. Perceptual errors due to visual illusion

When the pilots reached the end of the ridge that separates the valley of Öxnadalur and the valley of Hörgárdalur, the PF mentioned that they had noticed what looked like a break in the cloud cover over the head of the valley of Barkárdalur out the left window (see Figure 4).

Later, about the same time the pilots experienced the airplane losing altitude in the valley of Barkárdalur, the pilots realized that the passage was blocked with clouds.

The mountain passage at the head of the valley of Barkárdalur is located at about 3900 ft. From photos taken by the PF at the accident site, the ITSB estimated the cloud ceiling around the accident site to be around 2700 feet.

The ITSB believes that the light reflection from the snow on the glacier on top of the mountain passage may have been misinterpreted by the pilots as a break on top of the mountain range.

2.3.2.2. Misjudged height above terrain due to failure to prioritise attention

In the aft third of the valley the valley floor rises rapidly. Along the flight track, the last 2 miles before the accident site, the valley floor rises rapidly from 1320 ft up to 2260 ft, or by 940 ft. It took the airplane about 1.6 minutes to cover this distance at an airspeed of 75 mph.

During the 1.6 minutes before the accident, the airplane could have climbed between 941 ft and 1024 ft with a healthy running engine (taking the 2.6 ft/s downdraft in the valley of Barkárdalur into account). At the same time the valley floor rose by 940 ft, effectively nullifying any radio altitude change of the airplane during the climb.

The pilots were surprised that their height above terrain did not increase. The ITSB believes that the pilots did not adequetly take into account the rapid rise of the valley floor.

2.3.2.3. Poor decision

The ITSB belives that the decision to fly into the valley of Barkárdalur, with the airplane as heavy at it was, with reduced performance and questionable VFR conditions to have been poor. This decision was not based on actual flight conditions but was a spontaneous decision susceptible to various cognitive bias such as continuas bias.

2.3.2.4. Attempted VFR in marginal weather conditions across Tröllaskagi

According to the PF, the plan was to fly into the valley of Öxnadalur and see if there was a break in the cloud cover at the valley head, where they could fly over the heath/ridge of Öxnadalsheiði and then towards Keflavik Airport.

The ITSB collected the weather data that was available on the IMO website, before the flight. As can be seen in Figure 15, a low cloud cover was forecasted over Iceland at 14:00[27] on the day of the accident. According to the IMO forecast for flight conditions over Iceland, valid 12:00 to 17:00 at the day of the accident, the cloud ceiling was BKN/OVC between 800 and 2500 ft in northern Iceland and poor visibility in rain or drizzle. Furthermore the IMO forecast stated for visual flight conditions between parts of Iceland, that VMC did not exist in the northern part of Iceland. According to Figure 17 the weather forecast, prior to the departure at the day of the accident (August 9th), VFR conditions would not exist over the highlands on the route between Akureyri Airport and Keflavik Airport, until August 11th.

The Icelandic Meteorology Office (IMO) compiled a weather report for the ITSB in relation to the investigation. In its weather report, the IMO concluded that in the valley of Barkárdalur and the surrounding area there was a slow breeze and minimal amount of vertical movement of the air around the mountains. The IMO estimated the cloud ceiling in and around the valley of Barkárdalur to be very low and visibility limited due to fog or precipitation. The IMO also concluded that the weather conditions would not support VFR flight.

According to this, the ITSB believes the weather conditions did not support VFR flight from Akureyri to Keflavik, across the peninsula of Tröllaskagi.

2.3.2.5. Exceedance of limits of aircraft

The PF had prepared weight and balance chart for the airplane prior to the accident flight. The weight and balance chart was destroyed in the accident fire.

The investigation revealed that a new Weight and Balance Report had been issued on August 6th 2015 with 5370 lbs maximum gross weight limit.

The ITSB performed weight and balance calculations for the airplane from data it collected. These calculations revealed the actual weight of the airplane at takeoff from BIAR to be between 5882 lbs and 6041 lbs, based on the lower or upper limit of the calculated fuel on board.

[27] The takeoff from Akureyri Airport was at 14:01

This was between 512 lbs and 671 lbs over the airplane's maximum gross weight. See Appendix B for details.

The airplane was therefore found to be outside its allowable weight limits during takeoff from BIAR.

2.4. Survivability

The accident is estimated to have occurred in the valley of Barkárdalur around 14:45. The airplane was expected to land in Keflavik at 16:20.

2.4.1. Surviving in the valley of Barkárdalur

Both pilots were fastened in their seatbelts and alive inside the airplane immediately after the aircraft had crashed. The fuselage was resting on the ground on its left side with the right forward door pointing up to the sky and the left forward door blocked off by the rocky ground. The right door was stuck. The status of the larger aft doors is unknown, but based on the finding on site the ITSB believes that the left aft door was blocked off by the rocky ground and the right aft door blocked off by the right wing being bent over it after the crash. The forward cockpit window was intact, preventing any exit through it.

Both pilots released their seat belts and attempted to exit the airplane. There was a fire burning as well as smoke inside the airplane. The PNF decided to try to exit the airplane from the aft cabin area, which was partly blocked off by the ferry fuel tank. The PF attempted to exit through a cracked window in the right forward door.

The PF managed to exit the airplane through the right forward door window. The PNF did not manage to evacuate the airplane. The ITSB believes that the installation position of the ferry fuel tank between the aft doors in combination with the right wing being folded over the outer side of the aft right door, prevented the PNF from exiting the airplane from the aft cabin area.

Within 2 - 3 minutes from the crash, the airplane fuselage was engulfed in fire. This resulted in explosions when the PF had pushed himself backwards 10 - 15 meters away from the airplane wreckage. The ITSB determined the explosions to be from the fuel tanks.

The on-site investigation suggests that the PNF was located in the aft cabin area when the fuel tanks exploded and the airplane became engulfed in fire. The autopsy of the PNF suggests that he survived the crash but succumbed to the fire and smoke. According to the autopsy, the cause of death was traced to traumatic injuries to the inner organs or because of hyper-thermal trauma.

According to the PF, he did not have signal on his mobile phone. He thought about climbing the hills of the valley to try to receive a signal for his mobile phone, but due to his injuries he was unable to do that.

The fire self-extinguished within 25 minutes, with the exception of a fire in the aft section of the engine block, which was made out of magnesium.

About an hour after the accident, the PF had become severely cold, so he moved back to the airplane. The PF collected material that was capable of burning and put it onto the magnesium fire, which was burning in the engine block. The PF then used the fire to warm up.

According to the PF he noticed on two occasions, airplanes flying nearby, before a Coast Guard rescue helicopter located him on its flyby in the valley of Barkárdalur. When this occurred, the fire in the engine block had long extinguished. Figure 26 shows the wreckage of airplane N610LC on the day after the accident.

Figure 26: The wreckage of N610LC after the accident

2.4.2. Emergency Locator Transmitter

The investigation revealed that during the aircraft's last annual/100 hour inspection, in March 2015, the ELT[28] was inspected per FAA requirement 91.207(d), which states:

> *Each emergency locator transmitter required by paragraph (a) of this section must be inspected within 12 calendar months after the last inspection for--*
> *(1) Proper installation;*
> *(2) Battery corrosion;*
> *(3) Operation of the controls and crash sensor; and*
> *(4) The presence of a sufficient signal radiated from its antenna.*

The ELT passed the inspection and it was noted that its battery needed to be replaced no later than October 2017. According to the PF and an A&P[29] mechanic that had worked on the airplane, the ELT was located on the floor between the two pilot seats. No emergency signal was received from the airplane after the accident, nor was the ELT found at the accident site. Due to the severe fire and explosions in the cabin area as a result of the accident, the ITSB assumes the ELT was destroyed in the fire, before any signal could be received from it. The ELT conformed to both FAA and Icelandic regulations on ELT requirements.

2.4.3. Search and rescue

At 17:06 at the day of the accident, the Emergency Services were notified of a missing airplane enroute to Keflavik Airport from Akureyri Airport. The Rescue Coordination Centre in Skógarhlíð, Reykjavík, was subsequently activated. At this time, very limited information was known about the last whereabouts of the airplane and no emergency signal had been detected from the aircraft's ELT. The national search and rescue plan was therefore activated for the northern, western and southern parts of Iceland.

The last communication from airplane N610LC had been at 14:26 when the PF advised the ATCO at Akureyri Airport that they would go over Hörgárdalsheiði instead of Öxnadalsheiði.

[28] Emergency Locator Transmitter
[29] Airframe & Powerplant

At 18:26 the last known signal of the PF's mobile phone had been traced to a phone mast located at Vaðlaheiði. The search effort was therefore concentrated in the northern parts of Iceland, primarily in and around Tröllaskagi.

Around 20:00, the crew of Coast Guard heilicopter TF-LIF decided to concentrate their search effort around the area of the valley of Barkárdalur.

At 20:30 the crew of a coastguard's helicopter located the wreckage of airplane N610LC in the valley of Barkárdalur. This was about 5 hours and 45 minutes after the accident occurred.

2.4.4. Notification to the ITSB

The management of the Rescue Coordination Centre in Iceland for search and rescue of sea and air vessels falls within the responsibilities of the Icelandic Coast Guard, according to regulations 71/2011 and 1084/2011. According to article 15 of regulation 71/2011 the Icelandic Coast Guard, is responsible for notifying to the ITSB of an air accident without a delay. This responsibility does not include notification of a missing airplane.

No notification of the missing airplane was provided to the ITSB.

3. Conclusion

Findings:

- The pilots took on the roles of PF and PNF.

- The PF planned the flight as VFR across an area (Tröllaskagi), in weather conditions which did not support VFR flight.

- The PF performed weight & balance calculations for the airplane, without a proper knowledge of the actual amount of fuel on board the airplane.

- The weight and balance charts were brought on the flight and no copy was left behind at the point of departure.

- Before the fueling of the airplane on the day of the accident, the planned takeoff weight of the airplane was already above its maximum takeoff weight.

- The PNF fueled the airplane to an extent that brought the airplane weight far above the maximum allowable takeoff weight of the airplane. This considerably affected the airplane's performance. The PF was unaware of the amount of fuel in the ferry fuel tank and believed it to be close to empty (about 20 liters), while instead it most likely was between 41% and 77% full of fuel (between 118 and 219 liters).

- Barkárdalur, which is a narrow valley, was known to the PF and he had flown through it previously on another airplane type with much higher performance capability.

- In the valley of Barkárdalur the pilots were not activily managing the flight or planning ahead and did therefore not observe when the valley floor rapidly rose by 940 ft during the last 1.6 minutes before the accident. This, along with a minor downdraft, effectively nullified any change of their height above terrain during climb.

- The airplane most likely incurred serious carburetor icing in Barkárdalur, causing the airplane to lose power.

- The combination of the carburetor icing and the rapid rise of the valley floor caused the airplane to be at the valley floor much quicker than the pilots expected.

- The PF overestimated the performance capability of the airplane, as he was unaware of the total fuel on the airplane

- The PF tried to turn around in Barkárdalur with a bank angle of 30° - 40° and an airspeed of less than 60 mph.

    - The power required exceeded the power available from the propeller for 40° bank angle at an airspeed of less than 60 mph, due to the airplane's overweight condition.

- No ELT signal was received from the airplane.

- The ITSB was not notified of the missing airplane.

Causes:

- According to the ITSB calculations the airplane was well over the maximum gross weight and the airplane's performance was considerably degraded due to its overweight condition.

- Weather
    - VFR flight was executed, with the knowledge of IMC at the planned flight route across Tröllaskagi. The airplane was turned around before it entered IMC on two occasions and it crashed when the PF attempted to turn it around for the third time.
    - Favorable weather on for the subsequent flight between Keflavik Airport and Greenland on August 10th may have motivated the pilots to fly the first leg of the flight in poor weather conditions on August 9th.

- Terrain
    - The pilots failed to take into account the geometry of the valley of Barkárdalur, namely its narrow width and the fast rising floor in the back of the valley.

Contributing factors:

- CRM - Inadequate planning
    - The W&B calculations performed by the PF prior to the flight were insufficient, as the airplane's weight was well over the maximum gross weight of the airplane.

    - The plan was to look for an opening (in the weather), first in the head of the valley of Öxnadalur, then the head of Hörgárdalur and finally in the head of Barkárdalur.

    - The decision to fly into the valley of Barkárdalur was taken spontaneously, when flying out of the valley of Hörgárdalur and the pilots noticed what looked like a break in the cloud cover over the head of the valley of Barkárdalur.

- CRM – Failed to conduct adequate briefing
    - A failure of CRM occurred when the PNF did not inform the PF of the amount of fuel he added to the airplane prior to the flight.

- Overconfidence
    - The special ferry flight permit the pilots received for the ferry flight to Iceland in 2008 may have provided the pilots with a misleading assumption that such loading of the airplane in 2015 was also satisfactory.

- Continuation bias
    - The pilots were determined to continue with their plan to fly to Keflavik Airport, over the peninsula of Tröllaskagi, in spite of bad weather condition.

- Loss of situational awareness
    - The pilots were not activily managing the flight or staying ahead of the aircraft, taking into account various necessary factors including performance, weather and terrain.

- The airplane most likely incurred severe carburetor icing in Barkárdalur.

4. Safety Recommendations

The ITSB issues the following safety recommendations:

2015-075-F-021 T01

It is recommended to the Ministry of Transport and Local Government and to the Ministry of Justice to amend regulation 71/2011, article 15, to include notification to the ITSB when an aircraft is missing.

The ITSB would like to emphasize the following safety actions:

The ITSB wants to remind pilots not to plan or engage in VFR flights on flight routes under IMC.

The ITSB wants to remind pilots to make thourough weight and balance calculations.

The ITSB wants to remind pilots to stay within the weight and balance envelope limits given by the aircraft manufacturer, as an aircraft's performance can be considerably degraded if it is overloaded or out of balance.

The following board members approved the report:

- Geirþrúður Alfreðsdóttir, chairman
- Bryndís Lára Torfadóttir, board member
- Gestur Gunnarsson, board member
- Tómas Davíð Þorsteinsson, deputy board member

Reykjavik, 21. June 2018

On behalf of the Icelandic Transportation Safety Board

Ragnar Guðmundsson
Investigator-In-Charge

5. Appendix A – Fuel Quantity Calculations

The airplane was equipped with three main tanks under the cabin floor, which together could hold 360 liters of fuel. The airplane was also equipped with fuel tanks in the wing tips, which together could hold 164 liters of fuel. Several days prior to the accident a ferry fuel tank was installed in the cabin, behind the pilots' seats, which could hold 284 liters of fuel. The total fuel capacity of the airplane was 808 liters.

The last refueling of the airplane was performed by the PNF at 13:45 on the day of the accident, only 16 minutes before takeoff. The PF was absent during this fueling of the airplane, as he was making the final preparation for the flight inside a hangar. This was verified both by the PF as well as by a witness that stopped at the fueling tank for a discussion with the PNF. The witness statement furthermore provided details that the PNF had been fueling the ferry fuel tank (shown in Figure 9) inside the airplane when he arrived and that the fueling stopped when no further fuel was available from the airport's fuel tank. The investigation revealed that the fuel charge was for 298.91 liters of 100LL Avgas. The ITSB also confirmed that this fuel charge had depleted the fuel storage tank at the airport.

As the airplane was completely destroyed during the accident, it was not possible to measure the fuel on board at the accident site. It was therefore necessary to perform analysis to determine the fuel on board. For this it was decided to use two methods.

Both methods involved looking in details at all the fuel charges on the PF fuel account prior to the accident and all aircraft takeoffs from Akureyri Airport that had been made on any aircraft affiliated with the PF around the same time. The fuel charges were the following:

- 28.07.2015 at 16:41 = 106.16 liters AVGAS
- 29.07.2015 at 16:37 = 65.95 liters AVGAS
- 1.08.2015 at 16:49 = 117.17 liters AVGAS
- 4.08.2015 at 10:31 = 330.53 liters AVGAS
- 7.08.2015 at 11:01 = 222.33 liters AVGAS
- 9.08.2015 at 13:45 = 298.91 liters AVGAS

All fuel charges that matched with other aircraft takeoffs from Akureyri which were affiliated with the PF, were then deducted. These were Piper PA-18-150 on July 29th and a Dornier DO28 on August 4th.

Removing the following fuel charges:

- 29.07.2015 at 16:37 = 65.95 liters AVGAS → Piper PA-18-150
- 4.08.2015 at 10:31 = 330.53 liters AVGAS → Dornier DO28

The fuel charges that remained were the following fuel charges:

- 28.07.2015 at 16:41 = 106.16 liters AVGAS
- 1.08.2015 at 16:49 = 117.17 liters AVGAS
- 7.08.2015 at 11:01 = 222.33 liters AVGAS
- 9.08.2015 at 13:45 = 298.91 liters AVGAS

These fuel charges could all be matched with airplane N610LC takeoffs from Akureyri, except one. That was a fuel charge at Akureyri Airport for 222.33 liters of 100LL Avgas at 11:01 on August 7th. There were no takeoffs from Akureyri Airport on affiliated aircraft with the PF at that time. The ITSB therefore researched all aircraft affiliated with the PF that were located at Akureyri airport on August 7th. The only one of them that had fuel tanks capable of holding 222.33 liters of 100LL Avgas was airplane N610LC (as the previously mentioned Dornier DO28 had left Akureyri on August 4th, when it was ferry flown to the USA). In addition, the ITSB found that at the time of the fueling on August 7th, aircraft N610LC was being prepared for the ferry flight.

The ITSB therefore assumed in its analysis that this fuel charge was for airplane N610LC.

The first method of fuel analysis involved backtracking the fuel uplift and fuel usage on the airplane for the two weeks prior to the accident, using the flight endurance provided by the pilot to ATC as the initial base line and the subsequent as a verification check of fuel status prior to each flight.

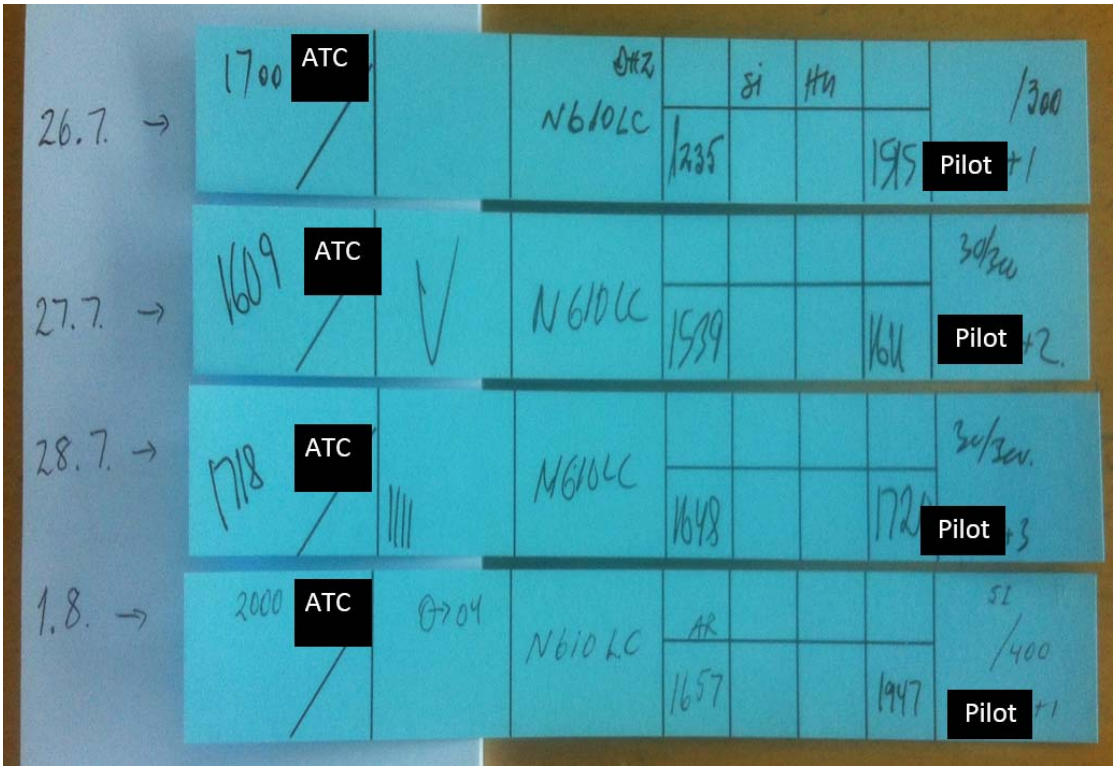


Figure 27: Isavia BIAR ATC data on N610LC flights two weeks before departure

According to Figure 27, the airplane started with flight endurance of 3 hours prior to the flight on July 26th.

According to the PF, the average fuel consumption of airplane N610LC was 25 USG/hr. According to the manufacturer[30] the airplane has a cruising endurance at 5000 ft (240 BHP) when installed with wing tip tanks (138 USG) of 5.68 hrs. This equals to 24.3 USG/hr[31]. For the purpose of the fuel calculations, the average fuel consumption of 25 USG/hr was used.

[30] Viking DHC-2 Beaver Airplane Flight Manual PSM1-2-1, Revision 11, Section 4, page 41
[31] 138 SG / 5.68 hr = 24.3 USG/hr

Method #1

Precursors:

Fuel endurance before flight on 26. July, as provided to ATC:	3	hr
Average fuel consumtion:	25	USG/hr
Estimated initial fuel before flight on 26. July:	75	USG/hr

26. July:

Fuel before flight:	75	USG/hr
Flight time according to ATC:	2,67	hr
Thereoff, the investigation revealed stop at Siglufjörður:	*1,5*	*hr*
Actual flight time:	1,17	hr
Estimated runup and taxi time of 8 minutes (before and after):	0,13	hr
Actual engine running time:	1,30	hr
Fuel consumption (25 USG/hr):	32,5	USG
Fuel remaining after flight:	42,5	USG

27. July:

Fuel before flight:	42,5	USG
Flight time according to ATC:	0,53	hr
Estimated runup and taxi time of 8 minutes (before and after):	0,13	hr
Actual engine running time:	0,67	hr
Fuel consumption (25 USG/hr):	16,67	USG
Fuel remaining after flight:	25,83	USG

28. July:

Fuel uplift:	106,16	liters
(in US Gallons)	28,08	USG

Fuel before flight:	53,92	USG
Flight time according to ATC:	0,53	hr
Estimated runup and taxi time of 8 minutes (before and after):	0,13	hr
Actual engine running time:	0,67	hr
Fuel consumption (25 USG/hr):	16,67	USG
Fuel remaining after flight:	37,25	USG

1. August:

Fuel uplift:	117,17	liters
(in US Gallons)	31,00	USG
Fuel before flight:	68,25	USG
Flight time according to ATC:	2,83	hr
Thereoff, the investigation revealed stop at Siglufjörður:	*1,5*	*hr*
Actual flight time:	*1,33*	
Estimated runup and taxi time of 8 minutes (before and after):	0,13	hr
Actual engine running time:	1,47	hr
Fuel consumption (25 USG/hr):	36,67	USG
Fuel remaining after flight:	31,58	USG

7. August:

Fuel uplift:	222,33	liters
(in US Gallons)	58,82	USG
Fuel before flight:	90,40	USG

No flight during this day

9. August:

Fuel uplift:	298,91	liters
(in US Gallons)	79,08	USG

Fuel before flight:	169,48	USG
Fuel before flight:	640,62	liters

According to the first method, there were about 641 liters of Avgas 100LL fuel in the airplane's fuel tanks prior to the accident flight's takeoff.

With regards to the first method, the calculations show that after the fuel uplift on August 7th, the fuel in the aircraft (90.4 USG) closely matched with what was required for filling the three main tanks of the airplane (95 USG).
The second method involved looking at the preparation for the airplane's last flight on August 1st, assuming that only the three main tanks of the airplane had been filled with fuel before that flight and then calculating the fuel uplift and fuel usage on the airplane since that time.

Method #2

Precursors:

Airplane three main fuel tanks full:	95	USG

1. August:

Airplane three main fuel tanks full after fueling:	95	USG
Flight time according to ATC:	2,83	hr
Thereoff, the investigation revealed stop at Siglufjörður:	*1,5*	*hr*
Actual flight time:	*1,33*	
Estimated runup and taxi time of 8 minutes (before and after):	0,13	hr
Actual engine running time:	1,47	hr
Fuel consumption (25 USG/hr):	36,67	USG
Fuel remaining after flight:	58,33	USG

7. August:

Fuel liftup:	222,33	liters
(in US Gallons)	58,82	USG
Fuel before flight:	117,15	USG
No flight during this day		

9. August:

Fuel liftup:	298,91	liters
(in US Gallons)	79,08	USG
Fuel before flight:	196,23	USG
Fuel before flight:	741,74	liters

According to the second method, there were about 742 liters of Avgas 100LL fuel in the airplane's fuel tanks prior to takeoff for the accident flight.

6. Appendix B – Weight and Balance Calculations

Weight & Balance at takeoff from BIAR			
Based on lower fuel limit	Weight (lbs)	Arm (in)	Moment (lb-in)
Empty weight	4.347	100,00	434.700
Pilot Flying - LH side	183	93,00	16.982
Pilot Non Flying - RH side	198	93,00	18.414
Fuel - Front main tank	209	95,50	19.913
Fuel - Center main tank	209	119,60	24.938
Fuel - Rear main tank	151	140,00	21.139
Fuel - Wing tip tanks	259	110,00	28.472
Fuel - Ferry flight tank	186	128,50	23.892
Ferry fuel tank (empty)	77	128,50	9.895
Luggage	44	194,00	8.536
Aircraft documents - RH float fwd section	21	34,00	697
Seat row #2 - Stored on top of third seat row			552
Weight, arm and moment:	**5.882**	**103,39**	**608.129**

Maximum Gross Weight	**5370 lbs**	*(STC SA610GL)*
Useful load (fuel, pilot, pax, cargo)	**1.023 lbs**	

512 lbs over maximum gross weight

Weight & Balance at accident site			
Based on lower fuel limit	Weight (lbs)	Arm (in)	Moment (lb-in)
Weight & Balance at takeoff from BIAR	5.882	103	608.129
Fuel consumed during flight	-122	119,60	-14.627
Weight, arm and moment:	**5.760**	**103,05**	**593.502**

390 lbs over maximum gross weight

Weight & Balance at takeoff from BIAR			
Based on upper fuel limit	Weight (lbs)	Arm (in)	Moment (lb-in)
Empty weight	4.347	100,00	434.700
Pilot Flying - LH side	183	93,00	16.982
Pilot Non Flying - RH side	198	93,00	18.414
Fuel - Front main tank	209	95,50	19.913
Fuel - Center main tank	209	119,60	24.938
Fuel - Rear main tank	151	140,00	21.139
Fuel - Wing tip tanks	259	110,00	28.472
Fuel - Ferry flight tank	346	128,50	44.398
Ferry fuel tank (empty)	77	128,50	9.895
Luggage	44	194,00	8.536
Aircraft documents - RH float fwd section	21	34,00	697
Seat row #2 - Stored on top of third seat row			552
Weight, arm and moment:	**6.041**	**104,05**	**628.635**

Maximum Gross Weight	**5370 lbs**	*(STC SA610GL)*
Useful load (fuel, pilot, pax, cargo)	**1.023 lbs**	

671 lbs over maximum gross weight

Weight & Balance at accident site			
Based on upper fuel limit	Weight (lbs)	Arm (in)	Moment (lb-in)
Weight & Balance at takeoff from BIAR	6.041	104	628.635
Fuel consumed during flight	-122	119,60	-14.627
Weight, arm and moment:	**5.919**	**103,73**	**614.008**

549 lbs over maximum gross weight

7. Appendix C – Performance Calculations

During the investigation the ITSB noted that the witness reports and pictures taken of the airplane during the flight indicated that the airplane was flying at low altitude. This could partially be explained by the low cloud cover over Tröllaskagi. It did however catch the ITSB's attention that witnesses reported the airplane flying at an unusually low altitude over Þelamörk. Figure 2 was therefore analyzed using photogrammetry. According to the analysis, the airplane in the red circle on Figure 2 was calculated to be at an altitude of about 475 feet MSL.

The location of airplane N610LC in Figure 2 is approximately 6.8 miles away from the end of RWY 01 at Akureyri Airport. The ITSB estimated that it would take the airplane about 6 minutes to cover that distance after takeoff, both based on calculations and the fact that the PF communicated with Akureyri Airport ATCO 6 minutes after takeoff and reported being over Þelamörk.

The climb performance and issues that could affect the climb performance were therefore analyzed in great details as part of the investigation.

The investigation revealed the climb performance of the airplane from Akureyri Airport with flaps TAKEOFF to be 411 ft/min based on the actual lower weight (5882 lbs) and 359 ft/min based on the actual upper weight (6041 lbs) of the airplane. This climb performance was much less than provided by the manufacturer under normal weight conditions (5090 lbs), which is 650 fpm[32]. This slow rate of climb after takeoff, towards Þelamörk, should have been an indication that something was wrong with the airplane's climb performance. This was around 60% of the normal climb performance of the airplane.

Regardless of this reduced takeoff climb performance, the airplane should have been able to climb to its altitude over Þelamörk in less that two minutes after takeoff.

The ITSB calculated the performance for the airplane, taking into account the original design, the STCs incorporated into it and the lower and upper limits of its actual weight. For this the ITSB used data provided in the manuals for the airplane, as well as design

[32] Viking Technical Manual PSM 1-2-1 DHC-2 Beaver, Secion 4, pg 40, Initial Rate of Climb (T.O. Power), Flaps „Take-off"

data for the airplane provided by the manufacturer. The ITSB also took into account the effects of the calculated atmospheric conditions in the valley of Barkárdalur at the time of the accident. Taking these into account, the stall speed and slow flight speed were determined for various conditions and bank angles.

In the performance calculation the ITSB initially only looked at the aerodynamics of the airplane and took into account the geometrics of the valley of Barkárdalur around the accident site location with regards to possible turn radius. Too high airspeed, and the geometric size of the valley of Barkárdalur would prevent the airplane from being able to turn around within the available valley diameter. The reverse of that, too low airspeed, and the airplane would stall. The bank angle was also a driving factor in the analysis. Too little bank angle and the geometric size of the valley of Barkárdalur would prevent the airplane from being able to turn around within the available valley diameter. However, this did not take into account whether the power available from the airplane's propeller would be able to match or exceed the power required.

Therefore the power required and power available curves for the airplane under all the above mentioned conditions were also calculated. This was then combined for the aircraft performance under various bank angles and airspeed.

The performance calculations were then used to answer the following questions.

7.1. Was it theoretically[33] possible to turn the airplane around?

Taking all the above constrains into account the ITSB calculated that, it would only have been theoretically possible to turn the airplane around in the valley of Barkárdalur in the area where the accident occurred under and in between the following two conditions:

Lower weight limit at Barkárdalur of 5760 lbs:

- 30° bank angle at 60-65 mph, flaps TAKEOFF
- 40° bank angle at 65-75 mph, flaps TAKEOFF
- 50° bank angle at 90-95 mph, flaps UP

[33] The ITSB wants to emphasize that this analysis only shows what was theoretically possible, without taking any minimum altitude requirements or cognative response time into account

Upper weight limit at Barkárdalur of 5919 lbs:

- 30° bank angle at 60-65 mph, flaps TAKEOFF
- 40° bank angle at 70-75 mph, flaps TAKEOFF
- 50° bank angle at 95 mph, flaps UP

All other bank angles (in increments of +/- 10°) and airspeed values (in increments of +/-5 mph) would have resulted in too large turn diameter for the area in the valley of Barkárdalur, the airplane stalling, the airplane exceeding its structural speed limit or the power required exceeding the power available (insufficient power) from the propeller/engine combination, resulting in the airplane losing altitude.

Based on the ITSB findings, the PF had selected the correct bank angle range (30° to 40°) to be able to make the turn, but not the correct speed range.

7.2. Why did the airplane lose altitude during the partially executed turn?

According to the PF, the flaps were in the TAKEOFF position. He reduced the airspeed down below 60 mph and then executed a turn with a bank angle of 30° – 40°.

As can be seen in Figure 24, the weight of the airplane greatly affects its performance. Under normal conditions, where the weight would have been below the manufacturer's maximum gross weight of 5090 lbs, performing a 30° turn at an airspeed just below 60 mph would have been fine with regards to the airplane performance. However, when taking into consideration the upper and lower limits for the airplane's actual weight, a 30° turn at an airspeed just below 60 mph results in the power available just barely exceeding the power required.

When the bank angle is then increased further, the performance deteriorates. As can be seen in Figure 25, a 40° turn at an airspeed just below 60 mph results in the power required exceeding the power available, while at the same time the airplane is about to stall due to its overweight condition. The PF states that the airplane did not reach this stall condition during the turn.

The ITSB believes the reason why the airplane lost altitude when the turn was executed can be explaned by the fact that the power required exceeded the power available.

The PF selection of airspeed (just below 60 mph) for the turn was therefore too low and it needed to be much closer to 80 mph for the airplane to be able to execute the turn without losing altitude.

7.3. Why did the experienced altitude loss not add up?

According to the PF, he suspected their altitude loss to be around 100 – 200 ft after the possible carburetor icing, before they decided to turn around. The pilots had also shortly before the partially executed turn become aware how close they were flying to the valley floor and it did not seem to add up with regards to their experienced altitude loss. At this time, the airplane had been flying with TAKEOFF flaps at airspeed of 75 - 80 mph.

Assuming a healthy running airplane (no carburetor icing) climbing at an airspeed of 75 mph, the ITSB performance calculations showed the climb rate for the airplane to be 796 ft/min for the lower limit of the actual weight (5760 lbs) and 744 ft/min for the upper limit of the actual weight (5919 lbs) at the time of the accident. At the same time the HARMONIE model from the Icelandic Meteorology Office also indicated minor downdraft of 2.6 ft/s, in the valley of Barkárdalur, which equals 156 ft/min.

Combining the above climb rate with the down draft, results in a net climb rate between 588 ft/min and 640 ft/min.

The ITSB analyzed the last two miles of the flight in the valley of Barkárdalur, before the accident. In this area, the valley floor rises rapidly from 1320 ft up to 2260 ft, or by 940 ft. It would have taken the airplane about 1.6 minutes to cover this distance at an airspeed of 75 mph. During these 1.6 minutes before the accident, the airplane could therefore climb between 941 ft and 1024 ft with a healthy running engine (no carburetor icing). At the same time the valley floor rose by 940 ft, effectively nullifying any change of their height above terrain during climb, before taking into account any negative performance effect due to carburetor icing.

It was therefore the rapid rise of the valley floor that made the pilots' experience of altitude loss not add up, causing them to be at the valley floor much faster than their experienced altitude loss indicated.