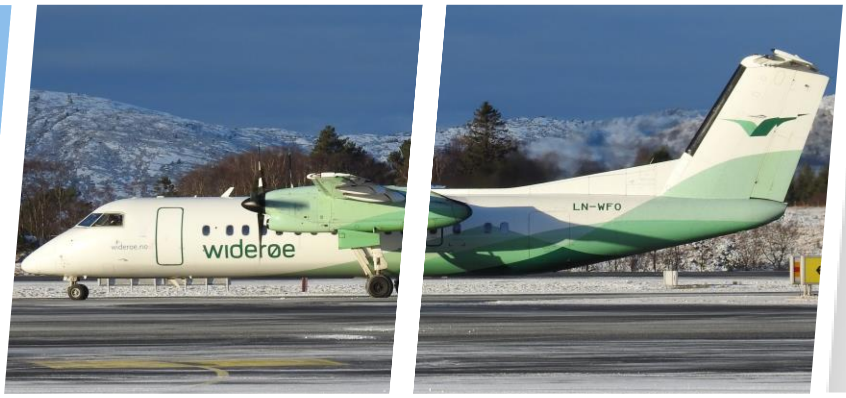
Norwegian Safety Investigation Authority



Published February 2023

REPORT AVIATION 2023/01

Serious aviation incident 20 NM north of Flesland on 20 January 2020 involving DHC-8-311, LN-WFO

Norwegian Safety Investigation Authority • P.O. Box 213, NO-2001 Lillestrøm • Phone: 63 89 63 00 • nsia.no • post@nsia.no

The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving flight safety.

The purpose of the NSIA's investigations is to clarify the sequence of events and causal factors, elucidate matters deemed to be important to the prevention of accidents and serious incidents, and to make possible safety recommendations. It is not NSIA's task to apportion blame or liability.

Use of this report for any other purpose than for flight safety should be avoided.

Photo: Marius Devik

Table of contents

Report on serious aviation incident

Table 1: Data relating to the incident

Type of aircraft:	De Havilland Aircraft of Canada Ltd. DHC-8-311
Nationality and registration:	Norwegian, LN-WFO
Owner:	Widerøe Asset AS, Norway
Operator:	Widerøes Flyveselskap AS
Crew/commander:	2 pilots and 1 cabin crew, no injuries
Passengers:	14, no injuries
Location:	Airspace north of Bergen Airport Flesland, approx. 20 NM from runway 17
Time of the incident:	Monday 20 January 2020, 2039 hours

All times given in this report are local time (UTC +1), if not otherwise stated.

Notification

The Norwegian Safety Investigation Authority (NSIA) received notification of the incident from Widerøe on Tuesday 21 January 2020. The incident had taken place the previous evening, and the NSIA received the commander's report on 22 January.

The NSIA classified the incident as a serious aviation incident and initiated a full investigation.

In accordance with ICAO Annex 13 Aircraft Accident and Incident Investigation, the NSIA notified the aircraft manufacturer De Havilland Aircraft of Canada Ltd, the Canadian Transport Safety Board (TSB) and the European Aviation Safety Agency (EASA), among others.

The NSIA has been assisted in its investigation by an accredited representative of the TSB and an adviser representing the aircraft manufacturer.

Summary

During climbout from from Kristiansund Airport Kvernberget (ENKB), WF577 inadvertently flew into an area of severe icing conditions. The crew took corrective action by changing course and altitude, but were unable to sufficiently limit the duration of the aircraft's exposure to severe icing conditions. As a result, ice formed on the aircraft and inside the engine air inlets.

On its approach to Bergen Airport Flesland, the aircraft lost engine power on the left engine, then on the right engine, and then on the left engine again. The aircraft's automatic ignition system restarted both engines, but the start-up sequence took time, and the aircraft was completely without engine power for a brief period. The engines flamed out due to ice detaching from the engine air inlets. The ice either entered the combustion chamber as slush and water and caused a flameout, or it disrupted the airflow into the engine sufficiently to stall it. The crew acted professionally in a highly demanding situation and landed the aircraft safely at Flesland.

The investigation has identified shortcomings in Widerøe's documentation concerning operations in icing conditions. In addition, The NSIA calls for a warning from the aircraft manufacturer De Havilland that the aircraft's engines could stop if exposed to severe icing conditions.

The use of weather radar by air traffic services has been a topic in previous NSIA investigations and a new assessment in order to provide this service is needed.

Neither moderate nor severe icing is explicitly defined in the joint European regulations, and the NSIA calls for clear definitions for use by both pilots and meteorological personnel.

The NSIA submits three safety recommendations following this investigation. One is addressed to Transport Canada, one to the Norwegian Civil Aviation Authority and one to EASA.

About the investigation

Purpose and method

The NSIA has classified the incident as a serious aviation incident. The purpose of this investigation has been to determine what caused the engines of WF557 to stop during the approach to Bergen Airport Flesland. The NSIA has also considered what can be done to improve safety and prevent the recurrence of similar incidents in the future.

The incident and the circumstances surrounding it have been investigated and analysed in line with the NSIA's framework and analysis process for systematic safety investigations (the NSIA method[1]).

Sources of information

The primary sources of information used in this investigation were excerpts from the aircraft's flight data recorder and cockpit voice recorder, and interviews with the crew. The airline's operating manuals in force at the time of the incident have also been reviewed in conjunction with documentation from the aircraft manufacturer. Relevant information from various aviation organisations (EASA, FAA and ICAO) has been collected and reviewed, as have incident reports from Widerøe and investigation reports from the US, British and Canadian accident investigation authorities. Widerøe has contributed its own internal report, and the Norwegian Meteorological Institute has prepared a report on the weather situation at the time of the incident.

The investigation report

The first part of the report, 'Factual information', describes the sequence of events, related data and information gathered in connection with the accident, what the NSIA has investigated and related findings.

The second part, the 'Analysis' part, contains the NSIA's assessment of the sequence of events and contributing causes based on factual information and completed investigations/examinations.

The final part of the report contains NSIA's conclusions and safety recommendations.

---

[1] *See https://www.nsia.no/About-us/Methodology*

1. Factual information

1. Factual information

1.1 History of the flight

On 20 January 2020, the crew of LN-WFO were scheduled to fly four flights between Bergen Airport Flesland (ENBR) and Kristiansund Airport Kvernberget (ENKB). The crew arrived at Flesland 45 minutes before the first scheduled departure time which was planned at 1410 hours. They reviewed the operational flight plans for the sectors they were scheduled to fly, as well as weather information and NOTAM[2] reports. There were strong winds in Kristiansund, and particular attention was devoted to this. They also noted the presence of a warm front in the area they would be flying in, and a forecast for mountain waves. The first flight to Kristiansund went as normal, and after landing, the crew retrieved updated flight plans and weather information in preparation for their return flight to Bergen. A SIGMET[3] report regarding heavy turbulence and mountain winds had been issued for the northern part of Western Norway. Moderate icing had also been reported in the areas where they would be flying. They experienced no icing during the next two flights.

Before the final departure for Bergen, the commander carried out an external visual inspection of the aircraft without finding signs of snow or ice. The temperature at the time was 9°C and it was raining, and the crew did not consider de-icing necessary. For the same reason, the air inlet was not checked for ice during this inspection.

The aircraft with the callsign WIF77G took off for Bergen at 1939 hours. When the crew contacted the air traffic control (Norway Control) for the northern part of Western Norway after departure, they were cleared directly to the first approach point (NIDGI) inbound Flesland. This clearance took them on a more direct course to Flesland (see Figure 1). They entered clouds at about 4,000 ft, by which time they had activated the aircraft's de-icing system. The aircraft's weather radar was not actively used during the climb.

Ice began to form on the aircraft around flight level FL140, and the crew observed a thin layer of ice on the wings. The crew expected to pass through the icing layer and climb above the clouds as they had on the three preceding flights. However, the icing intensified as they climbed.

When they levelled out at FL220, the aircraft was still in clouds with considerable icing. They did not notice changes to the aircraft's stability or performance other than the speed being somewhat lower than normal, which they considered to be the result of drag due to ice. This was confirmed by the propellers shedding ice that hit the fuselage and by vibrations in the aircraft. According to Widerøe's internal report, the experienced cabin attendant found the situation dramatic, with abnormally strong shaking, vibrations and loud bangs when ice shed from the propeller and hit the side of the fuselage.

The crew were actively working the aircraft's de-icing systems and tried different propeller RPMs in an attempt to remove the ice. The rotational speed was increased from 900 RPM to 1,050 RPM. They decided to descend to a lower altitude to find a layer of higher air temperature and requested an altitude adjustment at the same time as they submitted an aircraft report (AIREP[4]) about moderate icing to the air traffic service. The commander confirmed in an interview with the NSIA that he considered the intensity of the icing to be moderate throughout. They were granted an

---

[2] NOTAM is short for Notice to Airmen, which contains information about circumstances of importance to flying. A NOTAM is structured in accordance with the guidelines set out in ICAO Annex 15 – Aeronautical Information Services.
[3] SIGMET stands for SIGnificant METeorological Information. Such advisories contain significant meteorological information about weather phenomena that could affect aviation safety (ICAO Annex 3).
[4] AIREP is an observation of one or more meteorological conditions from an aircraft in flight.

altitude adjustment down to FL160 and began a gradual descent. Shortly after, they requested a course change to 250° to get closer to the coast. The course was later adjusted to 270°. They considered that this would take them to areas of warmer air and lower terrain. The aircraft was controlled by autopilot during the descent and as it continued its approach to Flesland. The crew did not consider disengaging the autopilot.

Figure 1: Map showing the route flown by WF577. The orange line indicates the planned route, while the blue line shows the actual route. Map: © The Norwegian Mapping Authority. Illustration: NSIA

The icing continued even after the aircraft approached FL160. Using the inspection lights, they observed a great deal of ice on the leading edge of the wings, on the propeller spinners and on the underside of the flap fairing. Abnormal amounts of ice accumulated on the left and right windshield wiper arm (*spigot*[5]). There was also ice on the lower part of the flight deck windows. The pilots have stated that the windows were nearly completely iced over at one point. They cannot remember seeing ice on or in the air inlet. They also stated that they considered the icing a nuisance, but not dangerous. The RPM was increased to 1,200 RPM for a while during the descent. The propeller blades shed ice that hit the fuselage with loud bangs, and they felt vibrations. They have later stated that the phenomenon was more annoying than worrying. They levelled out at FL160 approximately five minutes after starting the descent.

The crew did not wish to stay on a westerly course for too long, as that would eat into their fuel reserves. The course was adjusted 260° to shorten the distance to Flesland. They requested permission to proceed towards BR638 to continue south towards Flesland, and the request was granted. This is an approach point to Flesland that is located further west than NIDGI, for which they were originally cleared. They did not set a direct course immediately, but adjusted it incrementally on the way south. Some of the ice came off, but new ice also accumulated. The crew were aware that the level of the zero-degree isotherm[6] was about 6,000 ft and requested clearance to descend to FL100 in an attempt to stop the icing. The descent was gradual, and all the time they were varying the propeller's RPM. However, they did not succeed in shedding all the ice.

While descending to FL100, they found that the ice increasingly separated from the aircraft, and the intensity of icing decreased. A direct course was then set for BR638. They heard on the radio that there was another Widerøe flight in the area enroute from Bergen to Florø at FL140. They asked the air traffic service to check with the crew if they had experienced icing and received confirmation that this was not the case. They therefore decided to stop the descent at FL120. The icing conditions decreased in step with the decreasing altitude, and as they flew further west. They submitted another AIREP to the air traffic service about moderate icing in the area they had flown through. When the propeller vibrations subsided, the propeller speed was again reduced to 900 RPM.

The aircraft continued at FL120 on a southerly course towards Flesland. The crew still observed thick ice on the spigot, flap fairings and spinner (see Figure 2, Figure 3 and Figure 4). In interviews with the NSIA, they have stated that they had great confidence in the aircraft's ability to withstand icing, as they had experienced similar situations several times before.

---

[5] The windshield wiper arms on the DHC-8 have a small ice detector post where ice accumulates. This part is called a spigot.
[6] An isotherm is a line drawn on a weather chart joining places with the same temperature, in this case 0°C.

Figure 2: Ice on spigot. The photo was taken at FL120 approx. 50 minutes after departure. Photo: First officer of WF577

WF577 was cleared for approach to ILS W runway 17 and began its approach and descent towards Flesland. At this time, Flesland reported low cloud cover with precipitation, south-westerly winds and a temperature of 8°C. Ice dislodged from the aircraft at irregular intervals throughout the flight. As they approached 7,000 ft, the amount of ice that came off increased noticeably. Among other things, all the ice disappeared from the spigot. When the aircraft passed 6,700 ft, 20 seconds after the ice dislodged from the spigot, they lost power on the left engine. The first officer noticed a loss of torque and a drop in the turbine temperature and RPM, and he immediately informed the commander.

The crew quickly concluded that the engine had flamed out[7] and awaited the situation. They did not start the process of shutting down the engine and feather the propellers, as they expected the engine to restart automatically. This was soon confirmed, and they concluded that the occurrence could be due to ice in the engine. Data from the flight data recorder (FDR) show that the engine regained power and showed normal values after 25 seconds.

After another 51 seconds, the right engine lost power with the same indications as the left engine had shown. The aircraft passed 5,200 ft, and the crew declared an emergency to air traffic control. The crew believed the cause to be the same as with the left engine and waited to see whether the engine would restart automatically. The right engine took a little longer to regain power, as it took two attempts to restart it. It stopped immediately after the first automatic restart. When the right engine's power seemed to increase again, the power from the left engine dropped again. Thirteen seconds elapsed from the left engine lost power until the right engine had regained normal power. The aircraft was thus completely without engine power for a few seconds. This happened while the aircraft was starting its approach to runway 17 at Flesland. The left engine regained power after another 18 seconds, as the aircraft was passing 4,500 ft.

The loss of power on the left engine lasted for 25 seconds, the loss of power on the right engine lasted for 35 seconds, and the second loss of power on the left engine lasted for 31 seconds. The

[7] *Flameout refers to an engine losing power due to extinction of the flame in the combustion chamber.*

rest of the approach and landing was normal, and the crew cancelled the distress call. The aircraft landed at 2052 hours.

There was still a lot of ice on the aircraft when it was parked after landing, despite rainy weather and a temperature of 8°C. The commander contacted Widerøe's flight operations duty manager and it was decided to remove the crew from active service. The aircraft was towed into a hangar to be checked by technical personnel, and the CVR's circuit breaker was pulled just over an hour after the aircraft was parked at the gate.

Figure 3: LN-WFO in the process of parking. Ice is still visible on the leading edge of the wings, the nose, the propeller spinner and the area between the spinner and the air inlet. Photo: Avinor

Figure 4: Remaining ice on the nose, spinner and the area between the air inlet and the spinner despite 8°C and rain at the airport. Photo: Commander of WF577

1.2 Injuries to persons

Table 2: Injuries

Injuries	Crew	Passengers	Other
Fatal			
Serious			
Minor/none	3	14	

1.3 Damage to aircraft

After landing in Bergen, the aircraft was towed into a hangar where a technical inspection of the fuselage and engine was performed. Both engines were inspected with a borescope[8]. The inspection identified damage to some of the blades in the first-stage low-pressure compressor in both engines, and some damage to blades in the high-pressure compressor in engine number 2. One compressor blade was bent, and several others were chipped. No other damage to the aircraft was identified.

Figure 5: Borescope images showing damage to compressor blades caused by ice that came off the engine inlet and was sucked into the engine. Photo: Widerøe

1.4 Other damage

None.

1.5 Personnel information

1.5.1 COMMANDER

The commander got his initial flight training at a flight academy in the USA in 1990, after which he was an instructor for two years. He then worked for different companies before joining Widerøe in 1998. He became a captain in 2006 and has been based in Bergen for most of his time with the company. He was also based in Tromsø for a while. He was one of Widerøe's supervisors and had experience on the DHC-8 100/300 and Q400. The commander held a valid European ATPL (A)

[8] *A borescope is an inspection camera used for technical inspections of e.g. engines.*

and valid rights to fly DHC-8-300 and DHC-8-Q400, as well as a valid class 1 medical certificate without restrictions.

He worked a five days on/four days off schedule and commuted to Flesland on the days he worked. The incident took place on the first day of a work period, and he felt rested and fit to fly.

Table 3: Flying experience commander

Flight time	All types	On type
Last 24 hours	5	5
Last 3 days	5	5
Last 30 days	32:40	08:40
Last 90 days	133:20	34:10
Total	12,715	2,313

1.5.2 FIRST OFFICER

The first officer has worked for Widerøe since summer 2018. He was trained as a commercial pilot at the University of Tromsø, and the position in Widerøe was his first pilot job. He had instructor experience from both Pilot Flight Academy and the University of Tromsø. He held a valid CPL (A) and valid rights to fly DHC-8-300 and DHC-8-Q400, as well as a valid class 1 medical certificate without restrictions.

The first officer had slept well the night before the flight and had worked out before check-in.

Table 1: Flying experience, first officer

Flying experience	All types	On type
Last 24 hours	5	5
Last 3 days	5	5
Last 30 days	51:40	14:30
Last 90 days	137:10	31:10
Total	1,533	74

1.6 Aircraft information

1.6.1 GENERAL INFORMATION ABOUT THE AIRCRAFT TYPE AND STATUS OF LN-WFO

LN-WFO is a De Havilland of Canada Ltd. DHC-8-311 with serial number 493, and it was manufactured in 1997. The aircraft type is known as the Dash 8, 300 series. It is a twin-engine turboprop aircraft with a pressurised cabin and a maximum capacity of 50 passengers. The aircraft is certified for two pilots and one cabin crew.

Table 2: Aircraft details

Registration	LN-WFO
Manufacturer	De Havilland of Canada Ltd.
Model	DHC-8-311
Designation	Dash 8
Serial number	493
Build year	1997
Engine type	Pratt & Whitney PW123
Airworthiness Review Certificate (ARC)	Valid until 11 April 2020

1.6.2 MAINTENANCE

According to documentation provided by Widerøe, the aircraft and engines had been maintained in accordance with the company's approved maintenance programme, and the aircraft's most recent A check[9] was in October 2019. In preparation for the upcoming winter season, maintenance for winter operations was performed at the same time. This included inspection and function tests of the aircraft's de-icing and anti-icing systems. Moreover, the de-icing boots were polished with wax to help the ice detach from the boots once they are inflated. Widerøe has stated that this procedure was carried out during every A check.

1.6.3 MASS AND BALANCE

According to the cargo manifest, the aircraft was loaded within the mass and centre of gravity limitations set out in the airplane flight manual (AFM).

1.6.4 FLYING IN ICING CONDITIONS – CERTIFICATION REQUIREMENTS

The DHC-8-311 was certified by Transport Canada Civil Aviation (TCCA) on 31 July 1990 and later by the German certification authority (Luftfahrt-Bundesamt, LBA) on behalf of the Joint Aviation Authorities (JAA) on 15 August 1990. JAA was an association of European certification authorities that later became the European Aviation Safety Agency (EASA), of which Norway is a member. The aircraft was granted type approval by the Norwegian authorities on 23 February 1995.

When new aircraft types are designed, the authorities will set standardised specifications and impose design requirements on the aircraft manufacturers in a specification document. Before the aircraft type is accepted by the various national authorities, the manufacturer must demonstrate that the aircraft type complies with the requirements and specification set out in this document. The type certification process involves a series of test flights, simulations and analyses. The result of the certification will be published in the airplane flight manual (AFM), which in turn is approved by the relevant authorities and forms part of the aircraft's type certificate.

Today, aircraft types that are to operate from countries affiliated to EASA will be certified in accordance with the European certification specifications, CS 25 *Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes*. At the time DHC-8-311 was certified, both the Canadian and the European certification authorities used the US certification requirements specified in the Federal Aviation Regulation (FAR) Part 25, *Airworthiness Standards: Transport Category Airplanes*, for certification and type approval.

[9] The aircraft undergo regular maintenance inspections, and A checks are performed at intervals of 500 flight hours or 6 months.

At the time, aircraft that were intended to operate under all icing conditions were required to be fitted with anti-icing and de-icing equipment, which in turn had to be certified under Part 25. The equipment was to prevent ice from forming on and/or remove ice from the aircraft's critical surfaces, engine and propeller. Turbine engine aircraft were also required to demonstrate that they had effective systems for protecting the engine air inlets. The engines were certified separately for icing conditions in accordance with Part 33, *Airworthiness Standards: Aircraft Engines.*

The aircraft manufacturer had to make sure that the aircraft was capable of handling the icing conditions it was intended to operate in. The certification authorities had therefore added an Appendix C to Part 25 in which icing conditions were defined. The certification specifications thus defined the atmospheric conditions in which the aircraft could operate safely. It was known that the atmospheric variables with a bearing on icing conditions were the liquid water content of the clouds (g/m^3), the cloud droplet diameter (µm), the air temperature (°C) and the interaction between these variables. Appendix C thereby defined an 'envelope' based on these variables within which it was safe to operate the aircraft. The icing envelope was based on 'normal clouds' with relatively small droplets (40–50 µm).

Following the 1994 Roselawn accident[10] in the USA, it was found that Appendix C did not adequately cover the atmospheric conditions under which icing could occur. The certification specifications did not cover atmospheric conditions such as freezing drizzle and rain. The icing envelope was too small. Extensive regulatory amendment and harmonisation between the European, Canadian and US certification authorities followed in the wake of this accident. The result was ready in 2015, 29 years after the DHC-8-100 was first certified in 1986. Another appendix was added to Part 25. It dealt with *Supercooled Large Droplets (SLD)*[11] *Icing Conditions,* and defined, among other things, technical requirements for indicating to pilots that they are flying in SLD conditions. A new Appendix O was added to Part 25 that included the icing envelope for freezing drizzle and rain. At the same time, an Appendix D, *Mixed Phase and Ice Crystal Icing Envelope (Deep Convective Clouds),* which addresses the icing envelope for the engines, was added to Part 33.

At the same time, the European certification authorities harmonised their regulations with FAR Part 25 so that CS 25, *Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes,* now sets out identical requirements. These requirements apply to the certification of new aircraft and not retroactively to existing aircraft. DHC-8-311 was certified in accordance with Appendix C only. The aircraft manufacturer may nevertheless revise the airplane flight manual by inserting limitations and warnings as new knowledge emerges.

1.6.5 OPERATION IN ICING CONDITIONS – AIRPLANE FLIGHT MANUAL (AFM)

The airplane flight manual (AFM) is based on the results of the certification process and contains the manufacturer's instructions on how to operate the aircraft and under which conditions the aircraft may operate, for example day/night, instrument conditions and icing. In the chapter detailing limitations, the manufacturer describes which limits the aircraft should operate within. If these limits are exceeded, the aircraft will be deemed not airworthy. The AFM also contains recommendations and procedures that the manufacturer has deliberately not included in the chapter on limitations, as it will be up to the aircraft operators to set these limitations.

Under the limitations set out in the AFM, the DHC-8 may operate in icing conditions. It does not specify which icing conditions. In a revision dated 1996, a warning was added to the AFM that

---

[10] On 31 October 1994, an accident involving ATR 72-212 (N401AM) took place near Roselawn, Indiana, USA. The aircraft lost control in icing conditions and 68 people died in the accident.
[11] Supercooled large droplets (SLD) are water droplets with a diameter greater than 50 micrometres (0.05 mm) that exist in liquid form at air temperatures below 0°C. SLD conditions include freezing drizzle and rain.

severe icing *may* occur if the aircraft is operated in atmospheric conditions for which it has not been certified. It is implied that this means outside the criteria specified in Appendix C to Part 25. The intensity of icing can thus be characterised as severe if the liquid water content and droplet size exceed what is described in Appendix C. The fact that the aircraft is not certified for it does not necessarily mean that it is not permitted to fly in such conditions. The aircraft manufacturer regulates this by setting limitations in the airplane flight manual. There are no limitations regarding severe icing in the AFM for the DHC-8-311, but the aircraft manufacturer has nevertheless included a warning that severe icing may occur outside the criteria in Appendix C. According to the industry standard, a warning in this context means that personal injury may result if the warning is ignored.

The following limitations regarding icing are found in the AFM for DHC-8-311:

- *Engine intake by-pass doors must be open and engine ignition switch at MANUAL/AUTO for engine operation in icing conditions.*
- *When ice is detected, the AIRFRAME AUTO selector must be positioned FAST or SLOW.*
- *The autopilot must be disengaged in severe icing.*

The definition of icing condition is also stated. It is repeated in Chapter 4, *Normal Procedures*. In section 4.7 of the AFM (see Figure 6), the manufacturer starts by defining the atmospheric conditions that cause icing conditions. It follows with a warning that flying in conditions such as freezing rain and drizzle that exceed the capability of the ice protection system may result in ice forming aft of protected surfaces (runback[12]). The ice may not be shed using the ice protection systems and may seriously degrade the performance, controllability and stability of the aircraft. This is supported by a warning in a later part of the AFM stating that accretion of ice on the aircraft may change stall characteristics, stall speeds and the margins of the aircraft's stall warning systems. It is not mentioned that icing could cause flameout. For later DHC-8 models, the manufacturer has chosen to add the following sentence in the corresponding paragraph:

> […] Finally, ice ingestion by the engine or inlet flow distortions due to ice build-up on the intakes, can cause engine surging or flameouts.

This sentence is not included in the warning for DHC-8-311.

[12] *Runback normally occurs in conditions of freezing drizzle and rain (SLD conditions).*

de Havilland Inc.

PSM 1–83–1A | DASH 8 FLIGHT MANUAL | Section 4 D.O.T. Approved

4.7 OPERATION IN ICING CONDITIONS.

NOTE

ICING CONDITIONS:

Icing conditions exist when the SAT on the ground and for take–off is 10°C or below, or SAT in flight is 5°C or below, and visible moisture in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow, sleet, or ice crystals). Icing conditions are not considered to exist at temperatures of –40°C (–40°F) or below.

Icing conditions also exist when the SAT on the ground and for take–off is 10°C or below when operating on ramps, taxiways or runways where surface snow, ice, standing water, or slush may be ingested by the engines or freeze on engines, nacelles or engine sensor probes.

WARNING

Flight in freezing rain, freezing drizzle or mixed icing conditions (supercooled liquid water and ice crystals) may result in ice build-up on protected surfaces, exceeding the capability of the ice protection system or may result in ice forming aft of the protected surfaces. This ice may not be shed using the ice protection systems and may seriously degrade the performance and controllability of the airplane.

Severe icing conditions may be encountered during flight in visible rain with SAT below 0° C ambient temperature and specifically with droplets that splash or splatter on impact.

Severe icing may be identified by unusually extensive ice accreted on the airframe in areas not normally observed to collect ice, the accretion of ice on the propeller spinner aft of the spinner nose toward the propeller blades or ice accreted on the side windows of the flight compartment aft of the leading edge.

Figure 6: Airplane flight manual (AFM) on operating in icing conditions. Source: De Havilland

The AFM also states that severe icing conditions may be encountered during flight in visible rain with ambient temperature below 0°C, specifically if droplets splatter on impact. It then defines how severe icing can be identified by criteria other than precipitation or temperature. The following factors are specified:

- unusual ice accretion in areas not normally observed to collect ice, or
- accretion of ice on the propeller spinner aft of the spinner nose toward the propeller blades, or
- ice accretion in the flight compartment, on the side window aft of the leading edge.

The AFM describes what the crew must do if the aircraft enters severe icing conditions. The first action is to disconnect the autopilot. Before doing that, the pilot must hold the control wheel firmly, as the autopilot may have compensated for the icing by input to the flight control computer. If the pilot is not prepared to counteract these control forces, the aircraft could make an uncontrolled movement around the roll axis. If the autopilot is not disconnected, it could continue to compensate without the crew realising until it is no longer able to keep the aircraft level. The autopilot masks early signs of control problems. Eventually, it will disengage automatically, and the aircraft will enter the same uncontrolled movement around its roll axis as mentioned above. The aircraft must also maintain a minimum speed, and the crew must change the course and altitude to exit the icing conditions. Because the aerodynamic characteristics will be affected, the crew must avoid aggressive manoeuvring, as the stall margin may be significantly reduced. The aircraft may be considered to have exited the area of severe icing when there is no longer any ice on the side windows. The aircraft can be considered aerodynamically clean when the visible leading edges and wing tips are completely free of ice.

Flight in Severe Icing Conditions

Exit icing conditions, but avoid aggressive manoeuvring. Find an area that is warmer than freezing, or substantially colder than the current ambient temperature, or free of clouds.

Autopilot .... Disconnect immediately

– Be prepared for a possible roll requirement by firmly holding the control wheel prior to disconnecting the autopilot.

Condition levers .... MAX

Power levers .... Adjust as required, minimum 150 knots

Anti-ice and de-ice equipment .... Check ON

Ignition .... Check AUTO

When clear of icing conditions, return to normal operations but leave the de-ice system operating. Monitor the left and right leading edges and the wing tips. The aircraft can be considered aerodynamically clean when all ice is removed from the visible leading edges and wing tips.

Advise ATC and submit a PIREP.

Figure 7: Airplane flight manual (AFM) on flight in severe icing conditions. Source: De Havilland

The AFM (see Figure 8) contains a note stating that it can be assumed that the aircraft is no longer affected by the severe ice encounter when the side windows are free of ice. This note is not included in Widerøe's manuals.

PSM 1–83–1A | **de Havilland Inc.** **DASH 8 FLIGHT MANUAL** | Section 4 D.O.T. Approved

4. Minimum airspeed – 160 kt IAS.
5. Exit severe icing conditions by changing altitude and/or course as required.

CAUTION

Avoid aggressive maneuvering.

When clear of severe icing conditions:

NOTE

It can be assumed that the airplane is no longer affected by the severe ice encounter when the ice accumulated on the flight compartment side window is removed.

Figure 8: Note from the AFM. Source: De Havilland

1.6.6 ENGINE AND AIR INLET

The DHC-8-311 is equipped with two Pratt & Whitney PW123 free-turbine turboprop engines. The engine air inlet is located below the engine and forms an inlet channel with a plenum chamber[13].

[13] *A plenum chamber is a chamber that holds a high quantity of air at positive pressure. The chamber's function is to equalise the pressure to ensure a more even air distribution.*

The air that passes the air inlet enters the plenum chamber, which is designed to circulate the air (see Figure 9). Some of the air goes directly into the engine compressor inlet, which is located above the plenum chamber. The rest continues straight backwards and is channelled to the back of the chamber, where some of the air will be forced through the oil cooler and continue out through the nacelle[14]. The rest of the air will change direction and be forced back to the front of the air inlet before being led up into the engine compressor inlet.

This design means that precipitation and other contaminants that enter the air inlet with a certain momentum will move with the airflow and accumulate at the back of the chamber. At the back of the plenum chamber there is an intake bypass door that can be opened from the cockpit to allow contaminants to escape. This door is normally open in icing conditions, and that was also the case during the flight in question.

There are also two drainage holes at the bottom just inside the air inlet to drain away any water that may have accumulated in the air inlet, primarily while the aircraft is on the ground. Water that accumulates here may freeze and eventually detach as sheets of ice during flight. That is why it is important that this part of the air inlet is free of ice, snow and water before a flight. De Havilland has therefore issued a procedure describing how to check and clear the air inlet of ice (see Figure 10).

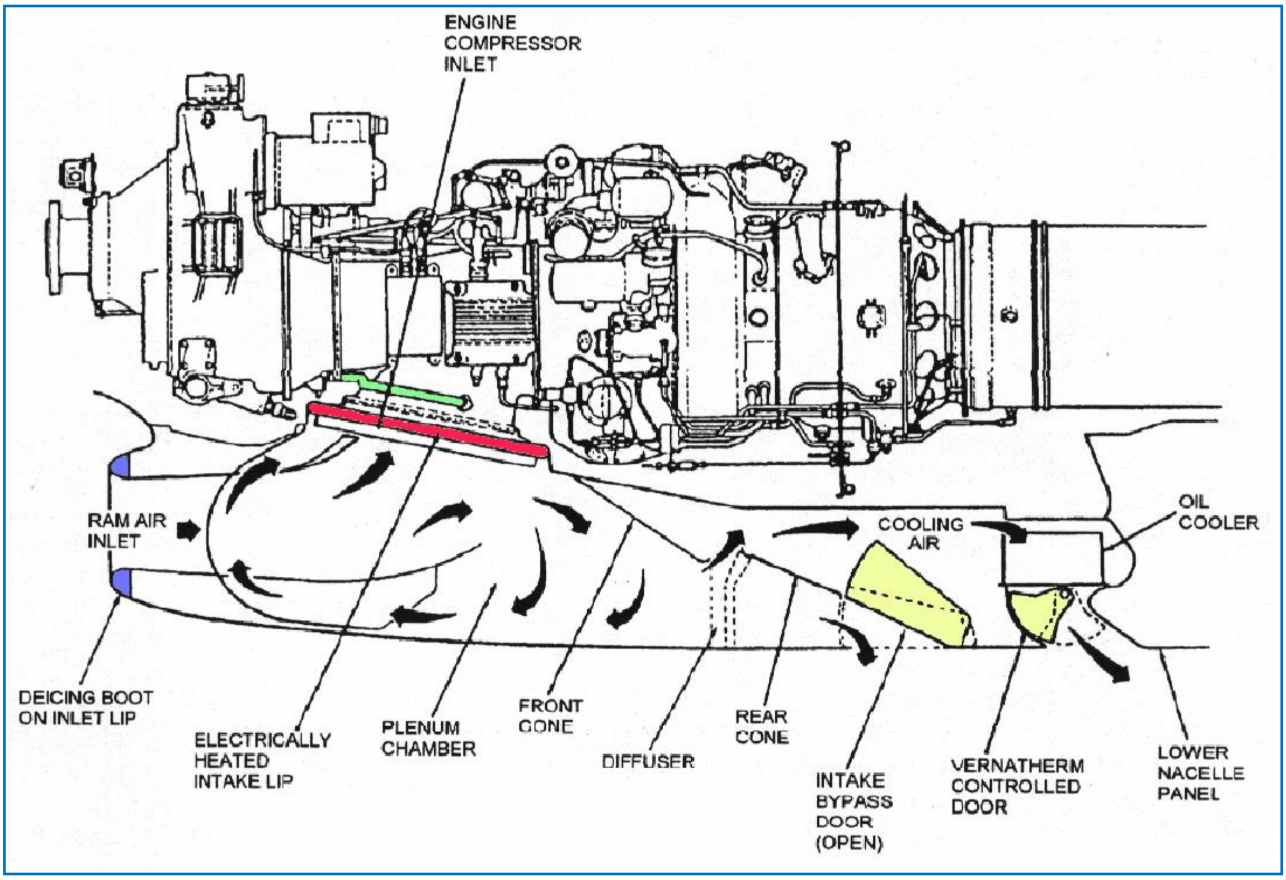


Figure 9: Illustration showing the engine and nacelle on a Dash-8-311. Source: De Havilland

[14] The word 'nacelle' is a term from aeronautical, ship and spacecraft design that refers to an enclosed compartment separate from the fuselage. Its purpose is often to protect the propulsion system, fuel or equipment.

3. Inlet Clearing for Ice and Snow Conditions

a. ACCESS: Gain access to the engine inlet (using ladder or cart)
b. FORWARD COWL and RAMP: use a strong lamp and check for any residual ice or slush that may melt and accumulate on the ramp.
c. RAMP DRAINS: Eliminate the residual ice or snow with the snow brush, verifying that water on the ramp has drained away and that the ramp drain holes are clear.
d. FINAL VERIFICATION (Forward Cowl): The forward cowl should be checked by tactile verification, to ensure no accumulation of clear ice remains on the ramp or in areas where it will melt and accumulate on the ramp.
e. AFT COWL: Use light to check the aft cowl. If ice/snow/slush discovered on the surfaces of (1) the forward cone, (2) the aft cone or (3) near the bypass door, clear accumulation with the snowbrush.
f. BYPASS DOOR: Check inside the bypass door and clear any residual accumulation in the vicinity of the bypass door with brush or gloved hand.
g. AFT COWL DRAINS: Verify the 5 lower drain holes are clear and free from debris.
h. FINAL VERIFICATION (Aft Cowl): (1) In the Aft Cowl, small amounts of accumulation on the floor of the lower cowl are not a concern. (2) Snow must be COMPLETELY clear from the upper surfaces of the forward and aft cone and around the bypass door. (3) If large amounts are on the floor, or the area under the ramp is suspected to have substantial accumulation, a heater should be used to melt and drain away the residual water. […]

Figure 10: Excerpt from De Havilland's procedure for checking the engine air inlets. Source: De Havilland

Widerøe has included parts of this procedure in its operating manuals. A tactile (physical) check of the inlet was not part of the procedure at the time of the incident.

Cold Weather Operations Pre-Flight Checklist
Engine Air Inlets.. Check
– Visually inspect the engine air intake. Contaminants like rain slush and snow may pool in the bottom of the engine intake and form an ice sheet which is hard to detect. The DHC-8 has suffered several engine flameouts as result of this ice breaking loose and interrupting the engine intake airflow. […]

Figure 11: Excerpt from OM B. Source: Widerøe

1.6.7 ENGINE IGNITION SYSTEM

The DHC-8-311's ignition system has electric spark plugs in the combustion chamber that ignite the fuel mixture. Once the fuel has been ignited, the spark plugs no longer serve any function and can be switched off. However, as an added safety measure the crew may activate the system so that the spark plugs provide continuous sparks. This is done in conditions where it is likely that the airflow could be disrupted or that combustion could be affected by moisture, resulting in a flameout. If this occurs and the switch is on, the spark from the spark plug will relight the flame.

The switch for the system has three positions: 'OFF', 'MANUAL' and 'AUTO'. In the 'OFF' position, the spark plug has no power and cannot produce a spark. With the switch in the 'MANUAL' position, the spark plug will provide continuous sparks. When the DHC-8 was first certified, these were the only two positions. 'MANUAL' was used to start up the engines, after which the switch was set to 'OFF'. To improve safety and prevent the engine from stopping, the switch was set to 'MANUAL' for certain parts of the flights, for example when flying in turbulence and icing conditions.

The manufacturer has since offered a voluntary upgrade of the system to include an 'AUTO' function. This function is intended to restart an engine that stops completely without a technical cause, as well as providing spark on start-up. By technical cause is meant failure of one or more engine components. If the RPM of the engine's high-pressure turbine drops below 60% while the switch is set to 'AUTO', the engine's ignition system will activate and the spark plugs will provide continuous sparks. This will ensure ignition of the fuel mixture in the combustion chamber. By comparison, the high-pressure turbine's idle running speed is 74–76%. In aircraft with this upgrade, the switch will normally always be set to 'AUTO'.

All Widerøe aircraft have had this modification.

1.6.8 DE-ICING SYSTEMS

The DHC-8-311 has a pneumatic de-icing system supplemented by electrical de-icing of selected systems. The flight deck windows, the sensors of the pitot-static system (including angle of attack sensor), the leading edges of the propeller blades, the compressor intake flange and the elevator horn are electrically heated. All these systems, except for the compressor air intake, are continuously heated. The intake flange is only heated when the intake bypass door at the rear of the plenum chamber is open and the air temperature is below 15°C. The electrical systems are intended to prevent ice from forming and are therefore referred to as anti-icing systems.

The pneumatic de-icing system consists of rubber boots inflated by hot compressor air led into them from the engines. The de-icing boots are located on the leading edges of the wings, around the engine air inlet and on the leading edges of the horizontal and vertical stabilisers. When the boots are inflated, any ice that has formed will break and fall off, which is why this is referred to as a de-icing system. The system is activated from the cockpit and automatically controlled. Not all the boots are inflated simultaneously. They are divided into six groups that are inflated in a given order. Each group is inflated for six seconds. After 36 seconds, all the boots have been inflated once and the system enters a rest period. Depending on the speed, the system has a rest period of 24 seconds (fast) or 204 seconds (slow) between cycles. The crew set the speed.

1.6.9 WEATHER RADAR

LN-WFO was equipped with a Honeywell Primus 800 (HW800) weather radar. It is the primary source of information about precipitation and areas of potential convective activity during flight. It scans the area in front of the aircraft, and signals reflected from water droplets are returned to the radar. The pilots' radar display will show the weather situation ahead in real time. The weather radar depends on liquid water that can reflect the radar beams. The presence of liquid water in combination with low (sub-zero) temperatures will indicate freezing rain and a risk of icing.

HW800 is a conventional weather radar that requires manual corrections and input for optimal use. It is not equipped with automatic tilt, nor does it have an inbuilt logic to filter out ground clutter.

The aircraft is certified in accordance with Appendix C to FAR Part 25 (see section 1.6.4), which means that the aircraft should not operate in icing conditions with a droplet size exceeding 50 micron.[15] The droplet size for drizzle and rain starts at 200 micron, while 50 micron is about half the diameter of a human hair.

The radar is less suited to detect icing in such conditions because the droplets are too small. It also lacks the ability to detect small ice crystals that contain little or no liquid water. Convective weather systems may contain high concentrations of such ice crystals.

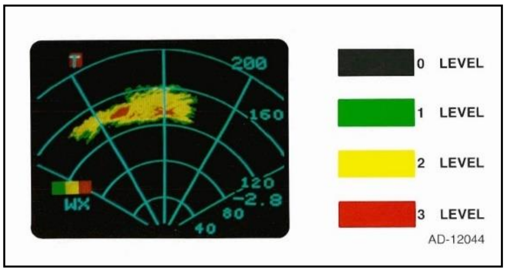
---

[15] CS-25 Appendix C Part I (a) and (b)

Freezing rain droplets will be more reflective. A weather radar is thus highly suited to the task of identifying cells with high water content and functions as a tactical tool to help pilots navigate around rain showers. It will also be suited to detect cells or areas of supercooled large droplets (SLD).

The weather radar is considered a reliable source that returns real-time data. Pilots should therefore avoid areas shown on the radar when the temperature is at or below freezing.

The weather radar in the aircraft has four levels of precipitation intensity: black, green, yellow and red, with red indicating a precipitation intensity of more than 12 mm/hour.



DISPLAY LEVEL	RAINFALL RATE (MM/HR)	RAINFALL RATE (INCHES/HR)	VIDEO INTEGRATED PROCESSOR (VIP) CATEGORIZATIONS: STORM CATEGORY	VIP LEVEL	RAINFALL RATE (MM/HR) (INCHES/HR)	*MAXIMUM CALIBRATED RANGE (NM) 12-INCH FLAT-PLATE	*MAXIMUM CALIBRATED RANGE (NM) 18-INCH FLAT-PLATE	*MAXIMUM CALIBRATED RANGE (NM) 24-INCH FLAT-PLATE
3 (RED)	GREATER THAN 12	GREATER THAN 0.5	EXTREME	6	GREATER THAN 125 (5)			
			INTENSE	5	50-125 (2-5)			
			VERY STRONG	4	25-50 (1-2)			
			STRONG	3	12-25 (0.5-1)	100	120	170
2 (YELLOW)	4-12	0.17-0.5	MODERATE	2	2.5-12 (0.1-0.5)	70	90	105
1 (GREEN)	1-4	0.04-0.17	WEAK	1	0.25-2.5 (0.01-0.1)	45	68	80
0 (BLACK)	LESS THAN 1	LESS THAN 0.04				—	—	—

AD-12043

Figure 12: The image on the left shows the weather radar display in the cockpit of a DHC-8. The table on the right shows colour codes based on precipitation intensity. Source: De Havilland

1.6.10 OTHER SENSORS AND DE-ICING INDICATORS ON BOARD THE AIRCRAFT

The DHC-8-311 has no indicators or instruments in the cockpit that warns pilots of icing. The crew therefore rely on visual cues to verify that ice is accumulating on the aircraft. The pneumatic boots on the leading edge of the wings are black, which makes it easy to see ice accumulating. The icing intensity can be assessed in relation to how effective the boots are at removing the ice.

There is also a spigot installed on each windshield wiper arm to indicate ice formation. The spigot is easily visible to pilots and projects just over an inch into the airflow.

Figure 13: Spigot of the type shown in Figure 2. Photo: Widerøe

Centrifugal forces will dislodge ice that forms on the propeller blades and fling it out in the propeller plane. This effect increases with the rotational speed of the propeller. Ice hitting the fuselage will produce sound and vibration, which are good indicators that the aircraft has entered an area of severe icing.

1.7 Meteorological information

1.7.1 THE WEATHER SITUATION

Following the incident, the NSIA requested that the Norwegian Meteorological Institute prepare a report about the weather situation in the area at the time of the incident. The complete weather report from the Norwegian Meteorological Institute is included as Appendix A.

The Norwegian Meteorological Institute reported that, during the time in question, there was a low-pressure system in the Norwegian Sea and a high-pressure system over the British Isles that extended far east over Europe. This resulted in a strong westerly flow of air between these two pressure systems, which hit the coast of Norway. The ground wind was southwesterly-westerly strong breeze to moderate gale, while storm to violent storm were observed in the mountains and at some lighthouses along the coast. Kvernberget Airport experienced gusts as strong as 50 kt. The wind at the top of Kvernberget mountain was measured to storm force winds with gusts in excess of 70 kt.

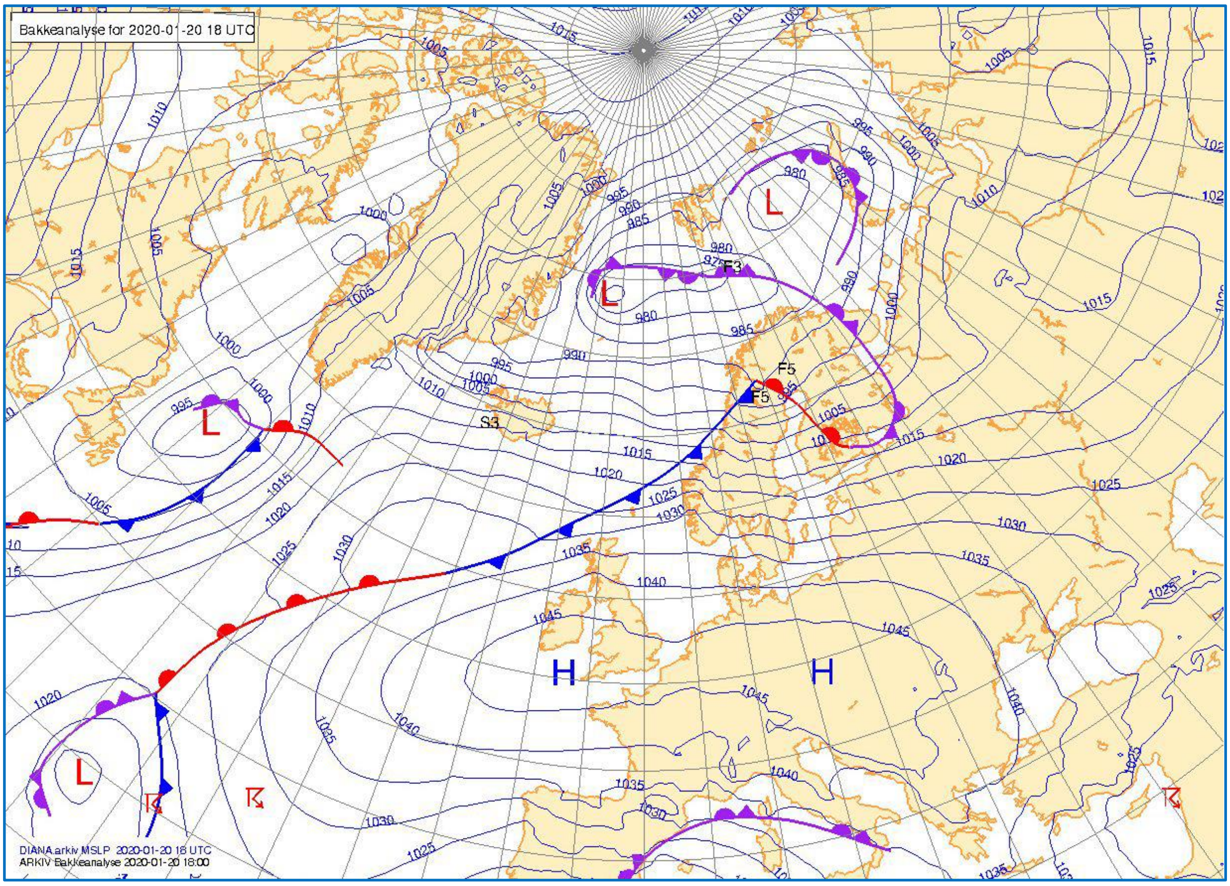


Figure 14: Overview map showing the weather situation on 20 January at 1800 hours (UTC). Source: Norwegian Meteorological Institute

METAR weather reports from Kvernberget and Flesland airports for the period before and after departure and climb showed the following:

ENKB 201820Z 24033G51KT 5000 SHRA FEW002 SCT012 BKN017 09/07 Q1013 RMK WIND 745FT 25058G71KT=

ENKB 201850Z 24034G50KT 7000 -SHRA FEW002 SCT016 BKN021 09/07 Q1013RMK WIND 745FT 25053G66KT=

ENBR 201820Z 18010KT 2000 -DZ BR VV002 08/08 Q1029 BECMG 25015G25KT TEMPO 3500 -DZ BR RMK WIND 1200FT 23016KT=

ENBR 201850Z 19010KT 2000 -DZRA BR VV002 08/08 Q1029 BECMG 25015G25KT TEMPO 3500 -DZ BR RMK WIND 1200FT 23017G32KT=

The strong winds caused mountain waves in the mountains of Southern Norway, which in turn caused turbulence to be forecasted in the Trøndelag region. The following SIGMET was valid for the area in question:

ENBD SIGMET C05 VALID 201500/201900 ENVVENOR NORWAY FIR SEV MTW FCST WI N6200 E00500 – N6215 E00500 – N6310 E00730 – N6245 E01130 – N6200 E01100 – N6200 E00500 SFC/FL400 STNR WKN

There was also a cold front parallel with the northern coast of Western Norway that was moving in a south-easterly direction. This weather system extended from northern Sweden to a point far out to sea east of Great Britain. The Norwegian Meteorological Institute wrote in its report that strong winds from the sea caused orographic lift, which in turn led to icing. In combination with mountain waves and convective clouds, this could intensify icing by further lifting supercooled droplets. Icing in connection with cold fronts is laterally limited compared to warm fronts, and often occurs in 'pockets' along the front. Icing in front of warm fronts affects a larger lateral area and is more common. Figure 15 below is taken from the Norwegian Meteorological Institute's report.

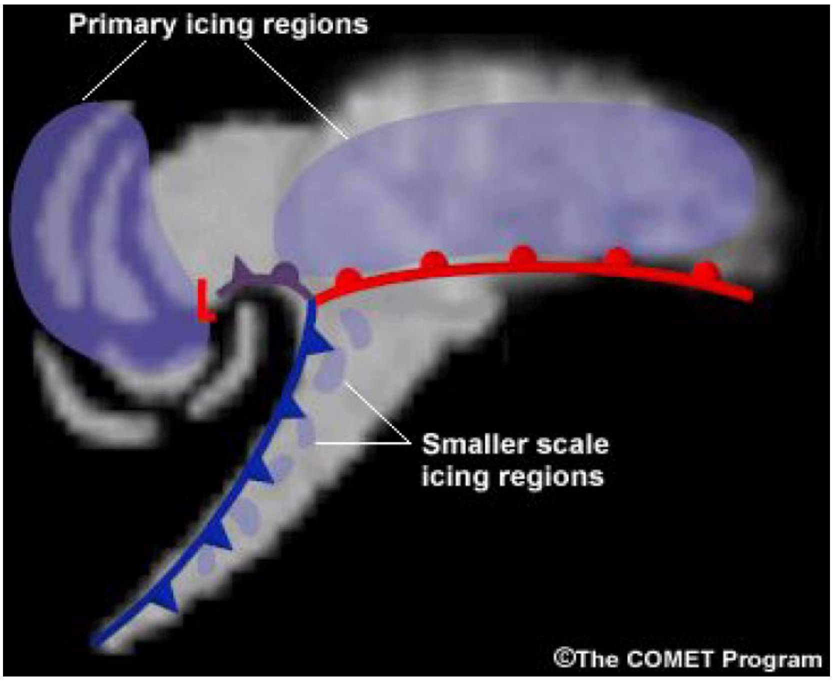


Figure 15: Illustration of icing in warm and cold front systems. Source: Norwegian Meteorological Institute

Moderate precipitation had been forecast in connection with the front during the period in question. The ground temperature was 8–9°C, and the zero-degree isotherm was between 3,000 and 5,000 ft. The Norwegian Meteorological Institute had received an AIREP concerning moderate icing in the area earlier in the afternoon. They wrote that this was expected in connection with a cold front moving in over land.

The following AIRMET[16] was valid during the time when the icing occurred. Figure 16 shows AIRMET coordinates plotted on a map.

ENBD AIRMET C05 VALID 201600/202000 ENVVENOR NORWAY FIR MOD ICE FCST WI N6200 E00500 – N6300 E00400 – N6500 E00605 – N6500 E01415 – N6400 E01400 – N6200 E01210 – N6200 E00500 3000FT/FL180 STNR NC

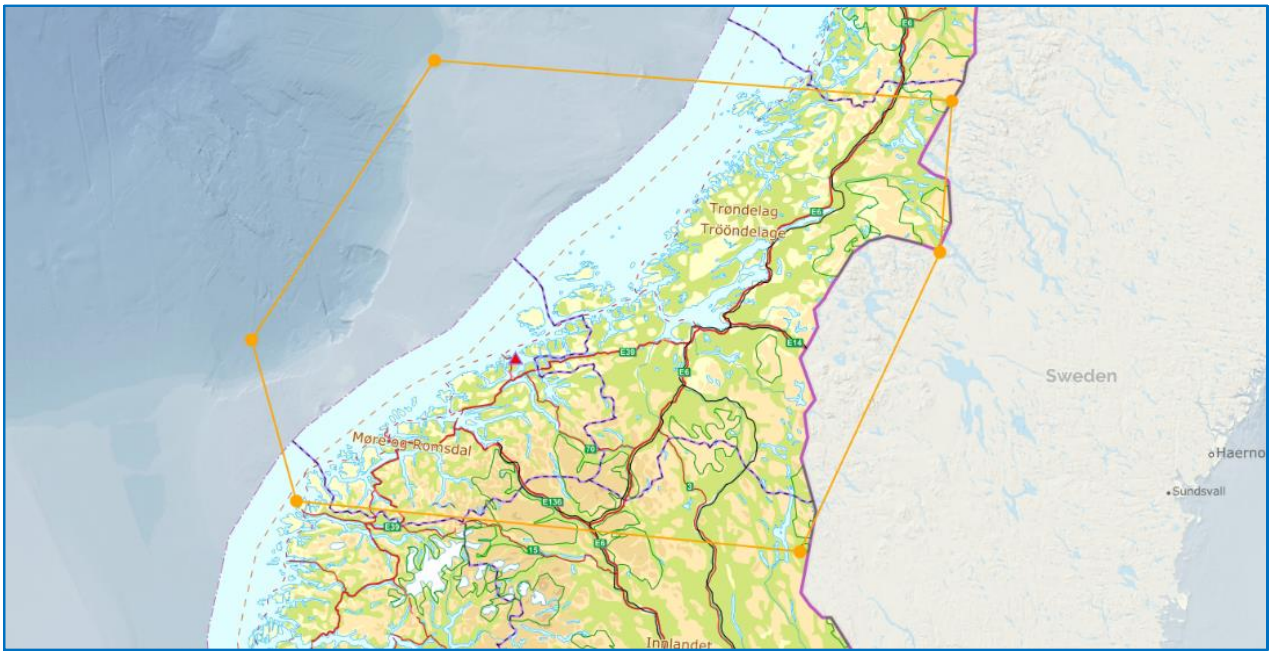


Figure 16: AIRMET coordinates plotted on a map. Map: © Norwegian Mapping Authority. Ilustration: NSIA

[16] In Norway AIRMET is used for warnings of moderate icing when weather conditions require it. Cf. BSL-G 1-3 § 5-5.

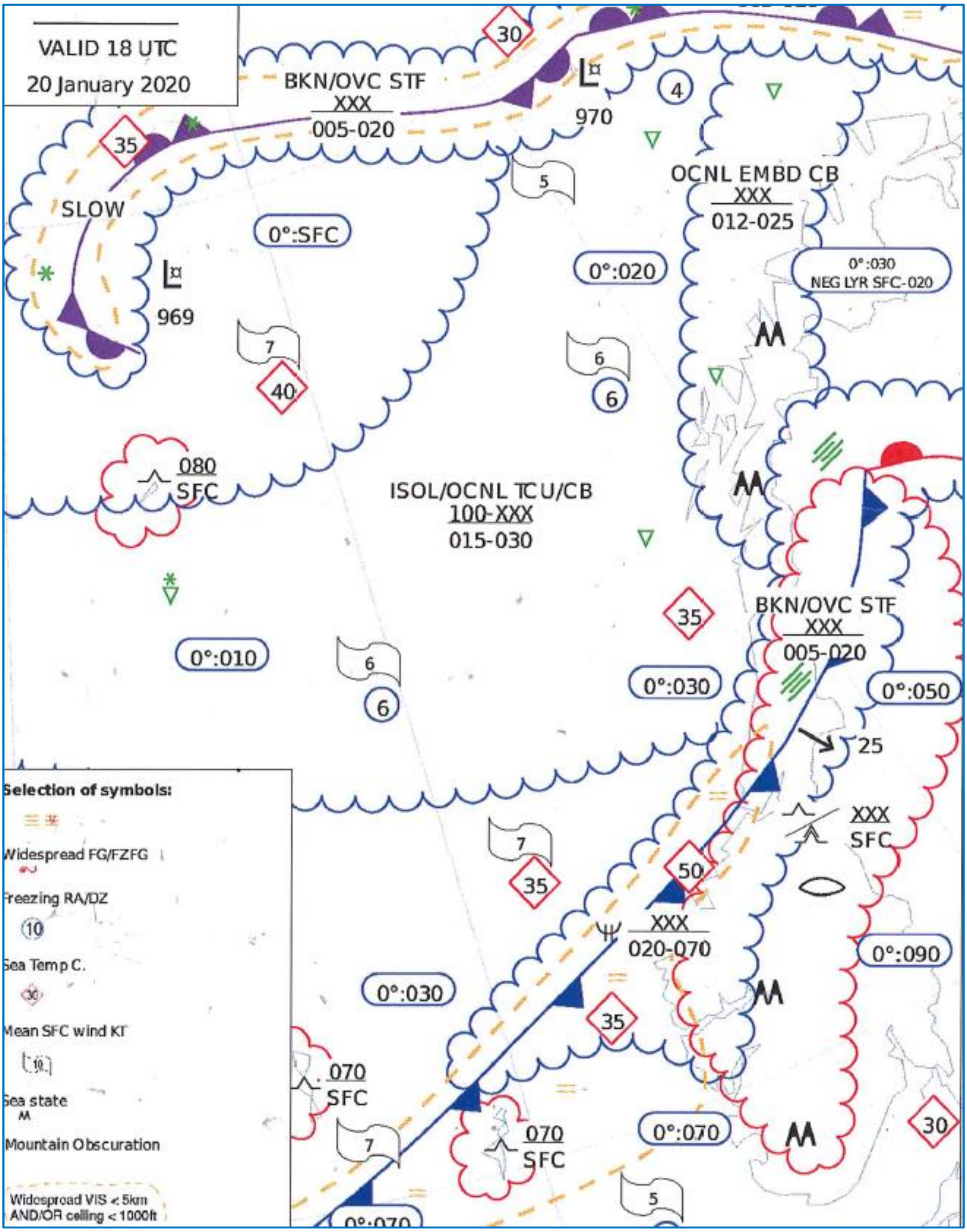


Figure 17: Section of significant weather chart valid on 20 January at 1900 hours. Source: Norwegian Meteorological Institute

1.7.2 METEOROLOGICAL INFORMATION AVAILABLE BEFORE THE FLIGHT

The process of communicating meteorological information to pilots can be divided into two main phases. One phase falls before the flight (the briefing phase), the other during flight (the flight phase). During the first phase, the pilots receive meteorological information for the route they are to be flying in a dedicated briefing package, including alternative routes and destinations. The minimum requirements for meteorological information to be provided are set out in ICAO Annex 3 – Meteorological Service for International Air Navigation (ICAO Annex 3), and in Commission

Implementing Regulation (EU) 2017/373, Annex V Part-MET. This information is brought on board either on paper or in electronic flight bag (EFB) format.

The briefing package available to the crew before the flight has been made available to the NSIA. It contained the operational flight plan in addition to information about weather and NOTAM, plus other essential information of relevance to the flight. The meteorological information consisted of TAF and METAR reports for a selection of airports along the route, in addition to AIRMET/SIGMET messages, significant weather charts and wind charts. The complete weather data from the briefing are included as Appendix B.

The briefing contained three different weather charts, including two significant weather charts and a wind chart (see Figure 18). The wind chart indicated the wind speed and direction at the planned cruising altitude. The planned route, with reporting points, was also shown on the map.

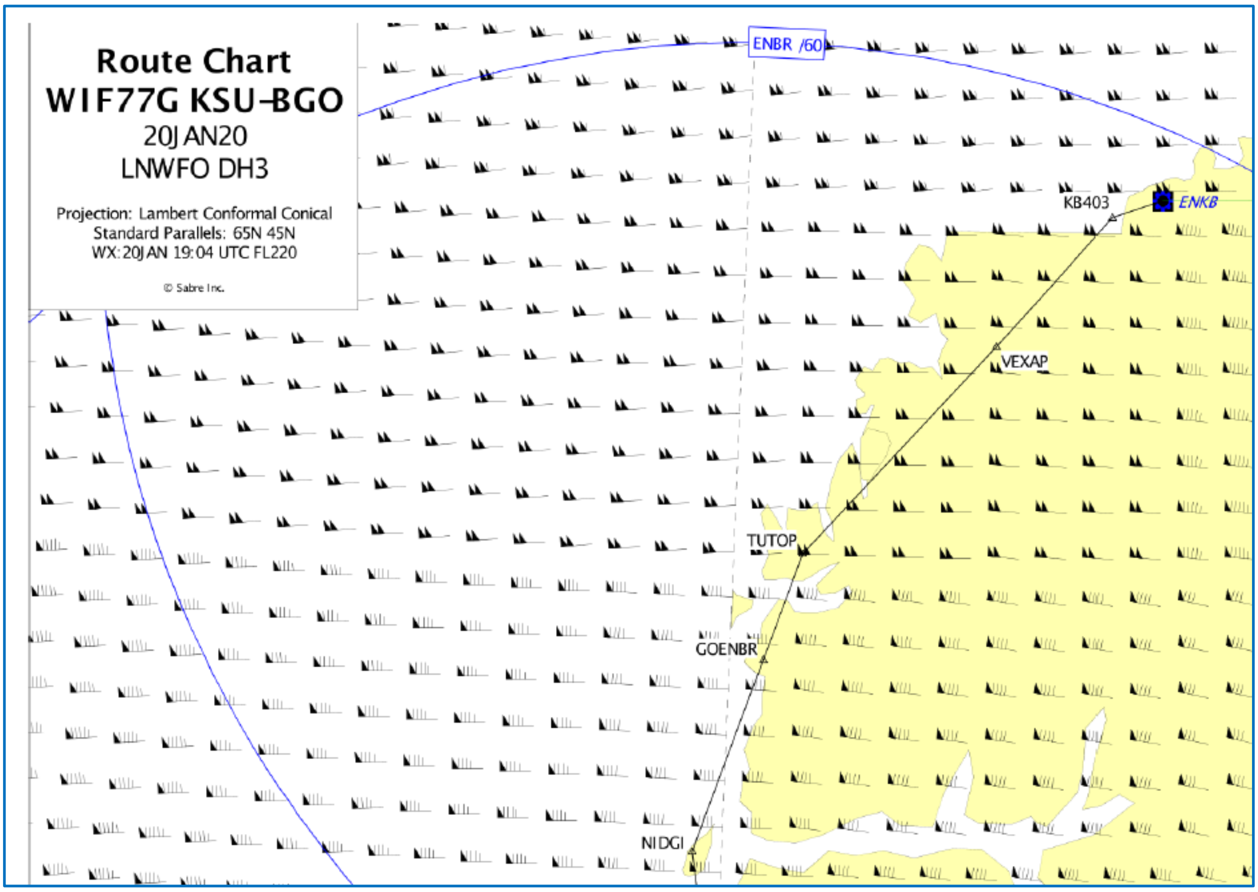


Figure 18: Section from the wind chart enclosed with the pilot briefing, showing the wind forecast for FL220. Source: Widerøe

One of the two significant weather charts had been issued by the World Area Forecasting Centre (WAFC) in London (see Figure 19), the other one by the Finnish Meteorological Institute (FMI). The weather chart from the WAFC meets all requirements for significant weather charts and shows the weather at altitudes above FL100 over a large geographical area. Aircraft operators can choose to use local significant weather charts that cover a smaller geographical area and show the weather situation from ground level. Widerøe had chosen to use the FMI's map because it covered Sweden and Finland as well as Norway. The Norwegian significant weather chart only covered Norway.

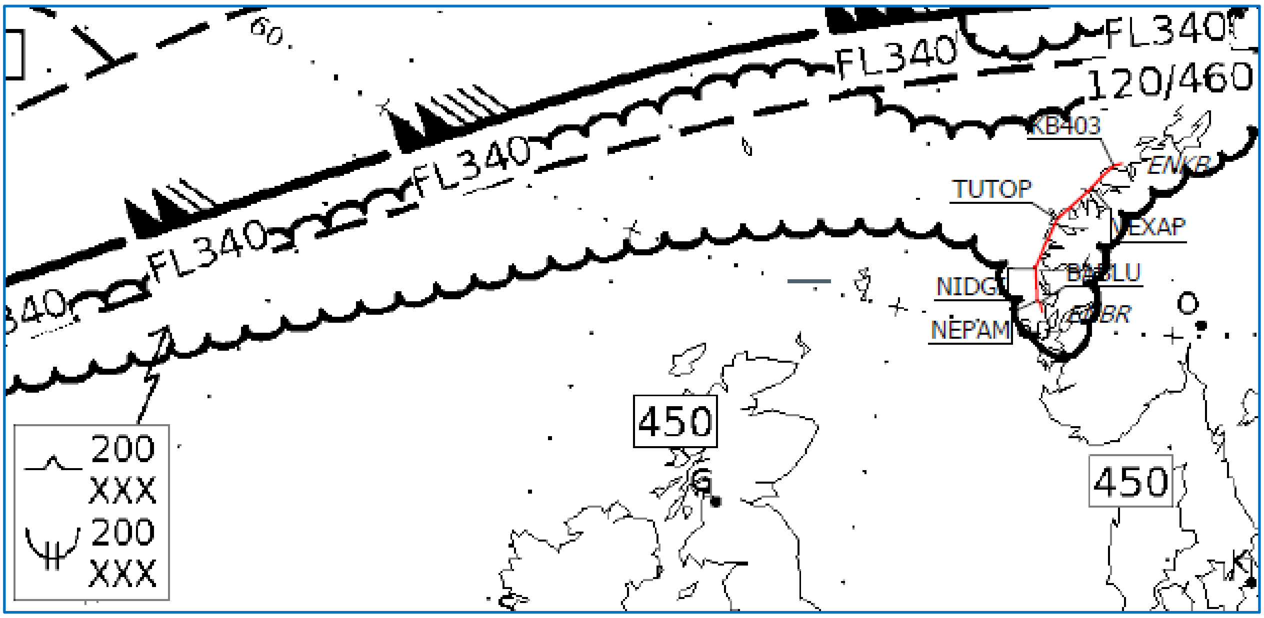


Figure 19: Magnified section of the WAFC significant weather chart valid on 20 January at 1900 hours. Source: World Area Forecasting Centre (WAFC)

The Norwegian Meteorological Institute had issued three active SIGMET/AIRMET messages concerning icing. They were included in the briefing in text form with coordinates. One of them concerned severe icing in the Helgeland region. The other two forecast moderate icing along the planned flight path up to a maximum of FL180. The flight was planned to take place at altitudes above this icing area (FL220), except for the approach and departure. This situation was reflected in the significant weather chart issued by the Norwegian Meteorological Institute (see Figure 17), but the information had not been made available to the crew, who had the Finnish version.

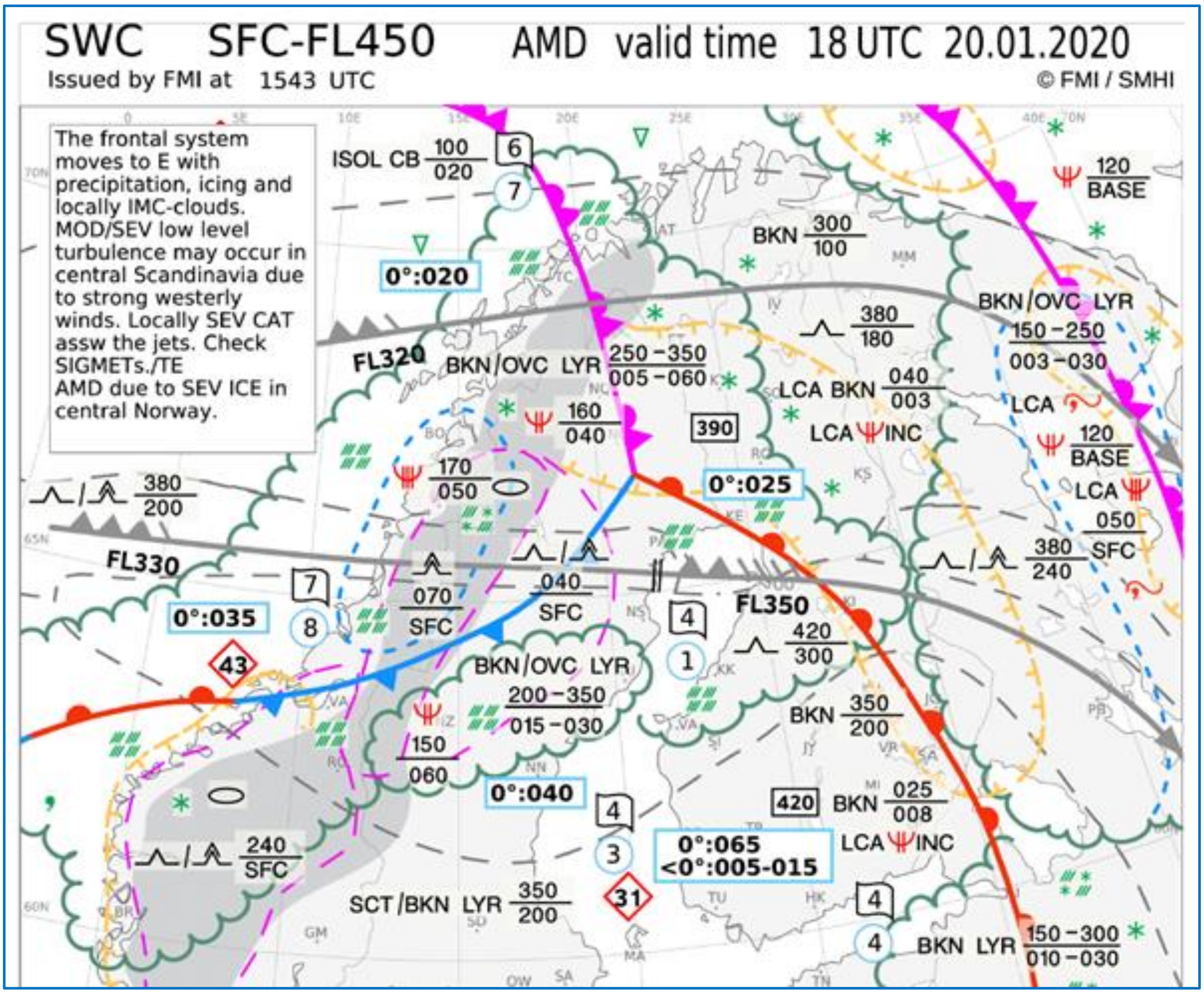


Figure 20: Section of the FMI's significant weather chart valid on 20 January at 1900 hours. The symbol indicating moderate icing is placed east of Bodø and covers the coast all the way south to Bergen. Source: FMI

1.7.3 METEOROLOGICAL INFORMATION AVAILABLE DURING THE FLIGHT

The availability of up-to-date weather information during the flight phase varies, and the information is often limited in terms of content and format. There are normally three sources of such up-to-date information, in addition to the human senses such as sight and hearing. They are:

1. Weather radar, as discussed in section 1.6.9.
2. Other weather sensors on board the aircraft, as discussed in section 1.6.10
3. Updates via communication channels.

Updates via communication channels could be updates that the pilots receive via the Aircraft Communications Addressing and Reporting System (ACARS), SatCom/WiFi or VOLMET[17] broadcasts on VHF/HF radio, and Automatic Terminal Information Service (ATIS).

Widerøe has neither ACARS nor SatCom installed in its DHC-8 aircraft, and Norway no longer operates a VOLMET service. This limits the available information to what the crew can receive

[17] *VOLMET or meteorological information to aircraft in flight is a global network of radio stations that broadcast TAF, SIGMET and METAR reports on short-wave frequencies, and in some countries also on VHF.*

from ATIS, or from the air traffic service on request. ATIS is airport-specific, and not all airports offer this service. Nor does it cover areas between airports.

The air traffic service uses information from SIGMET/AIRMET and information from aircraft. If no aircraft have reported weather conditions, the air traffic service has only airport-specific information available in addition to SIGMET/AIRMET. The crew of WF577 contacted the air traffic service to obtain updated information about icing, but received no new information because no one had previously experienced icing in the area. In this case, the pilots were left with the information they could download to their EFBs on the ground before each flight. This could be updated information for the operational flight plan or updated weather information.

Widerøe uses Jeppesen FliteDeck Pro as the route manual on its EFBs. This application allows for forecast icing at different altitudes to be displayed (see Figure 21). The figure below shows example where light, moderate and severe icing is forecast along the west coast of Norway. The example is not from the day of the incident. At the time of the incident, it was not a recommended procedure nor a requirement to check the Jeppesen application for forecast icing before a flight, and nor did the crew do so.

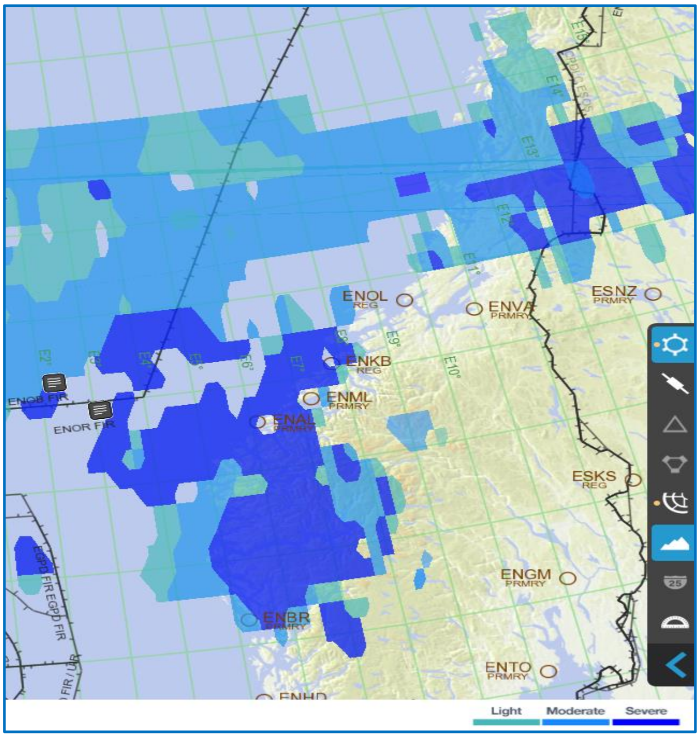


Figure 21: Illustration from electronic flight bag (EFB) showing icing in the same area. This image is from another day. Source: Jeppesen

1.8 Aids to navigation

Not applicable.

1.9 Communications

After departure, WF577 contacted Norway Control on the frequency 125,700 MHz. They were immediately offered a direct route to NIDGI, which was the first approach point to Bergen Airport. The offer was accepted, and the aircraft set a south-westerly course for the point.

When they started to experience icing, they requested altitude and course adjustments, all of which were granted. They also submitted an AIREP of MOD ICE to the air traffic service, which confirmed receipt.

When both engines flamed out, they made a Mayday call to Flesland Approach and they were given priority for landing on runway 17. The Mayday was cancelled 30 seconds later when engine power had been restored.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

1.11.1 COCKPIT VOICE RECORDER (CVR)

LN-WFO was equipped with an L3 Communications Solid State cockpit voice recorder (SSCVR) with 120 minutes' storage capacity. The voice recorder stores a recording of the communication between the crew members and between the crew and the air traffic service. The recordings will continue until the CVR is disabled by pulling the circuit breaker or the power supply is interrupted. The recording on the aircraft's CVR was secured after the incident, but some time passed before it was done. Consequently, the recording is missing the first 28 minutes of the flight. The recording was of good quality and has been highly useful during the investigation.

The following text is a summary of the dialogue that was recorded on the CVR between the two in the cockpit from the first engine failure until both engines were running normally again. During this period, they were also getting established on the ILS to runway 17 at Flesland.

Immediately after the left engine had a flameout, the first officer informed the captain that the torque on engine no. 1 was low. The captain confirmed this and they agreed that they had experienced a flameout and that the cause was probably ice that been sucked into the engine. They noticed that the engine restarted almost immediately.

A full check of all engine instruments on engine No. 1 was then carried out, with subsequent follow-up questions from the captain whether the first officer had made other observations. When he answered, they got another flameout. This time on engine No. 2. At the same moment, Flesland Approach called WF577 on the radio and gave them clearance for the ILS approach. The crew responded to the call and continued the approach towards Flesland. At the same time, they noted that engine No. 2 was regaining power, but that Engine No. 1 lost power for the second time. They were at this moment completely without engine power.

A few seconds later engine No. 2 restarted. The first officer informed the captain that approach mode was armed so they could continue the approach and at the same time they declared Mayday to Flesland Approach.

The crew continued the approach and the first officer informed of his plan to maintain good speed, good engine torque and plan for late configuration. They continued the discussion about the status of the ice and commented that most of it had loosened.

In total, the process described above lasted 2 minutes and 20 seconds.

1.11.1 FLIGHT DATA RECORDER (FDR)

The data for the flight in question were retrieved after the incident and made available to the NSIA. The recorded data were intact and have been important to the investigation.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

After landing on 20 January 2020, the aircraft was towed into a hangar at Flesland for technical examinations by Widerøe's personnel. Both engines were inspected with a borescope. The fuel tanks and filters were also examined to rule out the possibility of water in the fuel. The engines were examined, and some of the compressor blades were found to have sustained damage (see Figure 5).

The de-icing system (boots) on the wings and engine inlet were also checked, with no leaks or other faults being found.

The drainage holes below the air inlet were checked, and all were found to be open.

1.17 Organisational and management information

1.17.1 INTRODUCTION

Widerøes Flyveselskap AS was established in 1934, which makes it Norway's oldest airline. In 2021, the company stated that it was the largest regional airline in Scandinavia with a fleet totalling 40 DHC-8 (100/200/300 and the Q400 series) and three Embraer E190-E2. The company operates flights to several destinations in Norway and Europe. Widerøe's head office is in Bodø, and the company has a total of approximately 2,500 employees across its different bases and offices.

The company holds an Air Operator Certificate (AOC) to operate under the joint European regulations. The company's manual structure reflects this, and the pilots use only the company's operations manuals (OM). These manuals should address and cover the joint European regulations, the aircraft manufacturer's manuals, the regulations specific to Norway and the company's own procedures. In accordance with the joint European regulations, the operations manuals are divided into OM Parts A, B, C and D.

OM A describes the company organisation, its safety management systems and general information about how aircraft operations are to be carried out.

OM B describes how a specific type of aircraft is to be operated and includes the aircraft manufacturer's and the company's own procedures and limitations. Widerøe has three such manuals: one for DHC-8-100/200/300, one for DHC8-Q400 and one for E190-E2.

OM C contains the route manual with the company's navigation procedures and route maps including approach and departure procedures.

OM D describes how the company addresses the official requirements for pilots' training and instruction.

1.17.2 FLIGHT IN ICING CONDITIONS AND RELEVANT INFORMATION IN THE COMPANY'S OPERATIONS MANUALS

According to OM A, the crew shall report for duty 45 minutes before the first departure time for flights such as the flight in question. The time until departure should be spent collecting and reviewing information of relevance to the flights of the day. This includes checking weather and NOTAM information for the routes to be flown and deciding on the quantity of fuel to bring. For this purpose, Widerøe prepares a briefing package for the crew where all relevant information is enclosed. The crew are obliged to check the weather forecasts to evaluate where along the route icing could occur and where layers of milder temperatures can be found so they know which route to choose in case they encounter unusually intense icing. The crew also need to be aware of the air temperature and where the zero-degree isotherm is. This is described as follows in OM B:

> 2.11.8.20.1 General
> Flight in freezing rain, freezing drizzle, or mixed icing conditions (supercooled liquid water and ice crystals) may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or may not be shed using the ice protection systems, and may seriously degrade the performance and controllability of the aeroplane. The most effective means of avoiding exposure to hazardous icing include the following:
>
> – Use the weather forecast to evaluate where potential icing conditions are located in relation to the planned route, and which altitudes and directions are likely to be warmer or colder;
>
> – Stay aware of outside temperature. Know the freezing level (0 degrees static air temperature).

In interviews with the NSIA, the crew of WF577 stated that they had noted the icing forecast along the route, but that it was not emphasised or discussed. They mentioned that this kind of icing forecast was not unusual. It was implied that it is normal for crews to fly into areas of icing conditions and then take corrective action if the intensity of icing is perceived to be abnormal.

The company's aircraft are permitted to operate in icing conditions, subject to certain limitations. OM A describes how crews should deal with this in general terms. The company writes that the pilots must be aware that flying in icing conditions entails a higher level of risk and that they must understand the distinctive characteristics of different icing conditions and the potential effect on the aircraft's performance and limitations. Widerøe also describes the different types of icing that can accrete on the aircraft and the accumulation rates that pilots must consider.

In-flight Icing Accumulation Rates	
CAT	
Trace	Ice becomes perceptible, but is of no consequence and does not affect the performance of the aeroplane. It should be reported by pilots for meteorological purposes.
Light	The rate of accumulation may create a problem if extended flight in this condition occurs. It can be safely handled by the aeroplanes anti/de-icing equipment. No restriction to operations provided the systems are used.
Moderate	The rate of accumulation is such that even short encounters become potentially hazardous. The aeroplanes anti/de-icing equipment will safely handle it. However, for practical purposes, it should be a signal to the pilot to alter his flight path so as to avoid further exposure.
Severe	Adverse icing condition in which the rate of accumulation is such that the anti/de-icing equipment fails to reduce or control the hazard. Pilots must change the flight path immediately to establish more favourable conditions or land as soon as possible.

Figure 22: Table showing different degrees of icing. Source: Widerøe OM A

None of the company's aircraft are permitted to fly in severe icing conditions. Reference is made to the AFM and OM B for information about how pilots are to act if they inadvertently enter an area of such conditions. Leaving the area as soon as possible emerges as the top priority. All anti-icing and de-icing equipment must be activated before the aircraft enters icing conditions, and the crew must pay particular attention to the aircraft's speed and the possibility of uncontrolled roll movements. There is emphasis on how the icing affects the aircraft's aerodynamic properties, and consequently its stability, controllability and performance. The latter is associated with increased drag and decreased effect from the propellers.

Widerøe's OM B describes the same procedure for flights in severe icing conditions as reproduced in Figure 8, and it also describes a procedure for 'flight in actual icing conditions'.

Flight in Actual Icing Conditions

The primary indication of ice is a build-up on the ice detector post mounted on the windshield wiper arm. When in actual icing conditions, monitor accumulation of ice on the airframe and turn on all anti-ice equipment, including the INCR REF SPEED switch for the DHC-8-300. Do not wait for ice to build up before selecting airframe de-ice. Climb no slower than en-route climb speed.

Do not wait until ice has collected before turning on propeller anti-ice.

Condition Levers .... **As required**

– The effectiveness of the propeller de-icing system can be improved and propeller vibration reduced by operating the propellers at different RPMs.

De-ice Boots .... **AUTO**

– Monitor ice accumulation between boot cycles to confirm that the selected AIRFRAME MODE rate (FAST or SLOW) is appropriate;
– Cycle de-icing boots in FAST mode before starting hold, approach or landing when in icing conditions;
– Monitor wing and tail De-icer Boot advisory lights for normal operation.

If performance loss is significant in icing conditions, disengage autopilot. Stall properties may change with ice collection.

Figure 23: Excerpt from OM B. Source: Widerøe

OM A does not mention how ice could affect the engine itself, but states that large quantities of water in connection with thunder showers could cause an engine flameout.

OM A describes the following regarding severe icing:

Severe icing is often associated with supercooled large droplets (i.e. freezing drizzle or rain). Flight in these conditions is not covered by icing certification rules. Droplets covered by icing certification envelopes are so small that they are usually below the threshold of detectability. The most effective means of identifying severe icing conditions are cues that can be seen, felt or heard. This includes visual inspection of aeroplane surfaces, e.g. wings, propeller or windscreen. At temperatures near freezing it may be possible to detect large droplets splashing or splattering upon impact with the windscreen.
When exposed to severe icing in the form of supercooled large droplets, perform the following actions:

1. Disengage the autopilot and hand-fly the aeroplane. The autopilot may mask important cues or may self-disconnect and present unusual attitudes or control conditions.
2. Advise air traffic control and promptly exit the condition, using control inputs that are as smooth and small as possible.
3. Change heading, altitude or both to find an area that is warmer than freezing, substantially colder than the current ambient temperature, or free of clouds.
4. When severe icing conditions exist, reporting may assist other crews in maintaining vigilance. Submit a PIREP of the observed icing conditions. It is important not to understate the conditions or effects of the icing observed.

OM A goes on to mention that the certification standards have limitations, among other things when it comes to freezing rain and drizzle:

Also, it is important to remember that the certification standards provide protection for a wide variety of atmospheric conditions encountered, but not for freezing rain or freezing drizzle or for a mixture of supercooled droplets and snow or ice particles. Some aerofoils are degraded by even a thin accumulation of ice aft of the de-icing boots which can occur in freezing rain or freezing drizzle. For this reason, **the AFM/OM Part B must always be consulted** for aeroplane type specific information regarding flight in known icing conditions.

OM B Chapter 1 defines the aircraft's limitations. It states that the aircraft can operate in icing conditions, but that an icing rate corresponding to severe icing could result from operating in atmospheric conditions outside of those for which the aircraft was certified. The definitions of icing conditions and severe icing are also reproduced from the aircraft manufacturer's AFM.

WARNING: Severe icing may result from environment conditions outside of those for which the aeroplane was certificated.

It is not mentioned under the aircraft's limitations that ice could cause the engines to stop.

OM B Chapter 2 deals with normal procedures. The fact that ice could cause the engines to stop is mentioned twice in this chapter, first in connection with external inspection of the aircraft and then in a separate sub-chapter on icing. The importance of inspecting the engine's air inlet is emphasised in the description of the external inspection. It is mentioned that the DHC-8 has experienced several cases of flameout caused by ice detached from the air inlet disrupting the airflow.

OM B Chapter 2 also contains an extensive sub-chapter on icing, types of icing, classification of ice, freezing rain and droplet sizes, how ice affects the wing profiles as well as stability and controllability, and, finally, procedures for operating in icing conditions. Section 2.11.8.1.1 describes how ice that enters the engine or disrupts the airflow into the engine could cause the engine to stop.

The section also describes in detail what the crew should do if the aircraft inadvertently enters areas of severe icing. It is also mentioned that the crew must use weather forecasts to evaluate where potential icing conditions could occur in relation to the planned route, and at which altitudes and courses the air masses are likely to be warmer or colder. Visual cues that the crew can use to assess the degree of icing are also described:

Flight in freezing rain, freezing drizzle, or mixed icing conditions (supercooled liquid water and ice crystals) may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or may not be shed using the ice protection systems, and may seriously degrade the performance and controllability of the aeroplane. The most effective means of avoiding exposure to hazardous icing include the following:

- Use the weather forecast to evaluate where potential icing conditions are located in relation to the planned route, and which altitudes and directions are likely to be warmer or colder
- Stay aware of outside temperature. Know the freezing level (0 degrees static air temperature)

Tactile cues such as vibration, buffeting or changes in handling characteristics normally trigger a mental warning that ice has already accreted to a perceptible and perhaps detrimental level.
Typically, as ice increases in thickness, cues become more prominent. During flight, severe icing conditions that exceed those for which the aeroplane is certificated shall be determined by the following visual cues:

- Unusually extensive ice on the airframe in areas not normally observed to collect ice
- Accumulation of ice on the side windows of the flight compartment aft. of the leading edge
- Accumulation of ice on the upper or lower surface of the wing aft. of the protected area
- Accumulation of ice on the propeller spinner farther aft than normally observed

Considering the aerodynamic effects of icing, a special landing technique is also described, and the use of low flap settings is discussed and recommended:

If ice buildup exists on protected surfaces, selection of landing flap may be accompanied by stick force lightening or irregularities. Should this occur, immediately retract flap to previous setting and cycle the airframe de-ice several times. If possible, land using low flap settings to avoid the risk of tailplane stall.

OM B Chapter 12 *Aeroplane Systems* refers to the Widerøe Pilot Training Manual. The manual describes the engine's ignition system and includes a comment that ice could cause the engine to stop.

Widerøe's manuals contain several descriptions of how ice will affect the stability and controllability of an aircraft, and the aerodynamic aspects are emphasised. It is also implied that ingestion of contaminants such as ice or water could cause a flameout. This is mentioned in four different places in the manuals, but not summarised in such a manner as to show the link between severe icing and the risk of engine failure.

1.18 Additional information

1.18.1 REPORTED INCIDENTS OF A SIMILAR NATURE

1.18.1.1 Incidents involving DHC-8 aircraft

1 DECEMBER 2019, WIDERØE DHC-8-300, LN-WFC, TROMSØ
During a positioning flight with only the crew on board, the right engine stopped shortly after departure. The pilots declared an emergency, flew a visual landing circuit and landed with one engine on runway 36. The aircraft had been parked outside overnight in heavy snowfall, but the air inlet covers on both engines had been in place. The commander reported little snow on the aircraft surfaces before start-up, but the aircraft remained stationary for a while during de-icing in heavy snow showers and wind. In the incident report, Widerøe wrote that it was suspected that the engine failure was caused by ice detaching from the engine air inlet during take-off.

30 JANUARY 2005, WIDERØE DHC-8-103, LN-WIM, SANDNESSJØEN
LN-WIM was on approach to Sandnessjøen at an altitude of approximately 1,600 ft when the crew heard a low bang and discovered that the right engine was stopping. The lowest RPM registered was 42% before the engine re-ignited and returned to its normal engine settings. Widerøe's internal investigation committee deemed it most likely that precipitation had entered the air inlet while the aircraft was parked at Værnes Airport, and that it had frozen to ice that dislodged and was sucked into the engine just before the landing at Sandnessjøen. The investigation report contained 11 recommendations, many of which were not closed.

3 APRIL 2001, AIR CANADA REGIONAL AIRLINES DHC-8-100, C-GANS, SYDNEY, NOVA SCOTIA
The aircraft was climbing out from Sydney when the first officer discovered ice in the air inlet on the right engine. About five seconds later, the right engine stopped, but soon restarted thanks to the auto-ignition system. About two minutes after the restart, the right engine lost power again and restarted once again. After completing the required checklists, the first officer checked the air inlet again and observed that the ice was gone. The commander then checked the left engine and saw that there was ice in the left air inlet as well. A few minutes later, as the aircraft reached its cruising altitude of 14,000 ft, the left engine stopped and went through a similar flameout/relight sequence. The aircraft proceeded to its destination without further problems.

The Canadian aviation authority and certifying authority for the type of aircraft in question, Transport Canada (TC), concluded that the probability of both engines stopping due to icing and the pilots not succeeding in restarting at least one of them was low or improbable. De Havilland based this on the fact that no such incidents had taken place in the entire global fleet of DHC-8-100 aircraft, which had more than 10 million hours of flight time in total. Even though the auto-ignition system had worked, follow-up measures were nevertheless required to ensure sufficient assessment of the risk of ice accumulating during flight.

20 MARCH 2001, DHC-8-311, BRISTOL, UK
The aircraft experienced a flameout on both engines as it was standing ready for departure. Ice detached from the air inlets and disrupted the airflow to the engines. The ice had probably formed in the air inlet during ground stop.

14 FEBRUARY 1988, DHC-8-102, ST. JOHN'S, NEWFOUNDLAND
The aircraft experienced a flameout first on the right engine and then on the left while climbing out. Ice detached from the air inlets and disrupted the airflow to the engines. The ice had probably formed in the air inlet during ground stop.

7 OCTOBER 1987, DHC-8, KAPUSKASING, ONTARIO
The aircraft experienced a flameout in one engine while climbing out. Ice detached from the air inlet and disrupted the airflow to the engine. The ice had probably formed in the air inlet during ground stop.

1.18.1.2 Incidents in Norway involving other aircraft

Since 2000, the NSIA has published 14 reports on incidents and accidents whose causes have been related to icing. Five of these incidents concerned aircraft that entered areas of severe icing and were exposed for so long that their stability and controllability were affected, resulting in temporary loss of control. All aircraft involved were turboprop, but none of the incidents involved a DHC-8. The investigation reports regarding these five incidents are available on the NSIA's website[18] under report numbers 2000/81, 2006/31, 2009/02, 2015/09 and 2020/16.

The NSIA would like to draw attention to a paragraph from SL REP 2009/02 and a safety recommendation from SL REP 2007/23 concerning the use of weather radar systems. The first incident involved an ATR that entered severe icing conditions over the glacier Folgefonna in 2005[19] and the second involved a Kato Air aircraft that was hit by lightning in 2003.

> Despite the fact that there had been warnings of local moderate icing along the route, the weather radar was not in use when CST602 took off that morning. This may indicate that the crew had a low level of awareness of the importance of using the weather radar as an aid for avoiding severe icing. This could be quite understandable since, in ordinary use, the focus of weather radar is primarily the avoidance of areas subject to severe turbulence. The radar would however probably also have registered areas with heavy precipitation ahead. Information from the weather radar could thereby have made it possible for the crew to plan their route outside the cells with heaviest precipitation and greatest risk of severe icing, and would therefore have been an important aid if it had been put to optimal use. A lack of knowledge about the use of weather radar has been identified as a safety problem in civil aviation (Rosenkrans, W. 'Surveillance Without Surprise', April 2007, Flight Safety Foundation Aerosafety World). The AIBN pointed out the same problem in a report concerning an accident after a lightning strike, Kato Airline Bodø on 4 December 2003 (SL REP 2007/23).

> Safety recommendation SL 2007/22T.
> A functional airborne weather radar system and optimal use of such a system are important in localizing precipitation cells and thereby avoiding flying into areas with hazardous flying conditions. The AIBN recommends that the Norwegian Civil Aviation Authority and Kato Airline assess the best way to get more focus on maintenance of airborne weather radars in addition to sufficient training for optimal use.

1.18.2 DE HAVILLAND'S RESPONSE TO THE NSIA'S QUESTIONS RELATING TO THE INCIDENT INVOLVING LN-WFO

After the incident involving LN-WFO, the NSIA contacted De Havilland via the Transport Safety Board (TSB), the Canadian accident investigation authority. Several questions were asked relating to the incident, and the dialogue is summarised below. De Havilland's answers are reproduced in full in Appendix C.

[18] *https://www.nsia.no/Home*
[19] *The NSIA changed its name from AIBN (Accident Investigation Board Norway) in 2020.*

De Havilland acknowledges that ice can accumulate inside the air inlet behind the boot due to runback. They add that this will only happen if the aircraft is operated outside its certification criteria, for example if it enters SLD conditions. De Havilland also writes that no forms of engine tests have been carried out under such conditions, as such testing falls outside the certification requirements. The manufacturer has also stated that it will be difficult to detect ice in the air inlet even if it was to be painted a dark colour, as this form of ice would be clear.

When asked whether they have considered informing other operators that the engines could stop if the aircraft inadvertently enter areas of severe icing, De Havilland replied that the aircraft is not certified for operating under such conditions, and that the auto ignition system will ensure that it is restarted.

De Havilland emphasises how important it is that a tactile check of the inlet is carried out before flying to ensure that it is free of clear ice, as it may be difficult to detect such ice through only a visual check. De Havilland has already informed the operators of this in an All Operator Message (AOM) issued after the Nova Scotia incident in 2001. AOM 653 is enclosed with the present report. See Appendix D.

They consider information to operators about this incident to be addressed through the annual In Service Activities Report (ISAR[20]), where they also emphasise the importance of protecting the air inlet from ice while on the ground. They also refer to All Operator Message No 653 (2001), which also focuses on ground operations. The sources referred to contain only limited information about icing in air inlets during flight.

1.18.3 ACTION TAKEN BY WIDERØE AFTER THE INCIDENT

1.18.3.1 Internal investigation

Following the incident involving LN-WFO, Widerøe appointed an internal investigation committee. The committee's report contained ten internal recommendations and was published on 29 May 2020. An excerpt of these recommendations and the measures implemented is provided below. All ten recommendations with planned and implemented measures are reproduced in full in Appendix E.

- *It is recommended that the company enter into a dialogue with Avinor with a view to have AIRMET and SIGMET notifications visualised graphically in Aviobook in the future.*

  Measure: JEPPESEN will release a new version of its app FD PRO this month. In this version, all SIGMETs will be included and visualised on enroute charts.

- *The simulator at CAE OSL should be upgraded to the same configuration as Widerøe's Dash-8 100, 200 and 300 aircraft as regards auto ignition.*

  Measure: The simulator has been updated to include auto ignition.

- *It is recommended that the company raise awareness among its pilots about special weather phenomena that can cause severe icing conditions, how pilots can identify such phenomena and when the 'Flight in severe icing conditions procedure' should be applied.*

[20] *The manufacturer distributes annual In Service Activities Reports (ISAR) for all their aircraft types in which various technical and operational topics are discussed.*

Measure: Training base developed through a CBT. The planned measure will be implemented in the course of 2021.[21]

- *It is recommended that the company raise awareness among its pilots about the importance of making active use of the weather radar in relation to the aircraft's configuration.*

  Measure: […] Fleet Office has prepared a basis for and provided concrete input for training, including both OPC/PC and Line-Check. The pilots' awareness is expected to improve through line checks going forward.

- *The company should provide simulator training focusing on flameout and relight in all segments of flight.*

  Measure: The topic has been added to OPC and is followed up in a safety case.

1.18.3.2 Changes to OM A

Following the incident, Widerøe has drawn up an appendix to OM A (Appendix A to OM A 8.3.8) entitled *Isingsforhold i Norge* ('Icing conditions in Norway'). The appendix was produced in response to recommendation 7 in the internal report. It is a 25-page document that describes the types of weather in which icing can be expected and which forms of icing can be expected in the different regions of Norway where Widerøe operates. The appendix was drawn up in cooperation with the Norwegian Meteorological Institute. The following is an excerpt from the chapter about the region between Kristiansund and Bergen:

> On routes going north-east from Bergen (to Ålesund, Kristiansund, Molde, Hovden, Sandane, Førde), westerly winds will produce the most icing, especially when a warm front is passing in winter. The temperature on the ground will often be 5–10 degrees above freezing, with heavy precipitation in the form of rain along the coast and snow/sleet in inland areas. The difference from south-southwesterly winds is that westerly winds blow the warm, humid air further east over higher terrain. Icing remains at altitude, so 'climbing over it' is rarely a good solution. It is often a better solution to fly along the coast as far as possible when flying to these airports, as you do not have to go far inland from the coast for heavy icing to occur. In such conditions, the cloud tops are often at 20,000–22,000 ft, and icing occurs until you are above the clouds, but is usually most intense in the temperature range from -5 to -18 degrees. Icing conditions can cover a large geographical area. With north-westerly winds, the weather is often characterised by showers, which could create heavy icing, but will give you greater opportunities to fly around the showers. Warm low-pressure/warm fronts and westerly winds during winter present by far the greatest risk of icing on these routes.

Widerøe has also re-written section 8.3.8.3.1 of OM A about planning flights in icing conditions. It allows for flights to be planned through areas where severe icing has been forecast, provided that the crew have the experience and knowledge required to avoid these hazards:

[21] *This measures was implemented in 2021, and the NSIA has reviewed the CBT in its entirety.*

Pilots must be aware that flying in icing conditions involves hazards. In particular, they must understand the peculiarities of in-flight icing conditions and their effect on aircraft performance and handling, as well as the use and limitations of aircraft de-icing and anti-icing equipment. Icing forecasts are divided into:

– Severe icing issued as SIGMET

– Moderate icing issued as AIRMET.

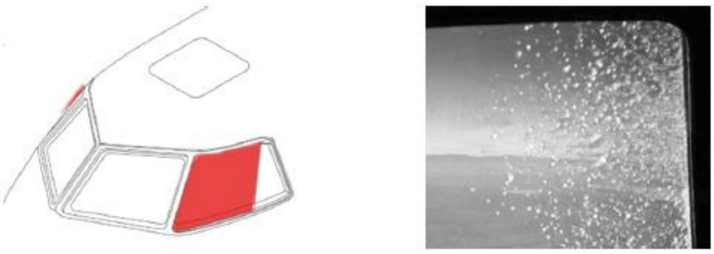
SIGMETs and AIRMETs cover large areas and timeframes, where the ice formation areas may be local or occasional. With this in mind, operations into areas of forecasted or reported severe icing (SIGMET) may be acceptable provided the flight crew's knowledge and experience allows them to identify how to avoid the hazard. Deviations from track, altitudes or complete re-routings shall be considered. Such decisions should only be made after a thorough analysis of all available relevant sources, preferably via consultation with an aviation meteorologist. Operation into areas of forecasted or reported moderate icing (AIRMET) should be conducted with increased caution. Flight crews must report to ATC in case of moderate or severe ice encounter. Ice formation on the ground and its effects are explained in Chapter 8.2.4 De-icing and Anti-icing on the Ground.

1.18.3.3 Changes to OM B

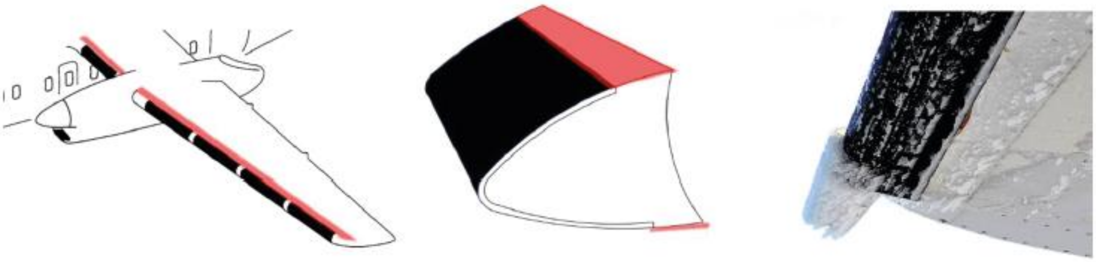
Widerøe has also amended OM B following the incident. Section 2.11.8.21.2 *Cues of Severe Icing* has been re-written, and photos have been added to illustrate what the crew should look for to verify severe icing on the aircraft. Figure 24 is taken from the updated version of OM B.

– Unusual extensive ice on the airframe in areas not normally observed to collect ice;

– Ice accumulation on the flight deck side windows, aft of the leading edge;



– Ice accumulation on the upper or lower wing surface, aft of the protected area;



– Ice accumulation on the propeller spinner farther aft than normally observed.

If severe icing is encountered, immediately request priority handling from ATC to facilitate a route or an altitude change to exit the icing conditions. The QRH item FLIGHT IN SEVERE ICING CONDITIONS shall be actioned to ensure all vital actions have been completed, including disengagement of the autopilot.

Figure 24: Cues of Severe Icing. Source: Widerøe OM B

1.18.3.4 Operational directive issued on 23 January 2021

Widerøe issued an Operational Directive to all its DHC-8 pilots in January 2021. The directive concerns inspection of the air inlet and bypass door before flying in icing conditions.

It also states that both the air inlet and bypass door must undergo a physical (tactile[22]) inspection. The following is quoted form the operational directive:

> Contaminants like rain, slush and snow may pool in the bottom of the engine intake immediately ahead of the bypass door and form an ice sheet that is hard to detect. If this ice accumulation is not removed, it can build up forward of the nacelle plenum and potentially cause an engine power interruption.
> Therefore, tactile inspections of the engine intakes must be performed during all extended ground stops when icing conditions (slush/snowfall) exist on the ground, or if moderate-to-severe icing conditions were encountered in flight. A visual inspection alone may not identify ice formed in the nacelle plenum, which could result in engine flameout. The inspections must be performed even if the intake covers have been fitted during ground stops.

The directive is included in its entirety in Appendix F.

1.18.3.5 Change of base arrangements

Prior to the incident involving LN-WFO on 20 January 2020, the bases at Bergen and Torp had both DHC-8-Q400 and DHC-8-300 aircraft based there, and the pilots would fly both types. This was changed following the incident, and Bergen and Torp became DHC-8-Q400 bases only. This enhances continuity on the one aircraft type that the pilots fly. The commander commented in an interview with the NSIA that he felt that he did not get enough hours on the DHC-8-300 to maintain good continuity.

1.18.4 USE OF THE AIRCRAFT'S WEATHER RADAR

The pilots are introduced to use of the aircraft's weather radar during the technical course for the DHC-8-100/200/300. The course consists of a Computer Based Training (CBT) course plus classroom-based teaching with a duration of approximately 15–20 minutes. There is no documented weather radar training in the Training Manual for type courses for the DHC-8-100/200/300, but according to the Route Training Syllabus, weather radar will be mentioned during several of the training days. According to OM D, the use of weather radar is reviewed annually through both theory and simulator training.

Honeywell Primus 800 (HW800)[23], which is installed on the DHC-8-100/200/300, is a conventional weather radar with technology dating from the 1980s. Optimum use of this radar requires good knowledge and procedures. For example, continuous use of tilt is necessary to cover areas of interest in front of the aircraft, depending on whether the aircraft is climbing, flying level or descending. It is also not equipped with filters to filter out ground clutter, which could interfere with the image. Modern weather radars can present a vertical picture of the precipitation situation in front of the aircraft, but the HW800 does not have this function.

[22] A physical or tactile inspection means that the person carrying out the inspection must use their palm to touch and feel the area to be inspected.
[23] Some of Widerøe's aircraft are fitted with the Honeywell Primus 660 (HW660), an older version of the same type of radar.

The pilots who flew on the day of the incident have told the NSIA that, in their experience, the weather radar in the DHC-8-300 did not work as well as the more modern and advanced weather radar in the DHC-8-Q400. Other Widerøe pilots that the NSIA has contacted have confirmed this.

As regards the use of weather radar in general, several pilots have stated that they primarily use it to avoid turbulence in convective[24] clouds and that they do not habitually use the weather radar to look for potential icing conditions in clouds.

Weather radar is mentioned in OM B Chapter 2 *Normal Procedures*, where the crew are to consider whether the weather radar should be turned on or left in standby mode before departure. The use of weather radar is also mentioned in section 2.1.6 on cockpit navigation display set-up during flight with expected changes of course due to challenging weather conditions:

> 2.3 Taxi, Take-off and Climb
> […] Condition levers.. Verify MAX
> – Select MAX if not already set.
> Weather Radar .... As required
> – Weather radar is selected STBY or ON as appropriate, with range as required. […]
>
> 2.1.6 Use of EHSI Display
> […] In conditions where weather avoidance may be required, it may be preferable for one pilot to display weather radar to assist with track deviations. […]

1.18.5 SIGNIFICANT WEATHER CHARTS AND ICING FORECASTS

The requirements that apply to meteorological services for civil aviation are set out in ICAO Annex 3. Each ICAO member state undertakes to have at least one meteorological office. These offices are to prepare standardised weather forecasts for aviation purposes for their region. In Norway, this function is filled by the Norwegian Meteorological Institute (MET). In the early 1980s, ICAO also drew up requirements for a global forecast system to address forecasts for upper air winds, temperatures and significant weather hazards such as icing and turbulence. This work resulted in the establishment of two global weather forecasting centres: the World Area Forecasting Centre (WAFC), operated by the UK Met Office in London, and the National Oceanic and Atmospheric Administration (NOAA), managed by the USA. The two centres prepare global significant weather charts covering large areas, and they also issue global warnings of significant weather phenomena, including anything from icing and turbulence to hurricanes and volcanic eruptions.

In the Nordic countries, Norway, Sweden and Finland each have a meteorological institute. At the time of the incident, Sweden and Finland issued their significant weather charts in collaboration.

ICAO Annex 3 recommends that flight crews be notified of significant weather phenomena such as icing and turbulence. It is also recommended that the intensity of such phenomena be forecast as moderate or severe. Unlike for turbulence, no definitions are provided for moderate and severe icing. Neither water quantity, droplet size nor temperature is mentioned in this context. It is mentioned that icing, turbulence and, to a large extent, wind shear are elements that for the time being cannot be satisfactorily observed from the ground and for which aircraft observations in most cases represent the only available evidence.

[24] *Convective clouds are called cumulus clouds (cumulus means ‘heap’ or ‘pile’ in Latin).*

EASA has implemented ICAO's recommendations in Commission Implementing Regulation (EU) 2017/373, Annex V Part-MET. The regulation also does not provide a clear definition of the distinction between moderate and severe icing. Turbulence values are provided, and it is stated that wind shear values are being developed. It is mentioned in this context that it is generally accepted that pilots use the terms moderate, strong and severe based largely on their own subjective perception when reporting wind shear. There is no corresponding comment on the intensity of icing.

There are currently no routine icing observations on which forecasts can be based. Icing intensity is estimated based on other observed and forecast meteorological conditions such as air humidity and temperature. Precipitation can be predicted, and the quantity of freezing rain can be estimated based on the rate at which the air masses are cooling down. It is difficult to determine the precise amount of water in a cloud and the droplet size of the liquid water. The speed at which an aircraft travels through the air mass and the aircraft's surface temperature are other crucial factors in determining how much ice is accumulated. Nevertheless, icing intensity is forecast in the significant weather charts using the categories moderate and severe.

The three significant weather charts available at the time of the incident all forecast moderate icing in the area where the flight was to take place. They did not differ much in terms of tops, but they all forecast icing below FL220, which was the planned cruising altitude.

The weather chart issued by the FMI also forecasted a curve in the cold front, which made it change into a local warm front just north of Stad. It also forecast severe icing along the coast of Helgeland. These front systems were not included in the chart issued by the WAFC, as it does not cover the atmosphere down to ground level.

1.18.6 SEVERE ICING CONDITIONS

The icing intensity will be perceived differently from different types of aircraft. In other words, what is light icing for one type could be perceived as severe for another. EASA has not quantified moderate or severe icing in its regulatory framework. The FAA's Aeronautical Information Manual (AIM) provides the following definition of severe icing:

> Severe Icing – The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary.

This definition dates from the 1960s, and we find the same one in Petter Dannevig's Norwegian book *Flymeteorologi* ('Aviation meteorology') from 1969. Many consider this definition to be the industry standard, despite the fact that neither ICAO nor EASA has defined the terms.

The lack of a clear and unambiguous definition of moderate and severe icing, as well as lack of standardisation between ICAO, EASA, FAA and the aircraft manufacturer, has been a well-known problem for years. Following the 1994 Roselawn[25] accident, the US National Transportation Safety Board (NTSB) wrote the following in its report:

[25] In 1994, 68 people were killed in the Roselawn accident in Indiana, USA, when an ATR 72 aircraft crashed after having lost control in icing conditions. The NTSB concluded that the cause of the loss of control was that ice had accumulated behind the de-icing boots on the wing.

> While these icing severity definitions provide some basis for assessing ice accumulation in PIREPs, they are subjective and are of limited use to pilots of different aircraft types. For example, using these definitions, 'light' icing for a Boeing 727 could be 'severe' icing for an ATR 72 or a Piper Malibu. The icing report provided by the captain of the A-320 Airbus that was holding at the HALIE intersection, near Roselawn, indicated that he observed about 1 inch of ice accumulate rapidly on his aircraft's icing probe**.** The captain provided a PIREP to ATC and reported the icing as 'light rime'. He stated in an interview after the accident that the anti-ice equipment on the airplane 'handled the icing adequately', and he believed the icing intensity to have been 'light to moderate'.
>
> The Safety Board concludes that icing reports based on the current icing severity definitions may often be misleading to pilots, especially to pilots of aircraft that may be more vulnerable to the effects of icing conditions than other aircraft. The Safety Board believes that the FAA should develop new aircraft icing intensity reporting criteria that are not subjective and are related to specific types of aircraft.

Following this accident, the FAA published a Pilot Guide: Flight in Icing Conditions (AC 91-74B[26]) in which it elaborates on this information. The following information is provided:

> Severe Icing – The rate of ice accumulation is such that ice protection systems fail to remove the accumulation of ice and accumulation occurs in areas not normally prone to icing, such as aft of protected surfaces and other areas identified by the manufacturer. A representative accretion rate for reference purposes is more than 3 inches (7.5 cm) per hour on the outer wing. Immediate exit is required by many Airworthiness Directives (AD), flight manuals, and operations regulations.

FAA considers an accretion rate of 75 mm/hour representative of severe icing. This equals 6.25 mm per 5 minutes. The rate for moderate icing is set to 25–75 mm/hour. A non-type-specific definition can be arrived at using these threshold values. For example, the ice that formed on the spigot of WF577 (see Figure 2) had accumulated in less than one hour and could serve as a good indication of icing intensity for the pilots.

EASA has not issued guidelines corresponding to those found in AC 91-74B in its operational procedures. EASA OPS CAT.OP.MPA.255 allows aircraft to fly into icing conditions if they have appropriate ice protection equipment and the flight manual permits. However, it is specified that the commander must immediately leave the area by changing course and altitude if the icing intensity exceeds the criteria set on certification. This leaves it up to the manufacturers to define icing conditions and set limitations in the flight manual.

The criteria set on certification are not reproduced in the flight manual (see section 1.6.4). Instead, the manufacturer has published criteria for severe icing based on visual observations by the crew (see section 1.6.5). From being based on concrete factors such as the liquid water content of the clouds (g/m^3), the cloud droplet diameter (µm) and air temperature (°C), this makes the threshold values more subjective and type-specific. Nor will it be possible to distinguish between moderate and light icing on this basis.

[26] The document can be downloaded here: https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1028388

1.18.7 THE NORWEGIAN METEOROLOGICAL INSTITUTE AND WEATHER RADAR

The NSIA has received weather radar data from the Norwegian Meteorological Institute for the time of the incident (see Figure 25). The illustration shows the precipitation detected by three of the nine radars based in Norway. The image is primarily based on the radar placed at Stad.

An analysis carried out by weather radar specialists with the Norwegian Meteorological Institute has concluded that the actual precipitation measured during the period in question exceeds that indicated by the radar image. Part of the reason for this is blockage caused by mountain formations blocking the radar beams. The degree of beam blockage in the area where the aircraft experienced the most intense icing is between 30% and 40%.

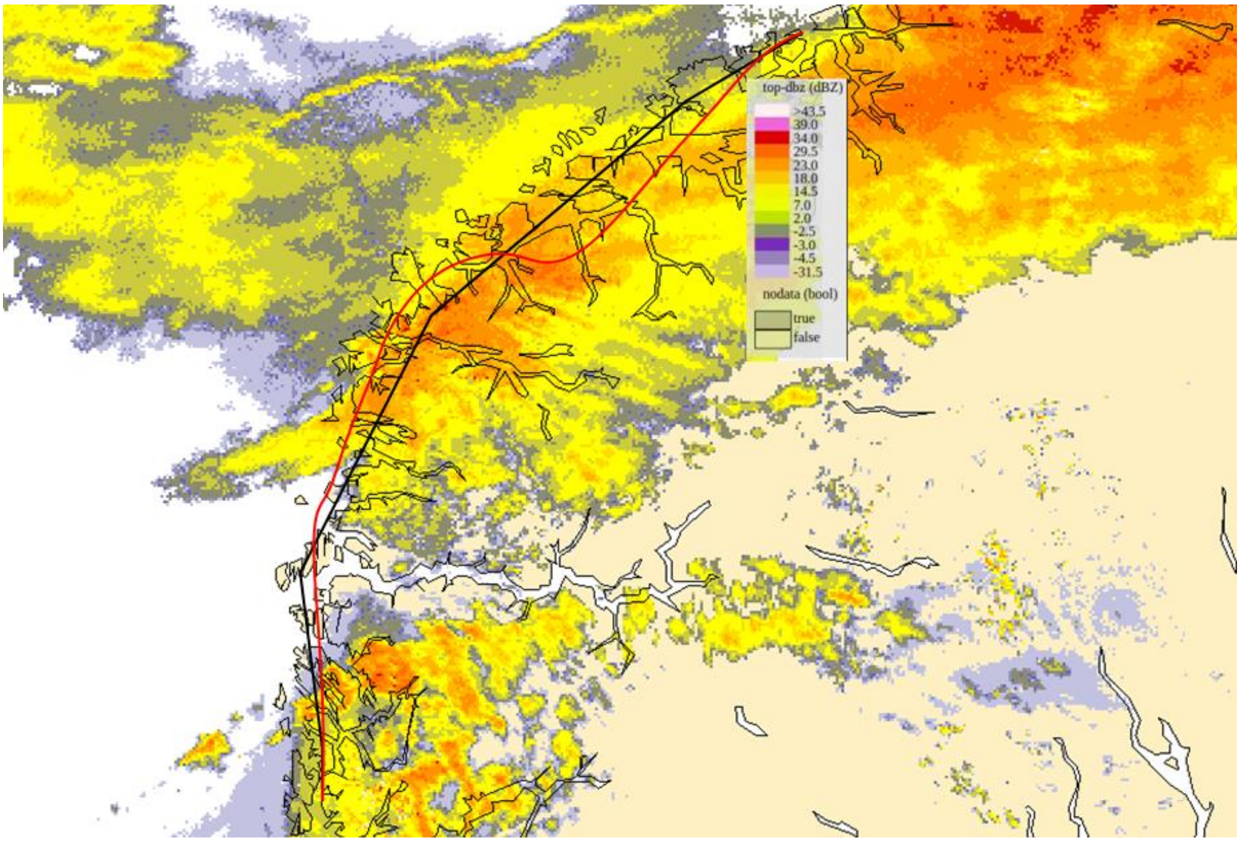


Figure 25: Map showing the weather situation and route between Kvernberget and Flesland airports. The planned route is shown in black, while the actual route is shown in red. The intensity of icing is indicated in yellow, orange and dark orange. Dark orange indicates the most severe icing. See the dBZ scale provided in the figure. Source: Norwegian Meteorological Institute/NSIA

1.18.8 THE AIR TRAFFIC SERVICE AND USE OF WEATHER RADAR

Following an incident in 2007 in which an aircraft from Kato Air was struck by lightning, leading to an emergency landing and total loss of the aircraft, the investigation authority (then called the AIBN) issued a safety recommendation to Avinor regarding presentation of weather information on the air traffic control service's radar displays:

> Safety recommendation SL 2007/23T.
> Presentation of weather on the air traffic control service's radar displays is important in avoiding aircraft being radar vectored into areas with hazardous flying conditions. The AIBN recommends that Avinor assess integrated presentation of information from weather radars on the air traffic control service's radar displays.

In 2011, Avinor responded to the recommendation issued following the Kato Air accident:

> SL 2007/23T Weather radar and implementation
> The quality of data generated by Memo's weather radar makes it impossible to integrate the data into our operations system. Avinor has integrated weather data into the information system RANDIS. Which units have or will have RANDIS is a matter of judgement and must also be discussed with the airport manager as the party ordering the service. As a compensatory measure, units that have challenging weather conditions will describe this in their local regulations. Among other things, it will state that they address safety by limiting capacity. This means that they will run less traffic when the weather conditions are challenging.

The Civil Aviation Authority of Norway (CAA-N) submitted its assessment later and recommended, with reference to the text below, that safety recommendation SL 2007/23T not needed to be followed up and could be closed.

> CAA-N's assessment:
> Follow-up of recommendation 2007/23T has been under assessment and review by Avinor for several years. By its wording, safety recommendation 2007/23T refers to considering the integration of weather radar information, which Avinor has considered and found not to be acceptable. CAA-N has followed the process closely and accepts that the radar display equipment currently used by Avinor is incompatible with presenting weather data from Met.no's weather radars. Dedicated weather channels on the primary surveillance radar (PSR) would be an optimal solution for good presentation of weather information, and this could provide a good, integrated presentation of relevant weather on the radar display equipment. However, developing system changes that would enable weather presentation in the NATCON system poses technical and well as financial challenges, and the PSR system only covers parts of Norway's airspace. As a compensatory measure, Avinor has integrated weather data into the information system RANDIS, while units with challenging weather conditions will reduce their capacity in demanding weather conditions so as to give more attention to weather conditions and address and provide information about them.

In 2020, the Norwegian Air Traffic Controllers Association was given an opportunity to comment on the NSIA's report following a serious incident involving a light aircraft of the type C172 that encountered icing conditions east of Stavanger in January 2020 (Aviation report 2020/13). The aircraft received good assistance from the air traffic service and was eventually vectored out of the icing conditions and landed safety at Sola Airport.

We wish to submit the following input to the report:
Weather radar: The report very clearly shows unintentional flight into TCU/CB. In this situation, the crew of the aircraft were aware of the risk of TCU/CB and planned to fly around or over them. This may have had a bearing on the sequence of events.
As mentioned in section 2.4.5, the air traffic service does not have access to well-functioning weather radar data. Except for pilot reports, the air traffic controller has no possibility of providing real-time information about weather conditions to flight personnel, and in principle thus no possibility of assisting pilots in avoiding flight in unfavourable and potentially dangerous conditions.
The Norwegian Air Traffic Controllers Association would like to make reference to safety recommendation SL 2007/23T in this connection:
'Presentation of weather on the air traffic control service's radar displays is important in avoiding aircraft being radar vectored into areas with hazardous flying conditions. The AIBN recommends that Avinor assess integrated presentation of information from weather radars on the air traffic control service's radar displays.'
This recommendation is just as relevant today as it was 13 years ago, and it should be a prioritised safety measure. In our opinion, a requirement for such support should be incorporated into Avinor Air Navigation Services' ongoing project 'FAS' (Future ATM System) for enroute services as well as other relevant updates to the ATM system in Norway.

In response to a question from the NSIA in September 2020, Avinor gave the following response regarding reconsidering the integration of weather radar on the air traffic controller's radar displays:

Avinor has no tool or system that provides an up-to-date visual representation of weather in a certain geographical area. In other words, we are not able based on our current technical solutions to assist aircraft in flight with weather information related to their geographical position. The presentation of weather information on other tools/displays will not be fit for purpose, as a presentation of the aircraft's relative position and the weather/precipitation is a prerequisite for issuing weather information to an aircraft.
The air traffic service issues weather information to flight personnel based on information available from the meteorological services and sensors as well as their own observations, if appropriate. Nevertheless, the assessment of risks associated with flight and meteorological conditions, as well as how to avoid any hazardous weather conditions, must be the commander's responsibility. Most aircraft today are equipped with on-board weather radars for this purpose.
For your information, Avinor is considering establishing a weather radar in Oslo TMA to be integrated into the new 'enroute system' (iTEC). The purpose of this is to ensure predictable traffic handling in connection with CB activity in the airspace, and to achieve the overarching goal of increased capacity.

ICAO has described international guidelines for the air traffic service and dealing with challenging weather situations. This information is found in ICAO Doc. 4444, of which an excerpt is reproduced below.

ICAO Doc. 4444 – Procedures for Air Navigation Services Air Traffic Management – 16th Edition 2016 – Chapter 8.6.9 Information regarding adverse weather.
[…]
8.6.9.1 Information that an aircraft appears likely to penetrate an area of adverse weather should be issued in sufficient time to permit the pilot to decide on an appropriate course of action, including that of requesting advice on how best to circumnavigate the adverse weather area, if so desired.
Note - Depending on the capabilities of the ATS surveillance system, areas of adverse weather may not be presented on the situation display. An aircraft's weather radar will normally provide better detection and definition of adverse weather than radar sensors in use by ATS.
[…]

1.18.9 CLIMATIC CHANGES THAT COULD HAVE A BEARING ON THE RISK OF ICING IN NORWAY

The NSIA has searched for documentation that climate change developments in recent years may have increased the risk of icing in Norway. The Norwegian Meteorological Institute supports the hypothesis, but adds that, at present, there is not enough research to conclude that this is the case.

A bulletin issued by the World Meteorological Organization (WMO) in 2016 quoted the following statement by Herbert Puempel, Chief of the Aeronautical Met Division of WMO:

> The general warming trend and increase of moisture in some latitude bands, with a more active dynamic of the flow, all point to an increased chance of occurrences of conditions favourable to icing. They also lead to an upward extension of the upper limit of icing layers due to the higher temperatures.

The topic of the bulletin[27] was climate change impacts on aviation.

The NSIA has also been in contact with several Widerøe pilots as well as the company's Safety Manager. They claim that they have seen more extreme icing in recent years, which could support Herbert Puempel's claim.

1.19 Useful or effective investigation techniques

No methods warranting special mention have been used in this investigation.

[27] https://public.wmo.int/en/resources/bulletin/climate-change-impacts-aviation-interview-herbert-puempel

2. Analysis

2. Analysis

2.1 Introduction

Engine failure due to icing is a problem that is well-known to affect the DHC-8. Widerøe has experienced several incidents since the company started to use this aircraft type in 1992. What makes this incident particularly serious is that both engines on WF577 failed during the approach. Had the engine failure happened a few minutes later, with the aircraft in full landing configuration with landing gear and flaps and at lower altitude, the outcome of the incident could have been far more serious and in the worst case resulted in an accident.

The NSIA has sought to clarify how ice could have entered the air inlets during flight and what measures can prevent this from causing the engines to stop. The investigation has also focused on determining why the crew found themselves in an area of severe icing and how this situation was subsequently dealt with.

The NSIA's assessment of the sequence of events is described in section 2.2. The local safety problems are analysed in sections 2.3 and 2.4. The investigation has also looked at organisational and systemic safety problems, and these issues are discussed in more detail in sections 2.5 to 2.8.

2.2 Sequence of events

The crew and aircraft had a short ground stop between the previous flight and the incident flight. The commander carried out an external inspection of the aircraft, but no tactile check of the air inlets was performed. According to the commander, the aircraft had not experienced icing during the previous flights. Based on this, in combination with the mild temperature, he concluded that there could not be any ice on the aircraft. The aircraft was therefore not de-iced before departure.

After taking off from ENKB, WF577 accepted a more direct course towards Flesland, and while climbing, the aircraft entered an area of severe icing conditions. Icing was forecast in the area, but the intensity was expected to be moderate, not severe. The crew took corrective action by changing course and altitude, but were unable to sufficiently limit the period of exposure to severe icing conditions. As the icing increased enroute to NIDGI, the crew decided to turn westbound towards the coast to areas with less icing. At this time, the aircraft was already in an area of icing that extended many nautical miles to the west, and WF577 was thus exposed to severe icing for several minutes even after the change of course. This led to ice forming on unusual areas of the aircraft and accumulating inside the air inlet on both engines. It was not possible for the crew to remove this ice as it was accumulating beyond the engine's de-icing systems.

On its approach to ENBR, the aircraft lost engine power first on the left engine, then on the right engine, and then on the left engine again. The engines flamed out due to ice detaching from the engine's air inlet when the aircraft descended to areas of warmer temperature. The ice that detached had either entered the combustion chamber as slush and/or water and caused a flameout, or disrupted the airflow into the engine sufficiently to stall it. The ice that had formed in and around the air inlet probably had insufficient momentum to escape the suction of the compressor inlet located on the ceiling of the plenum chamber directly above the point where the ice is assumed to have accumulated. Instead of following the airflow to the back of the chamber when it detached, the ice went straight up into the engine intake.

Both engines were restarted by the aircraft's automatic ignition system. Because of the start-up sequence, it took some seconds, maybe as much as half a minute, for the engines to regain normal power. The aircraft was therefore completely without engine power for a few seconds. The crew handled the situation in a professional manner and landed the aircraft safely at Flesland minutes later.

2.3 Crew preparations for the flight

2.3.1 THE CREW'S EVALUATION OF ICING RISK DURING THE PLANNING

During the planning phase, the crew had access to two significant weather charts, both of which indicated moderate icing. The chart from the Finnish Meteorological Institute (FMI) forecast moderate icing up to 16,000 ft, while the chart from WAFC in London indicated moderate icing up to and including 20,000 ft. The flight in question was planned for FL220, i.e. above the area of forecast icing. They still had to expect icing when climbing out from Kvernberget and during their approach to Flesland (see section 1.7.2).

They had wind charts indicating a strong westerly air current and information that the temperature conditions were not unusually cold. The operational flight plan indicated that the lowest temperature they would encounter during the flight was estimated to be minus 29°C at TUTOP, a waypoint roughly midway between Kvernberget and Flesland.

The Norwegian Meteorological Institute wrote in its report that the severe icing encountered on this flight was at an unusually high altitude. When the Norwegian Meteorological Institute sets the vertical extent, minus 20°C is often set as the upper limit, and in this case, that would correspond to FL180. The reason is that freezing water rarely occurs in such quantities at such low temperatures. By means of weather balloon data, they could confirm that the temperature at FL220 was nearly minus 30°C in the icing area. They also wrote that spontaneous freezing occurs at minus 40°C, at which temperature there will only be ice crystals. The Norwegian Meteorological Institute therefore did not expect severe icing in connection with the cold front in this area. The reason is that a cold front has only limited areas of freezing. They explained that it is possible that the air masses got extra lift from mountain waves, in addition to orographic lift. Orographic lift occurs when air masses and weather systems meet land and mountains and are physically lifted. Humid air rises quickly in the atmosphere, intensifying icing conditions. If the cold front had cells of convective[28] clouds, this would only have intensified this effect.

The crew have stated that they observed forecasts of moderate icing in the area. They considered this unproblematic. They also knew that icing was common in this part of Norway. However, they did not link the strong westerly winds to orographic lift, nor did they realise that this, in combination with front systems, could cause the known icing problems. Widerøe had described orographic turbulence in its manuals, but at the time of the incident, there was no mention of icing in connection with orographic lift. It was therefore not unnatural for the crew to focus on wind rather than icing in their preparations for the flight.

However, it must be mentioned that Widerøe had mentioned in its procedures that the crew should use weather forecast to evaluate where potential icing conditions could occur in relation to the planned route, and at which altitudes and courses the air masses were likely to be warmer or colder. The procedures also described the necessity of being aware of the ambient air temperature and the zero-degree isotherm. None of these elements were specifically reviewed during the preparations for the flight, but the forecast icing was noted along with the position of the zero-degree isotherm, the front system and mountain waves.

[28] Convective clouds are clouds formed by convection, a process whereby warm air rises because its density is lower than that of the surrounding atmosphere.

The crew had flown the route in question three times before the flight on which the incident occurred. Each time, they had flown above the clouds and experienced little or no icing. Based on this experience and the meteorological information available, the crew did not expect to encounter severe icing on the fourth trip. In interviews with the NSIA, the commander expressed uncertainty about whether he would have acted differently if he were to plan a similar flight with similar information available.

The form of the weather forecasts available to the crew meant that they were open to misunderstanding. The aircraft's CVR and subsequent interviews both showed that the crew were unaware of the cold front along the coast. They were aware of the front systems, but for understandable reasons, they believed the front to be warm, not cold. The available significant weather chart had a warm front indicated in a conspicuous red colour. They therefore ruled out the possibility of convective activity in the clouds. During interviews the pilots have explained that they did not experience any convective activity or turbulence during the flight.

According to Widerøe's procedures, planned flight into a known area of severe icing is not permitted. This rule was complied with in this case, as the icing had not been forecast. However, it is known that areas of more intense icing may be encountered during flight in moderate icing conditions. The manufacturer has therefore included instructions in the AFM on how to deal with such situations.

Based on the manuals and significant weather charts available to the crew, the NSIA considers it understandable that the crew underestimated the risk of icing. It was not unusually cold at operating altitude, they were to fly above the area of icing, they expected a warm front without convective activity, and the manuals in force at the time of the incident did not mention the link between orographic lift of air masses and icing.

2.3.2 AIR INLET INSPECTION BEFORE TAKE-OFF

Widerøe's manuals contain procedures for how a pre-flight inspection is to be conducted. Such an inspection must be carried out before every flight and consists of several elements, including an external inspection of the aircraft. The purpose of this inspection is to ensure that the aircraft is airworthy, and it includes an inspection of the engine air inlets. When operating in low temperatures and conditions defined as cold weather operations, several items are added to the pre-flight inspection. Among other things, it must be checked that all surfaces, including the air inlet, are free of snow and ice. Unlike De Havilland, Widerøe does not prescribe a tactile check of the air inlet.

Inspection of the air inlet requires extra equipment, as the personnel will need either a set of steps or a mirror. The crew had neither available and therefore carried out a superficial visual inspection. The commander has stated that he did not notice ice in the inlet. This means that the possibility of ice, snow and water in the lower cowl cannot be ruled out.

In the NSIA's opinion, the procedures for tactile inspection of the air inlet in icing conditions should be described in the company's OM B, and this matter is discussed in more detail in section 2.5.

2.4 The aircrew's choices and actions enroute

2.4.1 OFFER OF DIRECT ROUTE AFTER TAKE-OFF

After take-off from Kvernberget, the air traffic service offered the crew a direct route to NIDGI, which is the first approach point to Flesland. The offer was accepted, and they turned to a more southerly course (see Figure 25). It has emerged that this choice of route took WF577 further inland, where the precipitation was heavier and the risk of icing higher.

The NSIA believes an operational air traffic service weather radar possibly could have detected the areas of precipitation along the route taken by WF577 so that information could have been communicated to the crew and thus had a bearing on the choice of route.

The NSIA has previously elucidated this issue. Following an incident in 2007 in which a Kato Air aircraft was hit by lightning, the NSIA addressed a recommendation to Avinor to consider integrating information from weather radars on the air traffic control service's radar displays (see section 1.18.8). CAA Norway closed this recommendation in 2011, citing as grounds that the radar display equipment used by Avinor at the time was incompatible with presenting weather data from Met.no's weather radars.

A 2020 incident involving a C172 that suffered serious problems in icing conditions made the issue topical again. In the consultation round before the report was published, the Norwegian Air Traffic Controllers Association again called for weather radar data to be integrated on the air traffic controllers' radar displays as a safety measure in ongoing projects and updates to ATM systems.

The NSIA is of the opinion that the integration of weather data on Avinor's radar displays should be reconsidered in connection with the updates planned for the years to come. According to Avinor, they are considering establishing a weather radar in Oslo TMA to be integrated into the new 'enroute system' (iTEC). The NSIA believes that the same should be considered for other areas in Norway, and especially in the north-west region, A safety recommendation is therefore addressed to the Norwegian Civil Aviation Authority.

2.4.2 USE OF ON-BOARD WEATHER RADAR

An aircraft's on-board weather radar is designed to reflect particles in the air and project an image on a display in the cockpit. It is then up to the pilots to interpret what they see and to act based on their situational awareness. A radar has its limitations which means that knowledge, practice and experience are required to make optimum use of such equipment.

Proper use of weather radar can give the crew 'an extra set of eyes' outside the cockpit. Correct use can improve the pilots' situational awareness of the weather conditions, which could help them to make safer route choices, laterally as well as vertically, during the flight. The DHC-8-300 is equipped with a conventional radar based on old technology, and it requires know-how and active use of several settings during flight.

The crew of WF577 have explained to the NSIA that they were not sure whether the weather radar was turned on during climbout from Kristiansund during the incident flight. This could indicate that it was not being used. The crew have also stated that they normally did not use the weather radar to detect icing, but that it was used to identify cells in cumulonimbus clouds to avoid turbulence. It was also mentioned that they considered the radar in the DHC-8-300 to be inferior to that of the DHC-8-400 and therefore used it less. While preparing for the flight, the crew had noted only a warm front in the area where they would be flying, and this may be part of the reason why they did not make active use of the weather radar.

The crew probably encountered the heaviest icing between FL180 and FL220 enroute to Bergen. If the weather radar had been in use during the climb and after the change of course towards NIDGI, there is a chance they would have detected the icing conditions in the area they were heading into. The radar maps from the Norwegian Meteorological Institute show a high level of humidity in the area, but it cannot be determined whether it contained cells of convective activity. Based on information from the crew, there was little turbulence in the area. It is nevertheless probable that the clouds contained enough humidity to have been visible on the weather radar as green or yellow areas. That would have allowed the course to be adjusted at an earlier time so that they could have moved towards the coast and lower altitudes sooner and avoided the areas of most intense icing.

The NSIA has spoken with several Widerøe pilots since the incident, and it seems that practices vary between pilots when it comes to the use of weather radar. There seems to be a notion shared by a number of pilots that a weather radar's sole use is to identify cells in cumulonimbus clouds in order to avoid strong turbulence. Also, several of them pointed out that they have low confidence in the radar in the older aircraft (DHC-8-100/200/300) and that only the DHC-8-400 type is equipped with a radar capable of adequately detecting icing conditions.

Another factor could be that the manufacturer, De Havilland, has not emphasised use of weather radar in icing conditions because the radar would not detect liquid water content in clouds under the conditions for which the aircraft is certified. The DHC-8-300 is certified in accordance with Appendix C, which allows it to operate only up to a droplet size of 50 micron, which is far too small for the weather radar to reflect. It is well known that an aircraft might inadvertently end up in other icing conditions with larger droplets and more intense icing (SLD). In such conditions, the radar could probably detect the icing risk if used correctly.

Other factors pointed out by pilots include inadequate documentation, inadequate training and general attitudes to flying the DHC-8 in icing conditions. It would appear that many pilots have not considered icing to be a particular problem for the DHC-8, which may have had a bearing on their interest in using the weather radar.

Following the incident, the company has implemented a number of measures that have raised the level of knowledge about weather radar use. The NSIA has been given access to the documentation and course material prepared, and considers the measures to be adequate. In particular, the NSIA has a good impression of the CBT[29] course created following the incident. Use of weather radar is also mentioned as an element in training, both for simulator flights (OPC/PC) and line checks.

The NSIA believes that the sum of these measures will be sufficient to raise the level of competence and awareness of weather radar use within the company.

2.4.3 HOW THE ICING WAS DEALT WITH DURING THE FLIGHT

Widerøe's manuals devote a lot of attention to the effect of icing on an aircraft's stability and controllability. Ice will alter the aerodynamic surfaces, as well as increase drag and weight of the aircraft. Heavy icing will reduce the stall margin and may, in a worst-case scenario, result in loss of control. Through its long service life, the DHC-8-100/200/300 has proven that the aircraft's tolerance exceeds its certification limits. This flight is another indication of this, which also the manufacturer confirms. The level of confidence in the aircraft is therefore high.

On this flight, there were seemingly no problems with controllability or aerodynamic performance. However, it is uncertain how much the margins had been reduced. That is why the manuals explain what to do when entering an area of severe icing. Among the most important actions are to disconnect the autopilot and to avoid aggressive manoeuvring. The autopilot will compensate and could thereby mask control problems. The possibility of engine failure is not mentioned.

This confidence in the aircraft type and the company's experience of how it performs in icing conditions may have contributed to raising the threshold for what is considered an acceptable icing intensity. The lack of definitions of moderate and severe icing and pertaining threshold values may

[29] *Computer-based training*

have contributed to this development. Widerøe has defined severe icing to be icing that exceeds the capacity of the de-icing systems. What this means in practice is that the icing intensity cannot be assessed unless an aircraft is already in an area of icing.

This can be interpreted to mean that severe icing exists when the de-icing boots are incapable of removing all ice from the leading edges of the wings, but this is not mentioned as a visual reference. Neither the aircraft manufacturer nor the airline gives any quantitative definition of what constitutes abnormal icing intensity in their manuals, such as how far back on the propeller spinner ice should be expected or how white the de-icing boots can be. The one clear indication mentioned of severe icing is ice formation on the side windows. The manufacturer follows this up by stating in the AFM that the aircraft can be considered to have exited the area of severe icing when there is no longer any ice on the side windows. This is not reproduced in Widerøe's operating manuals.

Based on the crew's explanations in combination with the audio log from the CVR, it is clear that WF577 entered an area of high icing intensity. This, together with other visual indicators observed by the crew, make the NSIA believe they inadvertently entered an area with severe icing. Had the crew had access to better information about indications of severe icing and they had been aware of the real risk of engine failure, it is conceivable that the corrections made would have come quicker and been more effective. This could potentially have affected and reduced the aircraft's exposure time in the area of icing.

For example, the ice that accumulated on the spigot (see Figure 2) could have been a good reference point for the icing intensity. This would depend on it being defined by the authorities and followed up by the manufacturer. It appears that the build-up of ice on the spigot during the flight may have indicated more than what the FAA defines as severe icing. The NSIA estimates the length of the ice in the photo to be more than twice the length of the spigot. The spigot was measured to just over an inch (see Figure 13), and this would correspond to an ice accretion of approximately 50–60 mm. This occurred in the space of less than 50 minutes, which is close to the FAA's definition of severe icing, which is 75 mm/hour.[30] Assuming that this ice probably accumulated during the final part of the climb and while WF577 was heading west and beginning its descent, it is likely to have accumulated over a period of approximately 30 minutes, which corresponds to 100–120 mm/hour – well in excess of what the FAA defines as severe icing.

Following the incident, Widerøe has amended a chapter of OM B to contain images and text that describe indications of severe icing on DHC-8-100/200/300 aircraft. The NSIA considers this a good measure, but nevertheless wishes to emphasise the importance of following this up to ensure that all crew members are aware of the different indications of severe icing. This can shorten the duration of exposure and help to avoid similar incidents in future.

2.4.4 BUILD-UP OF ICE IN THE AIR INLET

In the NSIA's view, there are two different scenarios that could explain how the ice entered the air inlet and interfered with the engines, causing them to stop. The first scenario assumes that ice was present in the inlet before take-off and was not detected during the pre-flight inspection.

The design of the air inlet of the DHC-8-311 makes it vulnerable to water and snow accumulating in a cowl just inside the inlet opening. This is a particular problem if the aircraft is parked outside in rain or snow without the air inlet being covered and the temperature is around 0°C. In such cases, water and snow can freeze into large shards of ice that could dislodge and cause the engine to stop. This is a well-known problem, and there have been several incidents where DCH-8 engines have flamed out in flight for this reason. Previous incidents involving ice in the air inlet have shown

[30] *The FAA's definition concerns ice accumulation on the outer wing, which may differ from ice accumulation on the spigot.*

that ice will detach before or just after take-off. Experience shows that the ice will not remain in the air inlet for long before detaching, and the NSIA considers this a less likely scenario for the incident in question.

The second scenario assumes that ice has accumulated in the air inlet during flight. Observations from previous DHC-8-311 flights indicate that this is a possibility. If this ice detaches and ends up in the engine, it could cause a flameout. The ice on WF577 did not detach until the aircraft was on approach to its destination, at the same time as ice on the rest of the aircraft disappeared. The NSIA believes this suggests that the ice accumulated during flight, since previous experience of the DHC-8 type (all models) shows that any ice in the air inlet before take-off will normally detach quite soon during departure. Moreover, three flights had been completed on the same route that afternoon without any ice worth mentioning being observed, and the temperature was 8°C at Flesland and 9°C at Kvernberget.

This incident indicates that ice that builds up in the nacelle during flight in sub-zero temperatures will not necessarily detach before the aircraft reaches temperatures above zero degrees. This is important to be aware of when planning the descent profile before landing so that available options in the event of possible loss of engine power can be optimised.

The NSIA has only found one previous incident (see 1.18.1.1, Nova Scotia) in which this is believed to be a causal factor. In the report following that incident however, the manufacturer raised doubts about whether the ice formed in the air inlet during flight. The crew, on the other hand, claimed to have observed ice accumulating, and it could therefore not be ruled out. This question is relevant to the incident involving WF577, as the NSIA considers it highly likely that the ice built up during flight.

The manufacturer does not rule out the possibility that ice may accumulate in the air inlet if the aircraft enters an area of severe icing. They point out that this is a highly unusual situation and that the engine's automatic ignition system is designed to respond to such situations.

The NSIA is of the opinion that there is a risk of ice accumulating in the air inlet during flight and that this could cause the engine to flame out. This information should be clearly stated in the AFM, and the issue is discussed in section 2.6.

2.4.5 THE CREW'S CRM AND MANAGEMENT OF THE ENGINE FAILURE

The NSIA has reviewed the CVR recording and wishes to commend the crew for their consistently good teamwork and communication.[31] The communication was characterised by mutual trust and a high degree of professionalism, consistently focusing on the icing problem. The authority gradient was good, with the commander exhibiting clear leadership while allowing the first officer, who was flying the aircraft, to provide input. The first officer took an active role and continuously contributed with his assessments of the situation. Throughout the flight, he demonstrated what CRM terminology refers to as assertiveness[32].

When the first engine flamed out, WF577 was about to get established on the ILS approach to runway 17 at Flesland. The first officer identified the indications of flameout first and immediately informed the commander. The dialogue between the two pilots was clear and efficient (see section 1.11.1). The auto-ignition system quickly restarted the engine, and they carried out an immediate assessment of possible causes and checked the status of all engine instruments. They agreed that

---

[31] This is based on the CVR recording, which begins 28 minutes into the flight and continues until the aircraft is parked at the gate at Flesland.
[32] Assertiveness is defined as the quality of being able to confidently and vigorously state and defend one's opinion.

the cause had to be ice in the engine dislodging as they descended into warmer air. During the minutes that followed, the right engine flamed out, and then the left engine flamed out again. This situation could have led to instinctive actions such as shutting down an engine, and the NSIA would like to commend the crew for keeping calm, trusting their assessments after the first engine failure and letting the auto-ignition system restart the engines.

In less than two minutes, the crew had experienced three engine failures and restarts, correctly analysed the cause and agreed on how to handle the situation. They managed to get established on the ILS approach and declared an emergency to air traffic control. The NSIA finds the crew resource management (CRM) during this phase particularly praiseworthy, and believes that the following factors were particularly important:

- They provided each other with constant updates of mental models so that a shared understanding of events was established among the crew.
- Their communication was brief and precise – one or two words was enough.
- Even in a critical situation with a high stress level, the captain requested input.
- The crew continued to evaluate/diagnose the problem.
- They managed to avoid fixating, which is a possibility in stressful situations, and they continued to search for relevant information.
- The first officer gave a mini-brief – 'I'm keeping good speed, keeping good torque, configuring late' to inform the captain and keep him in the loop.

The NSIA would like to emphasise that the way the crew dealt with the engine failures was crucial to the outcome of the incident. Another reaction, for example if the pilots had started a go around or initiated engine failure procedures, could have resulted in a different, and more serious, outcome of the incident

2.4.6 USE OF THE AIRCRAFT'S AUTOMATIC IGNITION SYSTEM

All of Widerøe's aircraft have undergone a modification that means that the ignition system will automatically engage if an engine stops without a technical cause. This is described in more detail in section 1.6.7. In the situation encountered by the crew of WF577, where both engines flamed out, this system helped to restart the engines without the crew having to take any action.

The aircraft manufacturer considers the automatic ignition system a sufficient barrier to prevent lasting engine failure in icing conditions. It is therefore important that the crew understand how the system works and do not shut down the engine until the system has had a chance to restart it. In this case, the commander quickly identified ice as the reason for the engine flaming out, and the crew monitored the start-up sequence without interfering.

Widerøe has since intensified its flameout training, with a focus on the automatic ignition system.

2.5 Measures implemented by the company following the incident

Widerøe carried out an internal investigation immediately after the incident. A thorough report was prepared, and several internal areas for improvement were identified. A total of ten recommendations were submitted (see section 1.18.3.1).

The NSIA would like to draw attention to some of the recommendations that are deemed to be particularly important in helping to prevent the recurrence of similar incidents in future.

Widerøe has drawn up an extensive training programme (CBT) that deals with different aspects of flying in icing conditions. The NSIA has been given access to this programme and considers the content to be relevant and that it explains several important elements such as recognition of severe icing on the aircraft, use of weather radar and special weather phenomena that may lead to icing. The company has also added simulator training elements that cover use of weather radar and the auto-ignition system. The icing problem and use of weather radar are also emphasised during pilot line checks[33].

The company has introduced several changes to its OM A and OM B that will improve their procedures for flight in icing conditions. They have also issued an Operational Directive in 2021 (see section 1.18.3.4) with instructions for a tactile inspection of the air inlet, which is strongly recommended by the manufacturer. The NSIA is of the opinion that these instructions must be established and followed up over time to ensure that pilots always carry out this check when icing conditions exist. The NSIA does not believe that a tactile check of the air inlet would have made any difference to the sequence of events in connection with this flight, as there was probably no ice in the air inlets before take-off. However, the investigation has found that this item was missing from OM B. Similar previous incidents involving DHC-8 aircraft have shown that such a check could prevent ice from entering the engine.

2.6 Airplane flight manual (AFM) and certification

In its flight manual for the DHC-8-311, De Havilland has defined when icing conditions occur by referring to ambient temperature and visibility. It also describes that flight in freezing rain and drizzle or mixed icing conditions may result in ice build-up of an intensity exceeding the capability of the aircraft's ice protection systems. This is not very different from the FAA's definition of severe icing.[34] The manufacturer specifies that icing of this intensity will affect the performance, stability and controllability of the aircraft. It is not explicitly mentioned in this context that ice could cause the engines to flame out. The NSIA is of the opinion that information about the fact that ice could cause the engines to flame out is so important that it must be included in the AFM, as it has been for more recent DHC-8 models. The incident involving LN-WFO shows that this is an evident problem.

Following a comprehensive process, the certification specifications for transport aircraft were updated in 2014, and new requirements relating to flight in icing conditions were included. The icing envelope in the new Appendix O to Part 25 (see 1.6.4) has been expanded to include freezing rain and drizzle. The terms used to describe the atmospheric variables are the same as in Appendix C, which means that they are still not directly translatable to the terms used in meteorology (light, moderate and severe). The new requirements are not applicable to DHC-8-100/200/300 aircraft, as such amendments do not have retroactive effect.

The NSIA considers it important that a warning is issued in the AFM specifying that ice could cause the engines to flame out during flight. A recommendation is therefore addressed to Transport Canada to assure this is accomplished by the aircraft manufacturer De Havilland.

[33] As part of the company's safety management system, pilots are regularly checked by dedicated check pilots in a procedure known as line checks.
[34] Neither EASA nor ICAO has defined severe icing. Many in the aviation industry therefore considers this to be the applicable definition.

2.7 The aviation authorities' definition of severe icing and icing forecasts

The DHC-8-311 is certified for flight in icing conditions in accordance with Appendix C to Part 25. These conditions do not include freezing drizzle and rain. The certification authority (FAA) has quantified icing conditions and relates them to droplet size, liquid water content, temperature and pressure altitude[35].

The European operating regulations refer to the certification requirements, but do not apply the internationally acknowledged terms *light, moderate* and *severe* to describe icing intensity.

De Havilland also refers to the certification requirements, which also do not quantify threshold values for icing intensity. However, they state that severe icing could occur if the aircraft is operated outside the criteria set in connection with certification.

Based on the established 'truth' that severe icing occurs when the icing intensity exceeds the capacity of the aircraft's ice protection systems (see section 1.18.6), there appears to be an inconsistency between this definition and the assumption of airworthiness for aircraft certified for flight in icing conditions. The DHC-8-311's flight manual permits flight in all icing conditions. This is specified in the chapter on the aircraft's limitations. However, the warning indicates that the manufacturer cannot guarantee airworthiness if the aircraft is operated outside the certification criteria, and here the manufacturer uses the term *severe*. This can be interpreted to mean that severe icing must be considered excessive icing intensity even for protected aircraft.

A report issued by the U.S. Department of Transportation (DOT)[36] states that one reason for this inconsistency is that the previous FAA definition has never been updated to acknowledge the certification and operating rules in the Federal Aviation Regulations (FARs), which consider icing-certificated airplanes to be capable of flying in unrestricted icing conditions. This has now been corrected in FAA AC 91-74B. The FAA defines the intensity of moderate and severe icing by how quickly ice accumulates on the outer part of the wing (see section 1.18.6). This rate can be considered non type-specific. Neither ICAO nor EASA has such a definition.

The description in the European operating regulations would require the commander to first fly into the area of icing and then assess whether the icing exceeds the capability of the ice protection system before a decision can be made regarding continued flight. If the intensity is deemed too high, the aircraft must exit the conditions quickly. However, it may already be too late. Ice that has already formed in and around the air inlet must shed at some point, and could end up in the engine. Consequently, the auto-ignition system could be the only barrier against lasting engine failure, as was the case for WF577.

There also appears to be an inconsistency between the description of severe icing and meteorological forecasts. EASA ATM/ANS Regulation (EU) 2017/373 Annex V – Part MET, which is based on ICAO Annex 3, does not define severe icing. However, the same Regulation does require forecast centres to include risk of icing in their forecasts, using the terms *moderate* and *severe*. As a result of this, forecast centres issue icing intensity estimates based on different practices and use terminology that they assume will be meaningful to pilots. There is thus no link between the aircraft manufacturers and aviation authorities' concepts of icing intensity and how meteorologists forecast icing conditions.

[35] Pressure altitude relates to the aircraft's altitude above sea level in relation to the International Standard Atmosphere (ISA).
[36] DOT/FAA/AR-01/91. A History and Interpretation of Aircraft Icing Intensity Definitions and FAA Rules for Operating in Icing Conditions.

The NSIA considers it unfortunate that there is no link between meteorological definitions, aircraft certification requirements and the European operating regulations concerning flight in icing conditions, and believes this is an area that international authorities should look into. The NSIA notes the work done by the FAA in this connection, but calls for standardised international guidelines for the meteorological services. The NSIA also calls for the different degrees of icing intensity to be defined in the European operating regulations.

In the NSIA's view, EASA must investigate the elucidated issues relating to lacking definitions and inconsistencies regarding icing issues and ensure harmonisation with other international authorities. The NSIA therefore issues a recommendation to this effect.

2.8 Climatic changes that make icing a topical issue

There are indications that climate change could increase the risk of icing (see section 1.18.9). As regards Norway, a general increase in temperature could result in air containing higher levels of humidity hitting the coast of Western Norway and areas further north. In combination with more intense weather systems and higher wind speeds, this can give rise to conditions favourable for severe icing, especially when the air masses are mechanically lifted over mountain formations.

The NSIA sees a need for further research to substantiate the claim that icing intensity is or will be increasing along the coast of Norway. Nevertheless, the NSIA considers there to be sufficiently strong indications of this to make the issue relevant to aircraft manufacturers, pilots, meteorologists and air traffic controllers.

3. Conclusion

3. Conclusion

3.1 Main conclusion

While climbing from Kristiansund Airport Kvernberget, WF577 inadvertently flew into an area of severe icing conditions, and the crew took corrective action by changing course and altitude. However, they were unable to sufficiently limit the duration of the aircraft's exposure to severe icing conditions. As a result, ice formed on the aircraft and inside the engine's air inlets.

On approach to Bergen Airport Flesland, the aircraft lost engine power on the left engine, then on the right engine, and then on the left engine again. The aircraft's automatic ignition system restarted both engines, but the start-up sequence took time, and the aircraft was completely without engine power for a brief period. The engines flamed out due to ice detaching from the engine's air inlets. The ice either entered the combustion chamber as slush and water and caused a flameout, or disrupted the airflow into the engine sufficiently to stall it.

The crew acted professionally in a highly demanding situation and landed the aircraft safely at Flesland.

3.2 Investigation results

3.2.1 SEQUENCE OF EVENTS, OPERATIONAL AND TECHNICAL FACTORS

A. No areas of severe icing had been forecast along the route to be flown.

B. The crew had flown the route in question three times before the flight on which the incident occurred. Each time, they had flown above the clouds and experienced little or no icing.

C. No tactile check of the air inlets was carried out before the flight. Such checks were not described in Widerøe's procedures.

D. After take-off from Kristiansund, the air traffic service offered the crew a direct route to NIDGI, which is the first approach point to Bergen. This choice of route took WF577 further inland, where the precipitation was more intense and the risk of icing higher.

E. The crew did not use the weather radar.

F. The aircraft entered an area of severe icing.

G. The crew acted as if the icing intensity was moderate.

H. The crew changed heading and altitude to get down to milder airmasses.

I. The crew had an unclear understanding of the boundary between severe and moderate icing, which may have contributed to prolonging the exposure to severe icing conditions.

J. Ice that had accumulated in the aircraft's air inlets detached.

K. The ice that detached had either entered the combustion chamber as slush/water and caused a flameout or disrupted the airflow into the engine sufficiently to stall it.

L. The NSIA considers it most likely that the ice that entered the engine had formed in and around the air inlet during flight.

M. All of Widerøe's aircraft have undergone a modification which provides automatic ignition if an engine stops. This system has kicked in to prevent lasting engine failures in connection with several incidents involving icing problems.

N. The crew demonstrated good teamwork (CRM) and communicated well during the flight, particularly while dealing with the engine flameouts.

3.2.2 ORGANISATIONAL AND SYSTEMIC FACTORS

O. Widerøe did not have clear procedures in place for tactile checks of air inlets in icing conditions at the time of the incident.

P. Avinor has previously considered introducing the use of weather radar, but has concluded that there are technical and financial challenges associated with presenting weather in the NATCON system. However, Avinor is considering establishing a weather radar as part of the new ‘enroute system’ (iTEC) in Oslo TMA.

Q. Widerøe has introduced several changes to its OM A and OM B that will improve their procedures for flight in icing conditions.

R. The aircraft manufacturer De Havilland has not described in the AFM that ice could cause the aircraft’s engines to flame out.

S. EASA has not defined the concepts of moderate and severe icing for use by pilots and meteorologists. However, these parties are still obliged to use these terms in reporting and forecasts.

T. Other icing intensity concepts are applied in connection with aircraft certification, and there is no link between these terms and those that meteorologists are obliged to use.

3.2.3 ANY OTHER FACTORS

U. The climate has changed, and the increase in temperature has brought more humid air and stronger winds that could cause more severe icing along the coast, particularly in areas where air masses are mechanically lifted.

4. Safety recommendations

4. Safety recommendations

The Norwegian Safety Investigation Authority submits the following safety recommendations[37]:

Safety Recommendation Aviation No. 2023/01T

On approach to Flesland Airport on 20 January 2020, WF577 lost power on both engines after ice detached from the air inlet and entered the engine. The engines quickly restarted and the aircraft landed without problems. The most likely scenario is that the ice accumulated during flight because the aircraft inadvertently entered an area of severe icing with supercooled large droplets (SLD). The weather radar maps from the Meteorological Institute indicate that WF577 received a clearance after departure from Kvernberget which took the aircraft into an area with more icing than if the original flight plan had been followed. It has already been considered to establish a weather radar in Oslo TMA which will be integrated into the new "en route system" (iTEC). NSIA believes that this should also be considered for other areas in Norway, and especially in the north-west region. Being able to provide weather information in real time will make an important contribution to increased flight safety

The Norwegian Safety Investigation Authority recommends that the Norwegian Civil Aviation Authority implement a project in which Avinor, Norwegian Meteorological Institute and representatives from a suitable airline participate to assess possible solutions on presentation of updated (live) weather information that can be communicated to relevant flights.

Safety Recommendation Aviation No. 2023/02T

On approach to Flesland Airport on 20 January 2020, WF577 lost power on both engines after ice detached from the air inlet and entered the engine. The engines quickly restarted and the aircraft landed without problems. The most likely scenario is that the ice accumulated during flight because the aircraft inadvertently entered an area of severe icing with supercooled large droplets (SLD). Although the DHC-8 300 is not certified to fly in such conditions, the pilots should be warned about the potentially serious consequences of ice accumulation in the air inlet.

The Norwegian Safety Investigation Authority recommends that Transport Canada (TC) assures that De Havilland includes a warning in the Airplane Flight Manual (AFM) in which users are informed that the engines may flame out if an aircraft inadvertently flies into severe icing conditions. Ice can build up in the air inlet and subsequently detach and enter the engine.

[37] The Ministry of Transport forwards safety recommendations to the Norwegian Civil Aviation Authority and/or other involved ministries for evaluation and monitoring, see Norwegian Regulations regarding public investigations of accidents and incidents in civil aviation § 8.

Safety Recommendation Aviation No. 2023/03T

On approach to Flesland Airport on 20 January 2020, WF577 lost power on both engines after ice detached from the air inlet and entered the engine. The engines quickly restarted and the aircraft landed without problems. The investigation has identified an inconsistency between the definition of severe icing and meteorological forecasts. The definition of icing intensity contains no reference to atmospheric variables related to icing.

The Norwegian Safety Investigation Authority recommends that EASA clarifies the inadequate definitions as well as the existing inconsistency relating to icing problems and ensure that the results are harmonised with other international authorities.

Norwegian Safety Investigation Authority
Lillestrøm, 7 February 2023

Abbreviations and references

Abbreviations

AC	Advisory Circular
ARS	Aircraft Communications Addressing and Reporting System
AFM	Airplane Flight Manual
AIM	Aeronautical Information Manual
AIREP	Special air report
AIRMET	Air meteorological information reports
AOC	Air Operator Certificate
AOM	Air Operator Message
ARC	Airworthiness Review Certificate
ATIS	Automatic terminal information service
ATM	Air Traffic Management
ATPL	Air Transport Pilot Licence
ATR	Avions de Transport Régional
BECMG	Becoming
BKN	Broken
CAVOK	Ceiling And Visibility [are] OK
CB	Cumulus nimbus
CBT	Computer Based Training
CPL	Commercial Pilot Licence
CRM	Crew resource management
CS	Certification specifications
CVR	Cockpit Voice Recorder
DHC	De Haviland Aircraft of Canada
DOT	Department of Transportation
DZ	Drizzle
DZRA	Drizzle and rain

EASA	European Aviation Safety Agency
EFB	Electronic Flight Bag
EHSI	Electronic Horizontal Situation Indicator
EU	European Union
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FCST	Forecast
FDR	Flight Data Recorder
FIR	Flight Information Region
FL	Flight level
FMI	Finnish Meteorological Institute
FT	Feet
HF	High frequency
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
ISA	International Standard Atmosphere
ISAR	In Service Activities Reports
JAA	Joint Aviation Authorities
Kt/KT	Knots
LBA	Luftfahrt-Bundesamt – the German aviation authority
METAR	Meteorological Aerodrome Report
MHz	Mega Hertz
MOD	Moderate
MTW	Mountain waves
NC	No Change
NH	High pressure compressor rotor speed
NM	Nautical miles

NOAA	National Oceanic and Atmospheric Administration
NOSIG	No significant change
NOTAM	Notice to Airmen
NSIA	Norwegian Safety Investigation Authority
NTSB	National Transportation Safety Board
OFP	Operational Flight Plan
OM	Operations Manual
OPC	Operator Proficiency Check
OVC	Overcast
PC	Proficiency Check
PROB	Probability
PW	Pratt & Whitney
RA	Rain
RADZ	Rain and drizzle
RMK	Remark
RPM	Revolutions per minute
SA	Situational awareness
SAT	Static air temperature
SCT	Scattered
SEV	Severe
SFC	Surface
SHRA	Showers of rain
SHRASN	Showers of rain and snow
SHRASNGS	Showers of rain, snow, and hail
SIGMET	SIGnificant METeorological Information
SL	Sea level
SLD	Supercooled large droplets

SSCVR	Solid State Cockpit Voice Recorder
STNR	Stationary
TAF	Terminal Aerodrome Forecast
TC	Transport Canada
TCCA	Transport Canada Civil Aviation
TEMPO	Temporary
TSB	Transport Safety Board
TURB	Turbulence
UK	United Kingdom
UTC	Coordinated universal time
VCSH	Vicinity showers
VHF	Very high frequency
VV	Vertical visibility
WAFC	World Area Forecasting Centre
WI	Wind
WKN	Weakening

References

Widerøe’s operations manuals, OM A and OM B

DASH 8 Flight Manual (AFM)

DH8-SL-30-007 Winter Operation; Engine Intake Ground Inspection Practices

The Norwegian Meteorological Institute: Weather report for the northern part of Western Norway, 20 January 2020

Air Operations (Regulation (EU) No 965/2012)

Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes (CS-25)

Certification Specifications and Acceptable Means of Compliance for Engines (CS-E)

Air Traffic Management/Air Navigation Services (Regulation (EU) 2017/373)

DOT/FAA/AR-01/91 A History and Interpretation of Aircraft Icing Intensity Definitions and FAA Rules for Operating in Icing Conditions

AC 91-74B – Pilot Guide: Flight In Icing Conditions

AC 25-28 Compliance of Transport Category Airplanes with Certification Requirements for Flight in Icing Conditions

ICAO Annex 3 to the Convention on International Civil Aviation, Meteorological Service for International Air Navigation

ICAO Annex 6 to the Convention on International Civil Aviation, Operation of Aircraft

ICAO Annex 8 to the Convention on International Civil Aviation, Airworthiness of Aircraft

ICAO Doc. 4444 – Procedures for Air Navigation Services Air Traffic Management

Previously submitted incident reports from Widerøe and from international accident investigation authorities

Rosenkrans, W. ‘Surveillance Without Surprise’. April 2007. Flight Safety Foundation Aerosafety World

Petter Dannevig, *Flymeteorologi*, Aschehoug forlag, 1969

Appendices

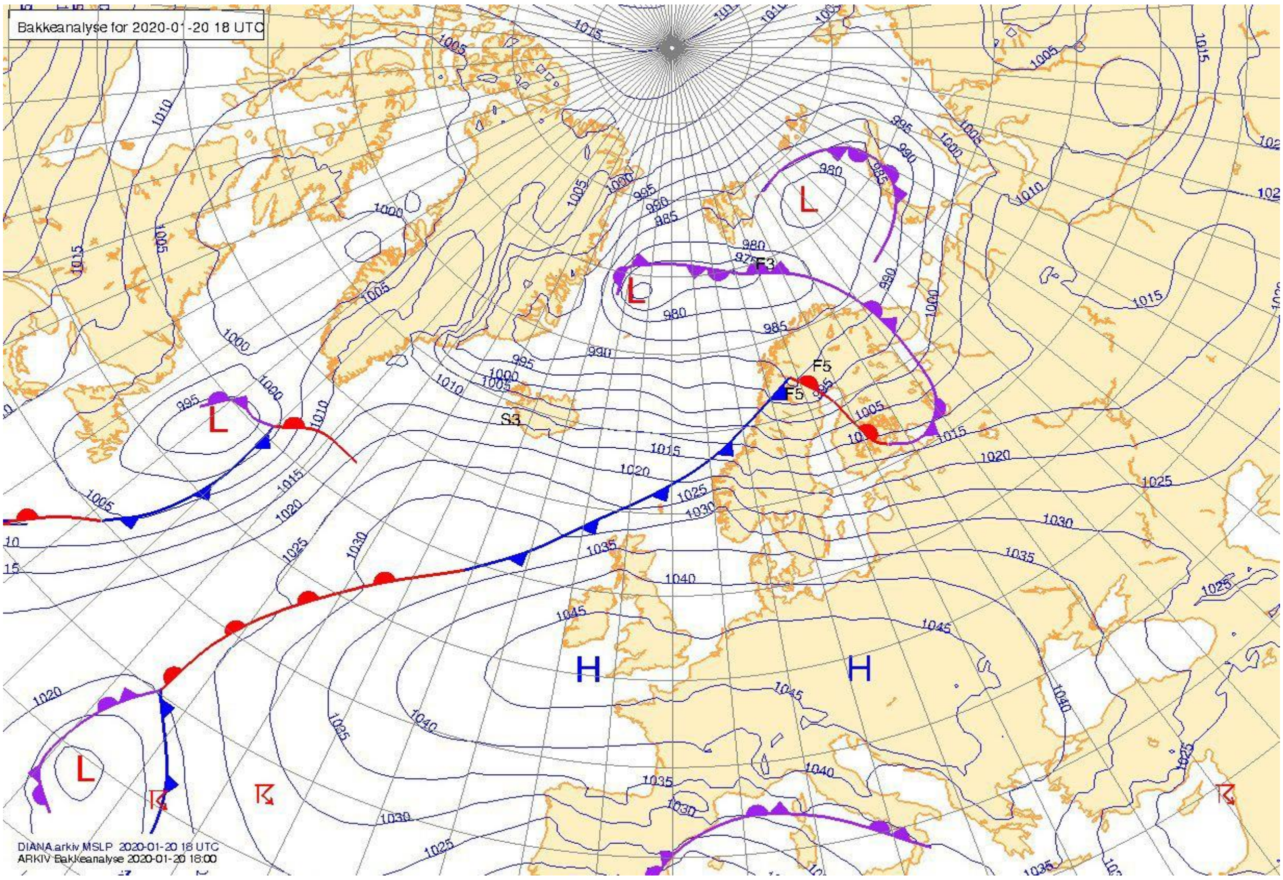
Appendix A Detailed weather report

(Translated by NSIA)

Detailed weather report for the northern part of Western Norway on 20 January 2020 prepared by the Meteorological Institute

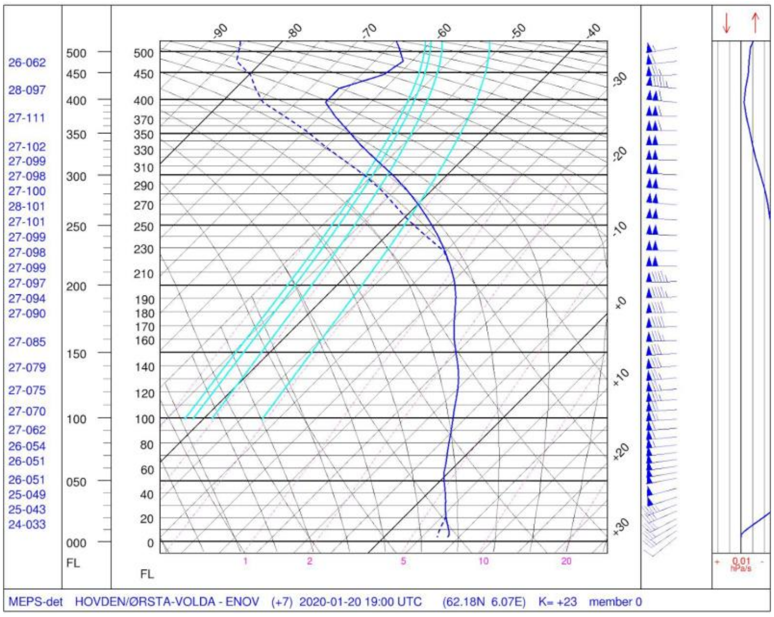
The weather situation in general

A low-pressure system in the northern part of the Norwegian Sea and a high-pressure system over the British Isles extending to Eastern Europe created a strong westerly flow of air. There was a cold front along the northern coast of Western Norway, and the front was moving east. The intense icing that the Widerøe plane experienced probably occurred in the cold front.



Sea level pressure and the meteorologist's analysis at 1800 UTC

The zero-degree isotherm was at about 3,000–5,000 feet.



Local weather conditions

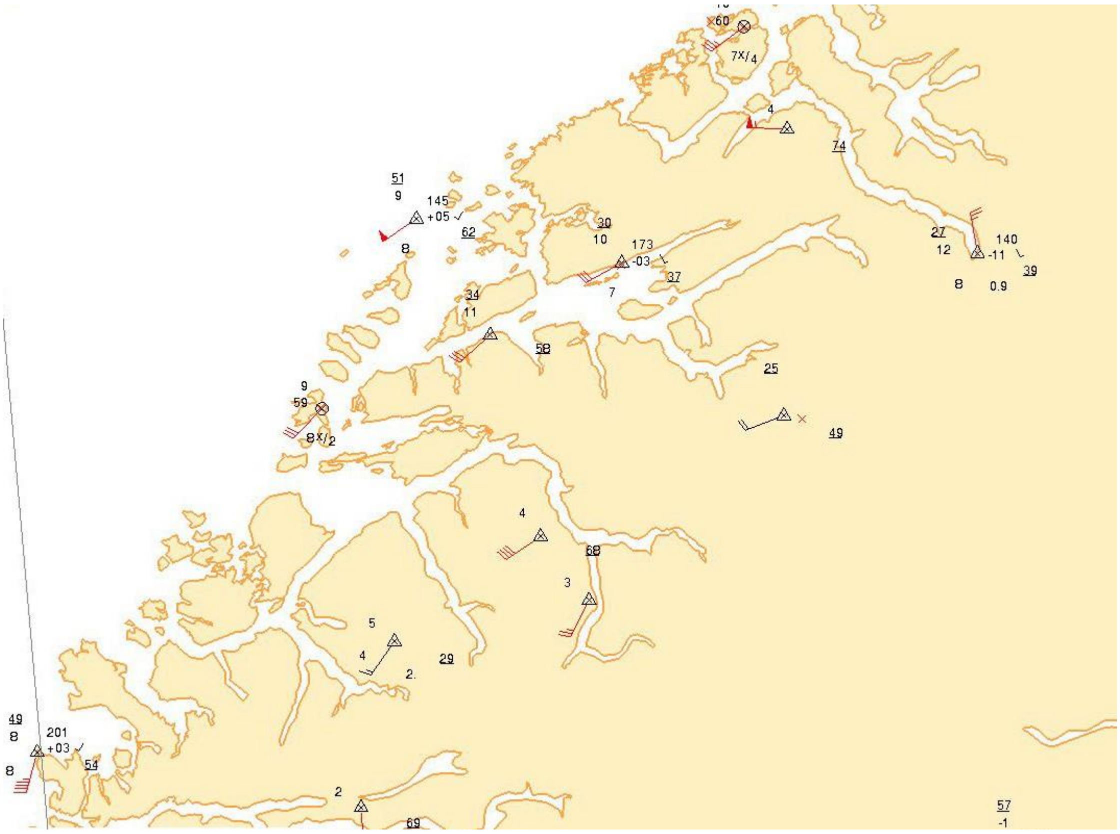
Visibility in the area was mostly between 5 and 10 kilometres. The weather was cloudy, and the cloud base was mostly between 1,400 and 2,500 feet. The ground temperature was 8–9 degrees Celsius. There was some precipitation, and in the northern part of Western Norway it was observed in the forms of rain, a mix of rain and drizzle and rain showers. The precipitation was mostly moderately intense during the period in question.

See the enclosed list of METAR.

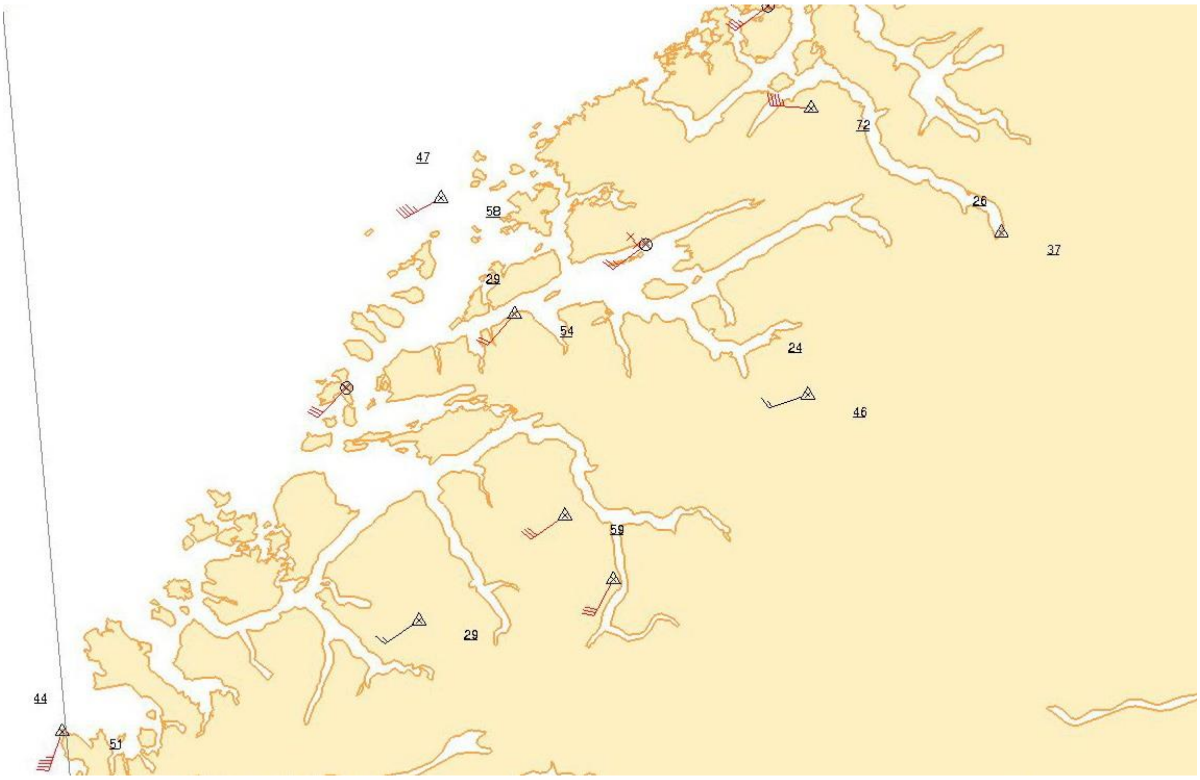
Wind

The ground winds in the afternoon and evening in question were south-westerly to westerly strong breeze to moderate gale.

Stronger winds were observed at mountain and lighthouse stations, several of which experienced storm to violent storm. Violent storm was observed at Reinsfjellet in Tingvoll at 1600 hours.



At the time of the most intense icing, the wind had started to subside, and at Reinsfjellet it had subsided to storm.



Kvernberget had gusts of about 50 knots around the time of the incident. The wind at the top of Kvernberget mountain was measured to storm force winds with gusts in excess of 70 knots.

METAR from Kvernberget for the time around take-off and icing:

ENKB 201820Z 24033G51KT 5000 SHRA FEW002 SCT012 BKN017 09/07
Q1013 RMK WIND 745FT 25058G71KT=
ENKB 201850Z 24034G50KT 7000 -SHRA FEW002 SCT016 BKN021 09/07
Q1013 RMK WIND 745FT 25053G66KT=
ENKB 201920Z 24031G45KT 7000 SHRA FEW006 SCT015 BKN037 09/07
Q1013 RMK WIND 745FT 25056G71KT=

Icing

The following AIRMET was valid during the time when the heavy icing occurred:

ENBD AIRMET C05 VALID 201600/202000 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N6200 E00500 - N6300 E00400 -
N6500 E00605 - N6500 E01415 - N6400 E01400 - N6200 E01210 - N6200
E00500 3000FT/FL180 STNR NC

According to Widerøe, the heaviest icing occurred at around 1900 hours UTC. This corresponds in time and space, but not intensity, to a pilot report of MOD/SEV ICE:

AIREP SPECIAL

ARS DH8C SEV ICE OBS AT 1900Z 20NM SE OF ENAL FL220

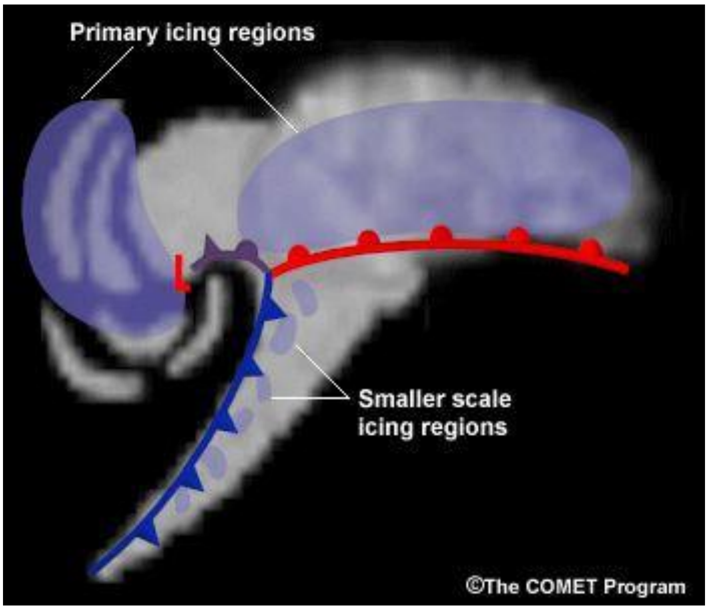
Note: Reports of MOD/SEV must be sent as SEV.

An additional assessment of the icing conditions was carried out based on this report.

We had previously received an AIRREP reporting moderate icing in the same area. The conclusion was that icing in the area was moderate, possibly bordering on severe in some locations. This corresponds to what would generally be expected when a cold front moves in over land.

From Widerøe's description of the incident, the icing was SEV in the area in question. This occurred at a surprisingly high level of FL220. This is above the level for AIRMET, which was set to FL180. The altitude where the temperature is -20°C is often used as the upper limit for vertical extent, since freezing water rarely occurs in large quantities at such low temperatures.

Skew-T diagrams indicate a temperature of nearly -30°C at FL220 in the area in question. Spontaneous freezing occurs at -40°C, at which temperature there will only be ice crystals.



Normally, a cold front will only contain limited areas of icing. When the fronts move in over land, the icing intensifies due to orographic lift. In this case, it is conceivable that mountain waves and/or TCU/CB in the cold front may have provided additional lift.

Turbulence

The strong westerly winds created mountain waves in the mountains of Southern Norway and low-level turbulence in the Trøndelag region.

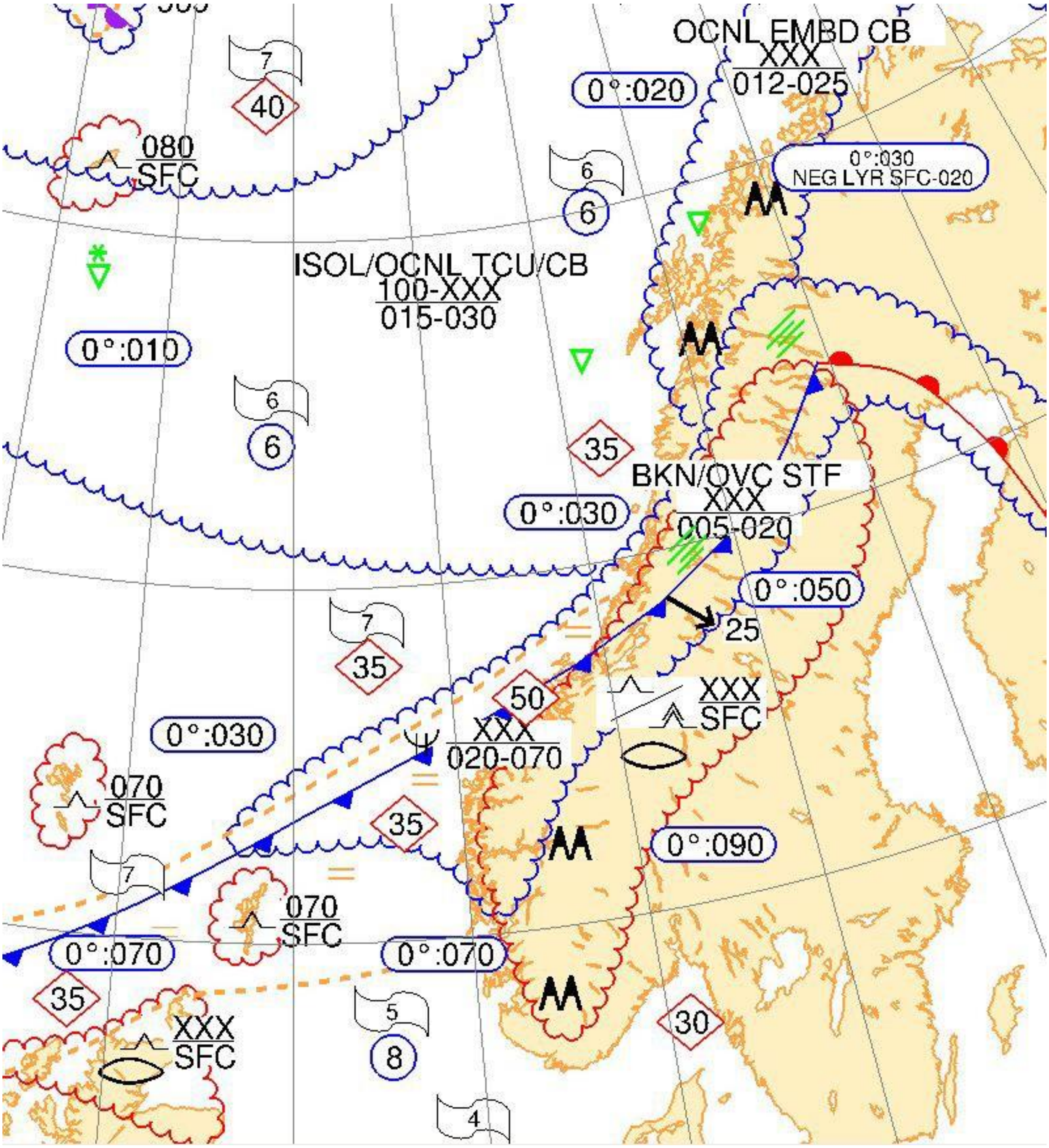
The following SIGMET for mountain waves was valid for the area in question:

ENBD SIGMET C05 VALID 201500/201900 ENVV-
ENOR NORWAY FIR SEV MTW FCST WI N6200 E00500 - N6215 E00500 - N6310 E00730 - N6245 E01130 - N6200 E01100 - N6200 E00500 SFC/FL400 STNR WKN

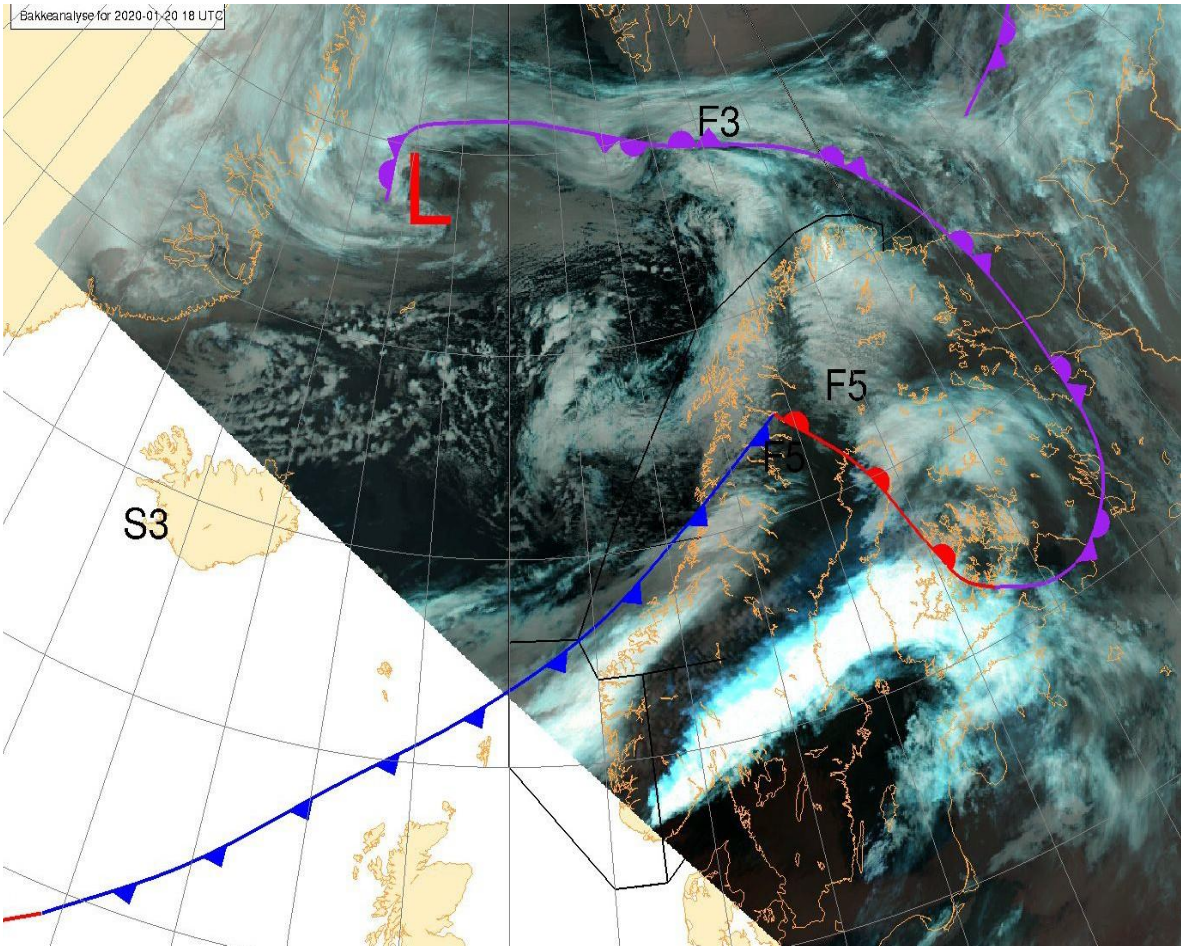
ENBD SIGMET C08 VALID 201900/202300 ENVV-
ENOR NORWAY FIR SEV MTW FCST WI N6200 E00500 - N6215 E00500 - N6245 E00645 - N6230 E01040 - N6200 E01100 - N6200 E00500 SFC/FL450 STNR WKN

Mountain waves may have contributed to more intense icing by providing additional lift. However, the mountain wave activity was subsiding at the time in question.

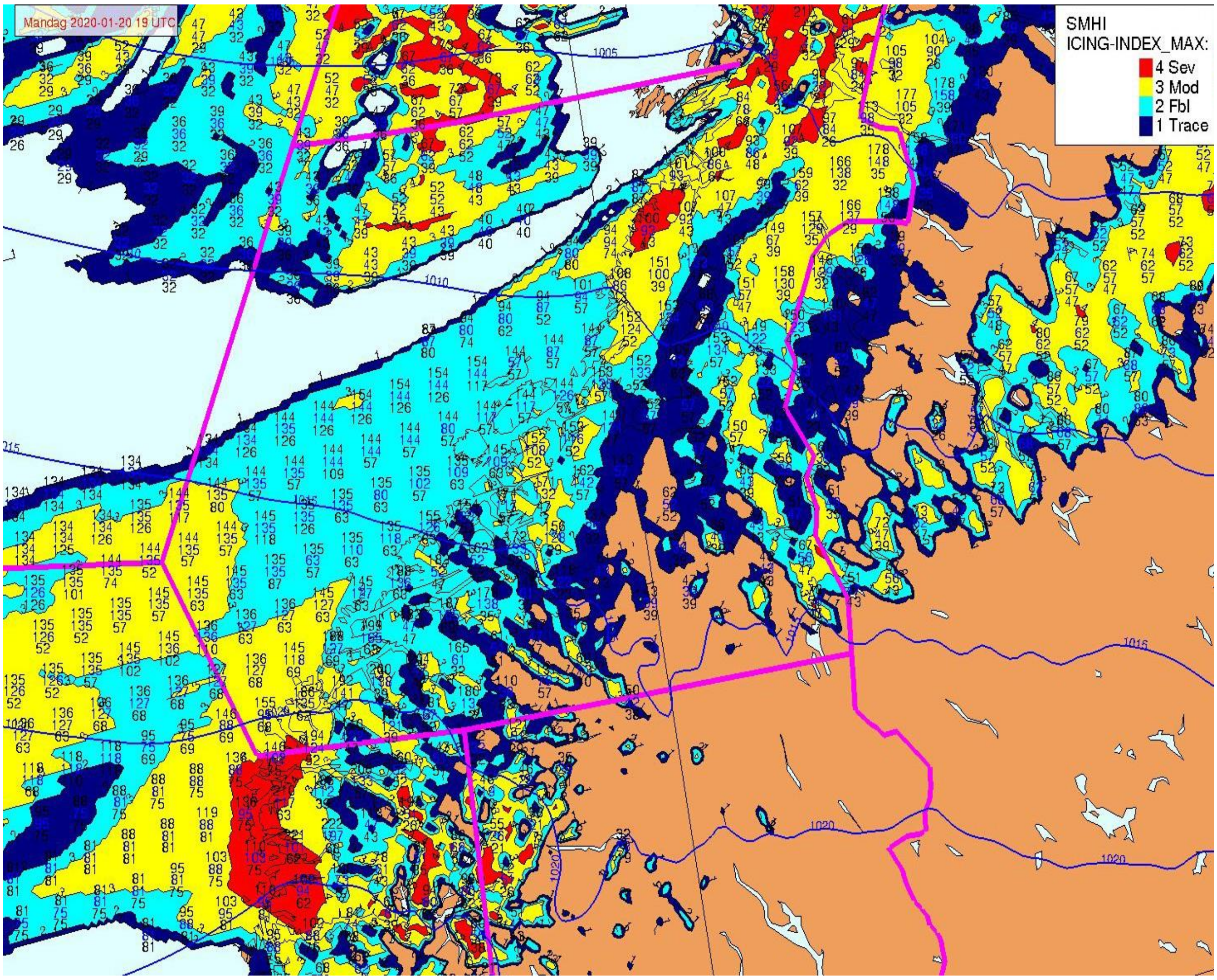
Figures



SIG chart valid at 1800 UTC

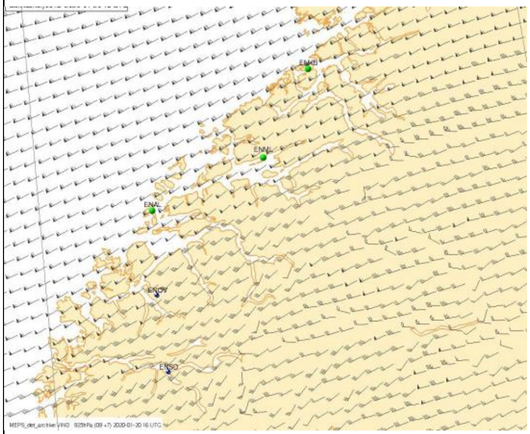
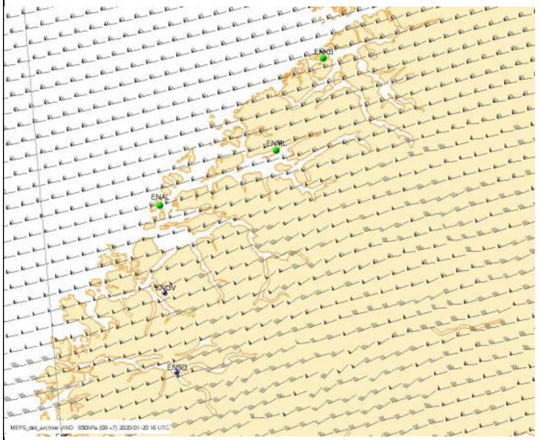
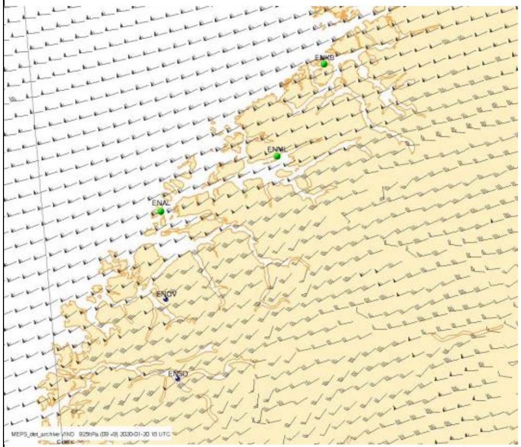
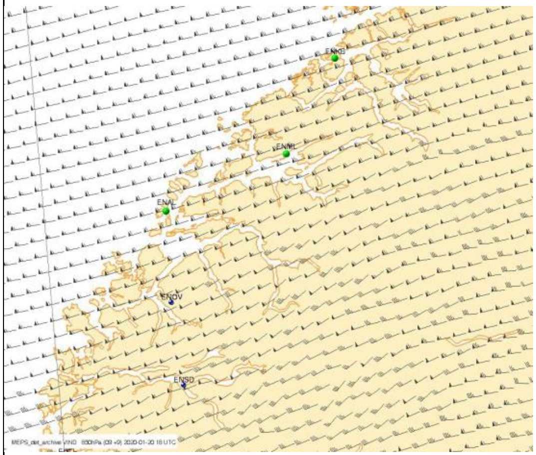
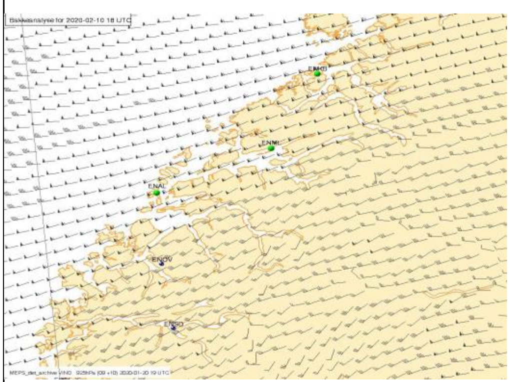
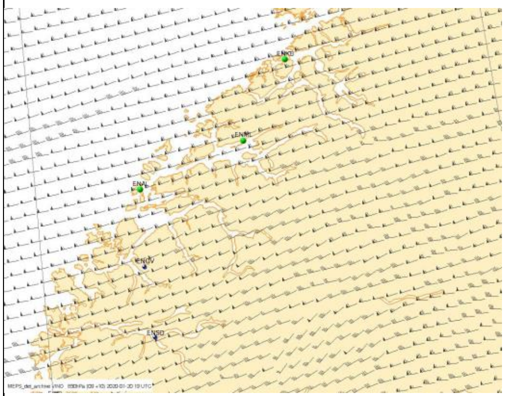


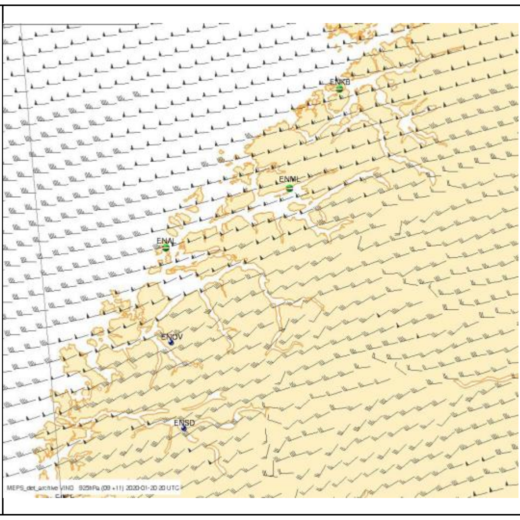
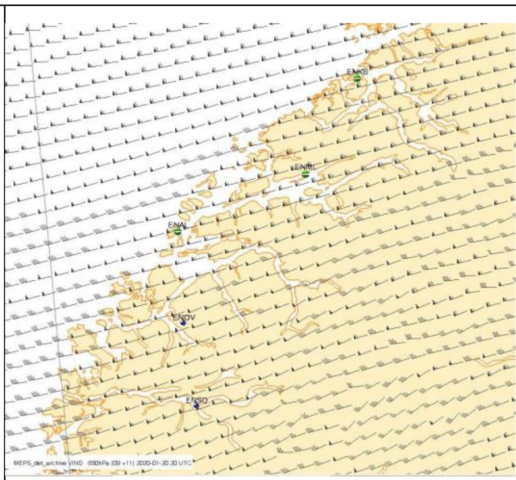
Satellite image and ground analysis at 1800 UTC



The model's icing index, 1800 UTC

Winds at altitude (from model)

	Wind 925 hPa (approx. 2,000 ft)	Wind 850 hPa (approx. 5,000 ft)
1600 UTC		
1800 UTC		
1900 UTC		

2000 UTC		

SIGMET/AIRMET

ZCZC
WSNO34 ENMI 201419
ENBD SIGMET C05 VALID 201500/201900 ENVV-
ENOR NORWAY FIR SEV MTW FCST WI N6200 E00500 - N6215 E00500 - N6310 E00730 - N6245 E01130 - N6200 E01100 - N6200 E00500 SFC/FL400 STNR WKN

ZCZC
WSNO34 ENMI 201426
ENBD SIGMET C06 VALID 201500/201900 ENVV-
ENOR NORWAY FIR SEV TURB FCST WI N6500 E01050 - N6310 E00730 - N6245 E01130 - N6350 E01400 - N6500 E01400 - N6500 E01050 SFC/FL180 STNR NC

ZCZC
WSNO32 ENMI 201437
ENSV SIGMET B05 VALID 201500/201900 ENVV-
ENOR NORWAY FIR SEV MTW FCST WI N5945 E00730 - N6000 E00620 - N6200 E00500 - N6200 E00730 - N5945 E00730 SFC/FL180 STNR NC

ZCZC
WANO32 ENMI 201512
ENSV AIRMET B07 VALID 201600/202000 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N5905 E00730 - N5845 E00545 - N6055 E00440 - N6200 E00500 - N6200 E00730 - N5905 E00730 3000FT/FL150 STNR NC

ZCZC
WANO34 ENMI 201516
ENBD AIRMET C05 VALID 201600/202000 ENVV-

ENOR NORWAY FIR MOD ICE FCST WI N6200 E00500 - N6300 E00400 - N6500 E00605 - N6500 E01415 - N6400 E01400 - N6200 E01210 - N6200 E00500 3000FT/FL180 STNR NC

ZCZC
WSNO32 ENMI 201815
ENSV SIGMET B06 VALID 201900/202300 ENVV-
ENOR NORWAY FIR SEV MTW FCST WI N5945 E00730 - N6000 E00620 - N6200 E00500 - N6200 E00730 - N5945 E00730 SFC/FL400 STNR WKN

ZCZC
WSNO34 ENMI 201826
ENBD SIGMET C07 VALID 201900/202300 ENVV-
ENOR NORWAY FIR SEV TURB FCST WI N6500 E01050 - N6245 E00645 - N6230 E01040 - N6350 E01400 - N6500 E01400 - N6500 E01050 SFC/FL180 STNR WKN

ZCZC
WSNO34 ENMI 201832
ENBD SIGMET C08 VALID 201900/202300 ENVV-
ENOR NORWAY FIR SEV MTW FCST WI N6200 E00500 - N6215 E00500 - N6245 E00645 - N6230 E01040 - N6200 E01100 - N6200 E00500 SFC/FL450 STNR WKN

ZCZC
WANO34 ENMI 201905
ENBD AIRMET C06 VALID 202000/210000 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N6200 E00500 - N6501 E01110 - N6500 E01415 - N6400 E01400 - N6200 E00850 - N6200 E00500 2000FT/FL180 MOV NE 15KT WKN

IGA

BODØ AOR (south of N65):

FBNO44 ENMI 201501

IGA PROG 201500-202400 UTC Jan 2020 NORWAY FIR COASTAL AND FJORD AREAS N6200 TO N6500

WIND SFC. SW-W/20-45KT, LCA 50-55KT COT. DECR W/15-30KT, LCA 30-40KT

WIND 2000FT. SW-W/40-60KT, COT 65-75KT. DECR 35-55KT

WIND/TEMP FL050: 240-280/60-80KT. BECMG 40-60KT / MS07-PS04 COLDEST LATE WIND/TEMP FL100: 260-290/60-70KT, INCR 70-80KT / MS06-MS04, LATE MS04-MS17 COLDEST LATE

WX. ....RA/DZ/BR, LATE SHRA COT

VIS. ....+10KM, 2-8KM IN WX

CLD.................. BKN/OVC 1500-2500FT, OCNL BKN 0500-1000FT, LATE SCT/BKN

2000-3000FT OCNL BKN 1000-1500FT, CB/TCU

0-ISOTHERM. .... FL050-070, LATE 2000-4000FT

ICE. ....MOD, OCNL MOD/SEV N-PART. BECMG FBL/MOD OCNL MOD ASSW

TCU/CB

TURB................. SEV. BECMG MOD, OCNL MOD/SEV.

OUTLOOK FOR TOMORROW: W/20-30KT, LCA 30-40KT, LATE VEERING NW. SHRA/SHRASN

STAVANGER AOR:

FBNO42 ENMI 201501

IGA PROG 201500-202400 UTC Jan 2020 NORWAY FIR SW PART COAST AND FJORD AREAS W OF E00730 AND S OF N6200

WIND SFC.......: N-PART: SW-W/10-20KT, 15-30KT COT, SW/40-55KT NEAR STAD FST HR. S-PART: W-NW/05-15KT.

WIND 2000FT. ......: S-PART: W-NW/25-35KT. N-PART: SW-W/35-50KT, LATE 30-45KT

WIND/TEMP FL050: 240-290/35-55KT / PS01-PS06, LATE N-PART MS03-PS01
WIND/TEMP FL100: 260-290/45-60KT, N-PART LCA 60-70KT / MS09-MS01
COLDEST N-PART, FST HR 00-PS01 S MOST PART.

WX. ....RA/DZ/BR

VIS. ....MAINLY 2-8KM

CLD.................. BKN/OVC 0800-2000FT, OCNL BKN 0200-0600FT

0-ISOTHERM.....: FL050-080, LATE: N-PART, 3000-5000FT, S-PART, FL060-FL100. OCNL INVERSION

ICE. ....MOD, S-MOST PART FBL/NIL

TURB................. FBL/MOD, OCNL MOD. SEV MTW N-PART

OUTLOOK FOR TOMORROW: W-NW/10-20KT, LCA 25-35KT. SHRA.

METAR

ENAL 201720Z 23033G44KT 6000 SHRA SCT006 BKN014 10/08 Q1018= ENAL 201750Z 23032G45KT 6000 SHRA SCT006 BKN014 09/08 Q1018= ENAL 201820Z 23031G43KT 6000 SHRA SCT006 BKN014 09/08 Q1017= ENAL 201850Z 23029G40KT 6000 SHRA SCT006 BKN014 09/08 Q1017= ENAL 201920Z 24031KT 6000 SHRA SCT006 BKN014 09/08 Q1017= ENAL 201950Z 24031KT 6000 SHRA SCT006 BKN014 09/08 Q1017= ENAL 202020Z 24031G42KT 6000 SHRA SCT006 BKN014 09/08 Q1017=

ENBR 201720Z 19011KT 3000 -DZRA BR BKN003 08/08 Q1030 TEMPO 2500 -DZRA BR RMK WIND 1200FT 22019KT=
ENBR 201750Z 19011KT 2500 DZ VV003 08/08 Q1030 BECMG 25015G25KT TEMPO 3500 DZ BR RMK WIND 1200FT 23015KT=
ENBR 201820Z 18010KT 2000 -DZ BR VV002 08/08 Q1029 BECMG 25015G25KT TEMPO 3500 -DZ BR RMK WIND 1200FT 23016KT=
ENBR 201850Z 19010KT 2000 -DZRA BR VV002 08/08 Q1029 BECMG 25015G25KT TEMPO 3500 -DZ BR RMK WIND 1200FT 23017G32KT=
ENBR 201920Z 19012KT 2000 -DZRA BR VV003 08/08 Q1029 BECMG 25015G25KT TEMPO 3500 -DZ BR RMK WIND 1200FT 23018G31KT=
ENBR 201950Z 19012KT 2000 -DZRA BR VV003 08/08 Q1029 BECMG 25015G25KT TEMPO 3500 -DZ BR RMK WIND 1200FT 24019G29KT=
ENBR 202020Z 22012KT 2000 -DZRA BR VV004 08/08 Q1028 TEMPO 25020G30KT 3500 -DZ BR RMK WIND 1200FT 24022KT=

ENFL 201720Z 21018KT 9999 VCSH SCT007 BKN009 09/08 Q1025=
ENFL 201750Z 21020KT 180V240 9000 -DZ SCT007 BKN009 09/08 Q1024=
ENFL 201850Z 21020G33KT 180V240 2000 -DZRA BR SCT005 BKN007 08/08 Q1023=
ENFL 201920Z 22024G34KT 2000 RADZ BR SCT005 BKN006 09/08 Q1023=
ENFL 201950Z 22024KT 3000 RADZ BR SCT005 BKN006 09/08 Q1023= ENFL 202020Z 23027KT 3000 -RADZ BR SCT005 BKN006 09/08 Q1022=

ENKB 201720Z 24031G43KT 6000 SHRA FEW003 SCT017 BKN023 09/07 Q1014 RMK WIND 745FT 25045G66KT=
ENKB 201750Z 24029G44KT 6000 SHRA FEW002 SCT015 BKN022 09/07 Q1013 RMK WIND 745FT 25050G73KT=
ENKB 201820Z 24033G51KT 5000 SHRA FEW002 SCT012 BKN017 09/07 Q1013 RMK WIND 745FT 25058G71KT=
ENKB 201850Z 24034G50KT 7000 -SHRA FEW002 SCT016 BKN021 09/07 Q1013 RMK WIND 745FT 25053G66KT=
ENKB 201920Z 24031G45KT 7000 SHRA FEW006 SCT015 BKN037 09/07

Q1013 RMK WIND 745FT 25056G71KT=

ENKB 201950Z 25034G47KT 5000 SHRA FEW006 SCT010 BKN014 09/07

Q1013 RMK WIND 745FT 26050G70KT=

ENKB 202020Z 26026KT 5000 SHRA VV013 07/06 Q1014 RMK WIND 745FT

28039G52KT=

1

ENML 201720Z 25025KT 9999 RA FEW010 SCT015 BKN025 09/08 Q1017=
ENML 201750Z 24023KT 9999 RA FEW010 SCT015 BKN025 09/08 Q1017=
ENML 201820Z 24021KT 9999 RA FEW010 SCT015 BKN025 08/08 Q1016=
ENML 201850Z 24023KT 9999 RA FEW010 SCT015 BKN025 09/08 Q1016=
ENML 201920Z 24024KT 8000 RA FEW010 SCT015 BKN025 09/08 Q1016=
ENML 201950Z 24024KT 9000 RA FEW010 SCT015 BKN025 09/08 Q1016=
ENML 202020Z 24027KT 9000 RA FEW010 SCT012 BKN020 09/08 Q1015=

ENOV 201720Z VRB08KT 8000 RA FEW018 BKN020 09/07 Q1021 RMK WIND
2175FT 23014G32KT=

ENOV 201750Z 23012KT 200V270 8000 -RADZ FEW018 BKN022 09/07 Q1021

RMK WIND 2175FT 23023G40KT=

ENOV 201820Z 23011KT 200V270 5000 RADZ FEW018 BKN021 09/07 Q1020 RMK

WIND 2175FT 24025G47KT=

ENOV 201850Z 22011G23KT 160V270 7000 RA FEW018 BKN025 09/07 Q1020

RMK WIND 2175FT 24027G41KT=

ENOV 201950Z 23012KT 7000 RA FEW020 BKN025 09/07 Q1019 RMK WIND

2175FT 24022G34KT=

ENOV 202020Z 23011KT 7000 RA FEW020 SCT025 BKN030 09/07 Q1019 RMK

WIND 2175FT 25025G44KT=

TAF

ENBR 201700Z 2018/2118 21015KT 6000 -RA SCT005 BKN010 TEMPO 2018/2104
25020G32KT 2000 DZRA BR BKN004 BECMG 2102/2105 31012KT FEW015 BKN025=

ENML 201700Z 2018/2022 27030G40KT 9999 -RA BKN018 TEMPO 2018/2022

4000 RADZ BKN012=

ENKB 201700Z 2018/2022 25030G45KT 9999 -RADZ FEW006 BKN015 TEMPO 2018/2021
26040G58KT 4000 RADZ BKN008=

ENFL 201700Z 2018/2103 20025G35KT 7000 -RA SCT006 BKN010 TEMPO 2018/2103
3000 DZRA BR BKN006 BECMG 2020/2022 29018KT=

ENAL 201700Z 2018/2023 23032G45KT 9000 -RA SCT008 BKN015 TEMPO

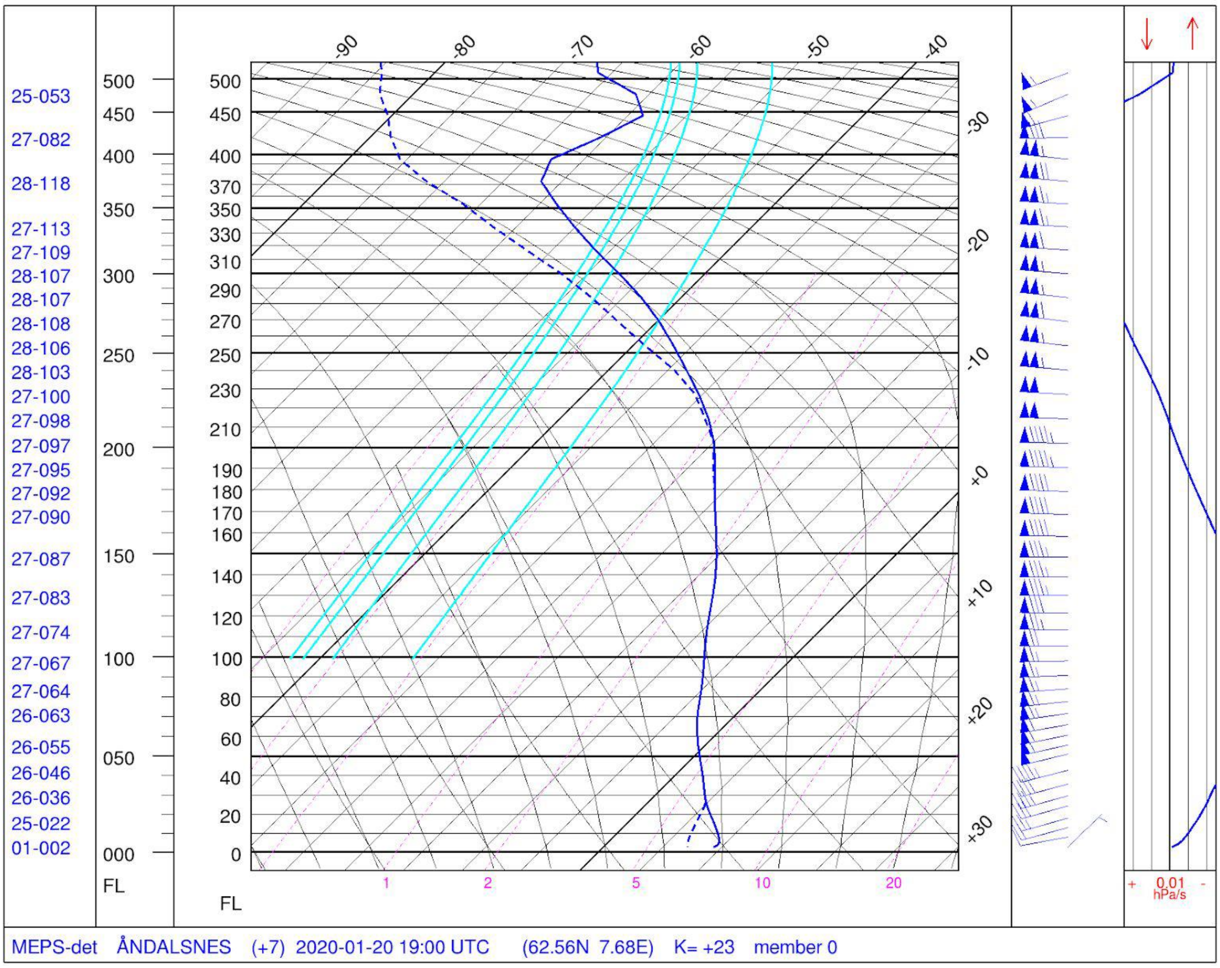
2018/2021 3000 RADZ BR BKN006 BECMG 2021/2023 27020G30KT=

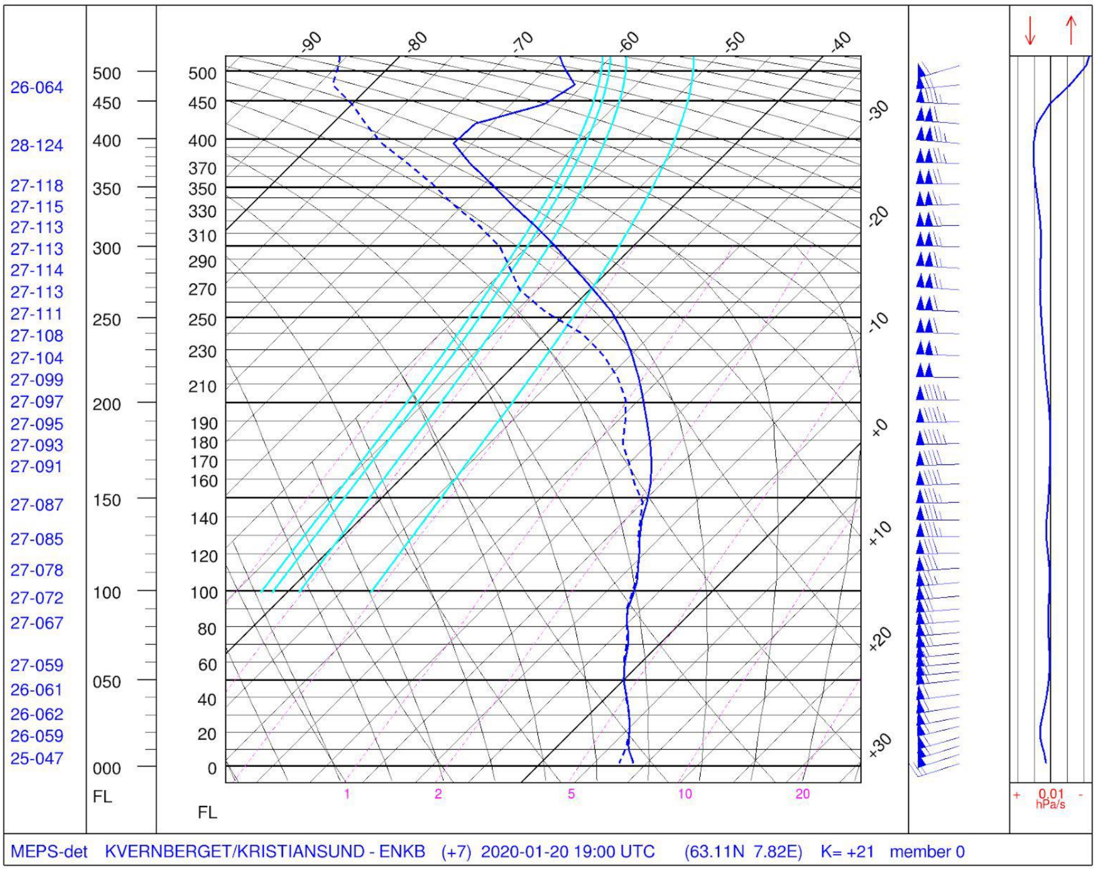
ENML 201834Z 2018/2022 27022KT 9999 -RA BKN018 TEMPO 2018/2022 27030G40KT 4000 RADZ BKN012=

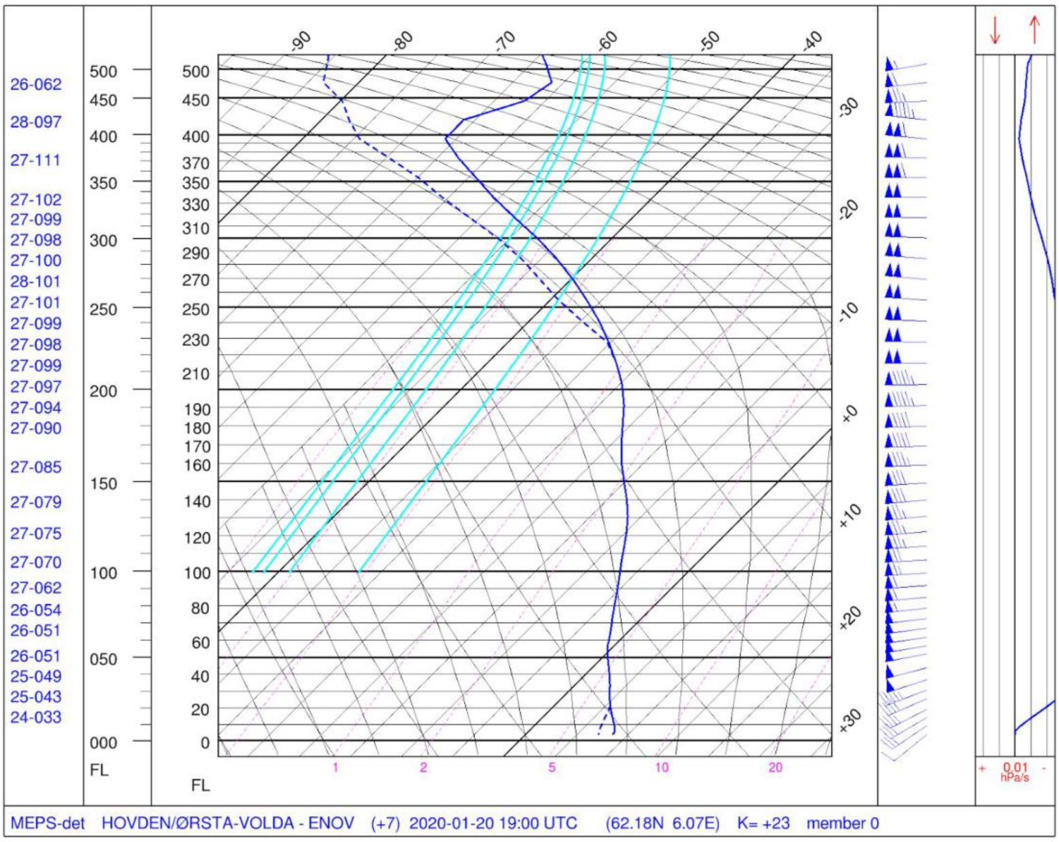
ENFL 201930Z 2019/2103 20025G35KT 7000 -RA SCT006 BKN010 TEMPO 2019/2103 2000 DZRA BR BKN006 BECMG 2020/2022 29018KT=

ENFL 202000Z 2021/2106 22025G35KT 3000 DZRA BR OVC004 BECMG 2021/2024 29018KT 9999 -SHRA BKN015=

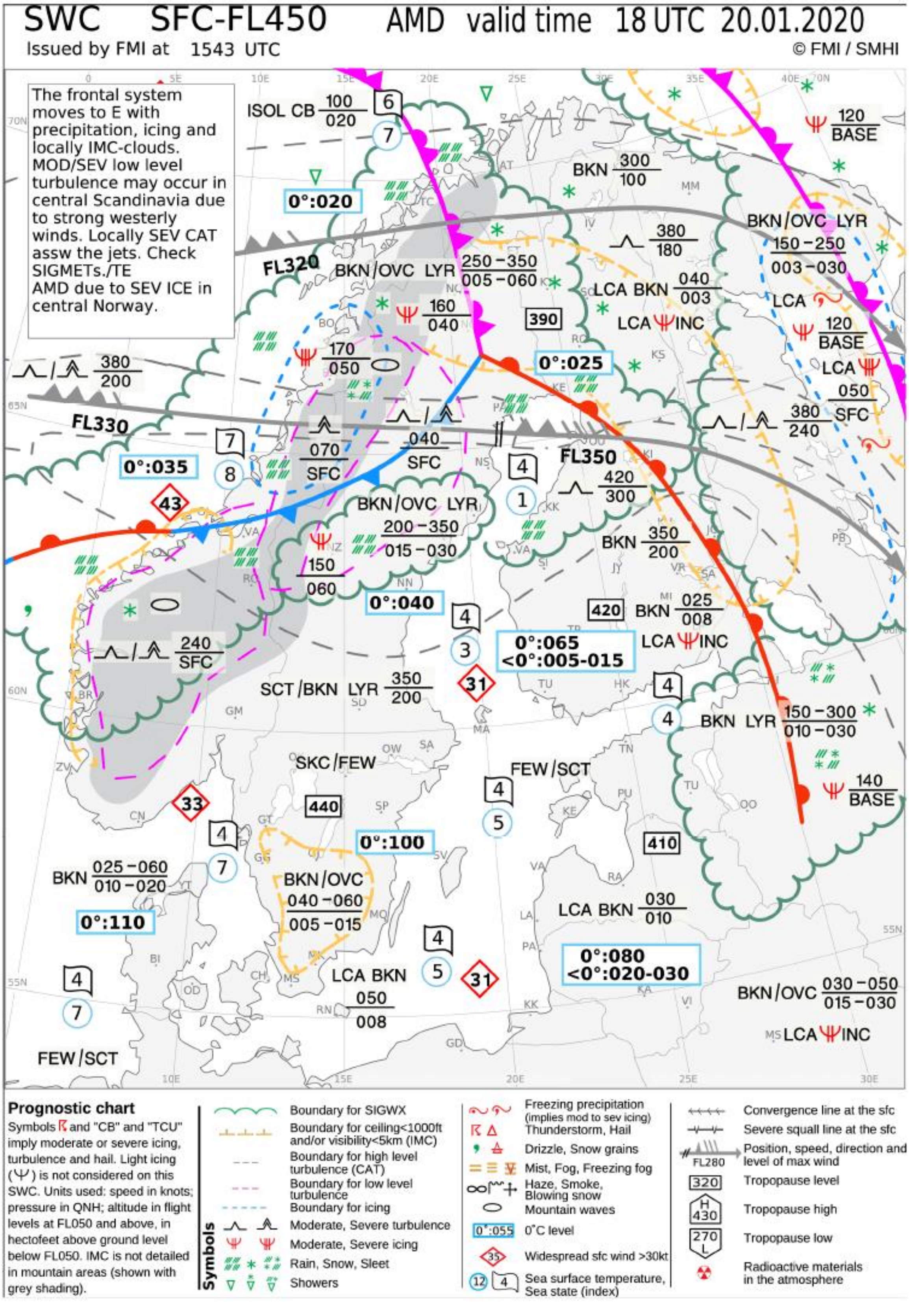
Skew-T diagrams




MEPS-det KVERNBERGET/KRISTIANSUND - ENKB (+7) 2020-01-20 19:00 UTC (63.11N 7.82E) K= +21 member 0


MEPS-det HOVDEN/ØRSTA-VOLDA - ENOV (+7) 2020-01-20 19:00 UTC (62.18N 6.07E) K= +23 member 0

Appendix B Extract from the briefing package



OPERATIONAL FLIGHT PLAN PAGE 1/5 RLSD .00Z					
WF577 **CS:**WIF77G PLN ID 05 **FLX CI 3** LBS IFR	20JAN20 DH3 LNWFO/	**ENKB/KSU 1825/P01.00** **ENBR/BGO 1930/P01.00** **FLT:0105 BLK:0105** **ETD:**20JAN/1825 **ETA:**20JAN/1937	FC VALID 201800 TO 210000 **PAX:** **TTL:0**	**GATE:**	**SLOT:**

ADD INFO/REMARKS:
IA:ENKB-ENBR

MEL/CDL ITEMS: *NO PERF PENALTY*

ROUTE TEXT:
ENKBR25 TUTOP1H TUTOP Z287 NIDGI -NIDGI2N ENBRR17
F220

ROUTE INFO:
GD 209 GCD 185 ESAD 257 W/C M46 TDV P0 MAXS 02/NIDGI COLDEST TEMP M29 AT TUTOP FLX CI 3 RT 10W VIA

STANDARD	FUEL	TIME
TRIP FUEL	1,250	01:05
CONT5MINUTES	73	00:05
ALTN (ENHD)	525	00:32
FINAL RES	580	00:40
COMPANY FUEL	0	00:00
ADDITIONAL FUEL	0	00:00
TAKE-OFF FUEL	2,427	02:22
TAXI	77	00:07
RAMP FUEL	2,504	02:29
EXTRA FUEL		
FINAL RAMP		
FUEL PENALTIES:		
+1000	+84	
10 KTS	+62	+00:03
-1000		
ONE FL LOWER	+0	+00:00

DISPATCH LOAD:			
		PAYLOAD:	
EZFW:	30106	MZFW:(S)	39507
ETOW:	32534	MTOW:(S)	43000
ELDW:	31284	MLDW:(S)	41998
ELDF:	1,177	**MIN DIV:**	**1,105**

FMS INIT LOAD:	
ENKB/ENBR	
LDG ELEV:0166 FT	PRF FACTOR%:8.0
FLX CI:3	TOC TROP:40347

ALTN	**DIST**	**TIME**	**FL**	**FUEL**
ENHD (F)	98	00:32	120	525
ENZV	129	00:40	140	650
ENAL	182	00:52	250	829
ENML	204	00:56	250	864

PIC REASON FOR EXTRA:
[]WX []ZFW+ []ATC []OTHER ....

OPERATIONAL FLIGHT PLAN PAGE 2/5 RLSD .00Z

WF577 **CS:**WIF77G PLN ID 05 **FLX CI 3** LBS IFR	**ENKB/KSU 1825/P01.00** **ENBR/BGO 1930/P01.00** **BLK:0105** **ETD:** 20JAN/1825 **ETA:** 20JAN/1937	**TIME/FUEL** **OFF BLOCK:...../....** **AIRBORNE: ...../....**	**FL / FUEL** **TOC:......./.......**

RWY/INT:		EZFW:	30106	AZFW:	
RTG/ASMD:		ETOF:	2,427	ATOF:	
V1:		ETOW:	32534	ATOW:	
VR:		ETRF:	1,250	ATRF:	
V2:		ELDW:	31284	ALDW:	
VREF:				DLI:	
FLAPS:				LIZFW:	
MFRA:				MAC:	
T/O CG:				STAB:	

DEP INFO (ATIS):	CLEARANCE:

T/O ALT:	EET	CREW	PAX	SOB
ENVA	01:05	/	/ / / /	

***FILED* - AT 1526Z/20JAN20**

(FPL-WIF77G-IS
-DH8C/M-DFGLORVY/S
-ENKB1825
-N0270F220 TUTOP/N0250F220 Z287 NIDGI
-ENBR0105 ENHD ENZV
-REG/LNWFO OPR/WIF.CONTACT INFO WIF ON DUTY STAFF. +4775513700
RVR/300 PBN/B2B3B4D2D3O2O3S2 DOF/200120)

DIFF

-RTNG- N0250F220 TUTOP Z287 NIDGI
-RTNG- ...TUTOP Z287 NIDGI
-RTNG- ...TUTOP Z287 NIDGI
-INFO- OPR/...STAFF: +4775513700

AWY **RNP** **MGA**	**WPT FRQ** **NAME/FIR** **LAT/LONG**	**DIST** **REMD** **ACCD**	**MT** **TT** **VAR**	**TIME** **ACCT** **REMT**	**ETA** **ATA** **REV**	**FL** **TRA** **SHR**	**WIND** **SAT** **TDV**	**TAS** **MN** **G/S**	**RQRD** **ACCF** **FOB**
184FT	ENKB25 KRISTIANSUND-KVER N63069E007510	0 209 0		0 0000 0105					2,427 77
TUTOP1H 049	TOC VEXAP/-16NM N62508E007044	28 181 28	231 233 02E	13 0013 0052		CLB			2,035 470
TUTOP1H RNP010 049	VEXAP N62394E006426	16 165 44	221 221 00W	5 0018 0047		220 403 02	274/100 M28 P1	266 .436 193	1,933 571
TUTOP1H RNP010 058	TUTOP N62000E005272	53 112 97	222 222 00W	17 0035 0030		220 413 02	268/099 M29 P0	271 .445 193	1,585 919

OPERATIONAL FLIGHT PLAN PAGE 3/5 RLSD .00Z									
AWY	**WPT FRQ**	**DIST**	**MT**	**TIME**	**ETA**	**FL**	**WIND**	**TAS**	**RQRD**
RNP	**NAME/FIR**	**REMD**	**TT**	**ACCT**	**ATA**	**TRA**	**SAT**	**MN**	**ACCF**
MGA	**LAT/LONG**	**ACCD**	**VAR**	**REMT**	**REV**	**SHR**	**TDV**	**G/S**	**FOB**
Z287	TOD	57	197	16		220	270/087	252	1,292
	NIDGI/-3NM	55	198	0051		420	M28	.413	1,213
059	N61058E004500	154	01E	0014		02	P1	213	
Z287	NIDGI	3	197	1		DSC			1,287
		52	198	0052					1,217
059	N61037E004486	157	01E	0013					
-NIDGI2N	BABLU	41	163	10		DSC			1,202
		11	164	0102					1,303
038	N60284E005094	198	01E	0003					
-NIDGI2N	ENBR17	11	170	3		DSC			1,177
045	BERGEN FLESLAND	0	170	0105					1,327
166FT	N60182E005128	209	00W	0000					

DEST ATIS

TIME / FUEL	TIME / FUEL	TIME / FUEL
TOD:......../......	**ON BLOCK:......../......**	**LANDING:......../......**
ETA:........	**OFF BLOCK:.......**	**AIRBORNE:.......**
ACTUAL BURN:........	**BLOCK TIME:........**	**FLT TIME:.......**

ALTERNATE ROUTE SECTION ENHD/HAU									
AWY	**WPT FRQ**	**DIST**	**MT**	**TIME**	**ETA**	**FL**	**WIND**	**TAS**	**RQRD**
RNP	**NAME/FIR**	**REMD**	**TT**	**ACCT**	**ATA**	**TRA**	**SAT**	**MN**	**ACCF**
MGA	**LAT/LONG**	**ACCD**	**VAR**	**REMT**	**REV**	**SHR**	**TDV**	**G/S**	**FOB**
166FT	ENBR 166 FT	0		0					1,105
	BERGEN FLESLAND	98		0000					
	N60176E005131	0		0032					
DCT	TOC	16	003	6		CLB			917
	BEGOD/-44NM	82	003	0006					
045	N60205E005134	16	00W	0026					
DCT	BEGOD	44	181	14		120	272/056	190	694
RNP		38	183	0020		406	M8	.299	
045	N59383E005095	60	02E	0012		02	P1	182	
DCT	TOD	11	174	4		120	272/057	185	642
	ENHD/-27NM	27	175	0024		406	M8	.292	
026	N59273E005114	71	01E	0008		03	P1	185	
DCT	ENHD 87 FT	27	174	8		DSC			580
023	HAUGESUND KARMOY	0	174	0032					
87FT	N59206E005128	98	00W	0000					

ALT ATIS

ALTERNATE ROUTE SECTION ENZV/SVG									
AWY	**WPT FRQ**	**DIST**	**MT**	**TIME**	**ETA**	**FL**	**WIND**	**TAS**	**RQRD**
RNP	**NAME/FIR**	**REMD**	**TT**	**ACCT**	**ATA**	**TRA**	**SAT**	**MN**	**ACCF**
MGA	**LAT/LONG**	**ACCD**	**VAR**	**REMT**	**REV**	**SHR**	**TDV**	**G/S**	**FOB**
166FT	ENBR 166 FT	0		0					1,230
	BERGEN FLESLAND	129		0000					
	N60176E005131	0		0040					

OPERATIONAL FLIGHT PLAN PAGE 4/5 RLSD .00Z									
AWY **RNP** **MGA**	**WPT FRQ** **NAME/FIR** **LAT/LONG**	**DIST** **REMD** **ACCD**	**MT** **TT** **VAR**	**TIME** **ACCT** **REMT**	**ETA** **ATA** **REV**	**FL** **TRA** **SHR**	**WIND** **SAT** **TDV**	**TAS** **MN** **G/S**	**RQRD** **ACCF** **FOB**
DCT 045	TOC BEGOD/-41NM N59586E005113	19 110 19		7 0007 0033		CLB			1,008
DCT RNP 045	BEGOD N59383E005095	41 69 60	181 183 02E	13 0020 0020		140 406 03	272/061 M12 P1	190 .302 179	805
DCT 032	TOD ENZV/-34NM N59040E005311	35 34 95	161 162 01E	11 0031 0009		140 413 02	278/054 M11 P2	185 .293 203	653
DCT 029 29FT	ENZV 29 FT STAVANGER/SOLA N58526E005383	34 0 129	161 162 01E	9 0040 0000		DSC			580
ALT ATIS									

ALTN	**ROUTE TEXT**	**DIST**	**TIME**	**FL**	**FUEL**
ENHD (F)	DCT BEGOD DCT	98	00:32	120	525
ENZV	DCT BEGOD DCT	129	00:40	140	650
ENAL	DCT INTUM Z289 TUMIM DCT	182	00:52	250	829
ENML	DCT OLDAS Z288 TUMIM DCT	204	00:56	250	864

OPERATIONAL FLIGHT PLAN PAGE 5/5 RLSD .00Z							
UPPER WIND SUMMARY							
CLIMB SPOT WIND							
ALT	WIND	ALT	WIND	ALT	WIND	ALT	WIND
5000	250/052	**18000**	274/094	**24000**	276/103	**30000**	276/103
TDV	M5	TDV	P1	TDV	P1	TDV	M3
TEMP	P0	TEMP	M20	TEMP	M32	TEMP	M47

WINDS/TEMPERATURES ALOFT FORECAST						
	39000	34000	30000	24000	18000	10000
KB403	278104M62	276110M55	276103M47	276103M32	274094M20	260073M6
VEXAP	278105M62	276111M55	276103M47	274104M32	274094M20	260073M6
TUTOP	274116M64	272113M56	268106M48	268104M32	270091M21	260068M7
NIDGI	272099M64	272095M56	270091M47	272091M32	268081M20	260055M6
NEPAM	272100M64	272096M56	270091M47	272091M32	266081M20	260055M6
BABLU	274073M64	274070M55	276073M46	280075M33	274070M20	272053M4
ENBR	274073M64	274070M55	276073M46	280075M33	274070M20	272053M4

DESCENT SPOT WIND							
ALT	WIND	ALT	WIND	ALT	WIND	ALT	WIND
30000	276/073	**24000**	280/075	**18000**	274/070	**5000**	264/035
TDV	M2	TDV	P0	TDV	P1	TDV	M1
TEMP	M46	TEMP	M33	TEMP	M20	TEMP	P4

WF577 >> ENKB >> ENBR >> Jan 20, 2020 18:25

Fuel			Weights			
	PLND	**REVISED**		**PLND**	**REVISED**	**ACTUAL**
TRIP	1250	1311	DOW	27214	-	
CONT	73	-	PAYLOAD	2892	-	-
ALT1	525	-	ZFW	30106	-	-
ALT2	650	-	Block	2504	3230	-
FRES	580	-	RMPW	32610	33336	-
ADD	0	-	TAXI	77	-	-
MIN TO	2427	2614	TOW	32534	33259	-
TAXI	77	-	TRIP	1250	1311	-
MIN REQ	2504	2691	LW	31284	31948	-
EXTRA	0	539	LDG Fuel	1177	1842	-
BLOCK	2504	3230	Underload	9401	9401	-
REASON	-		LIMIT	ZFW	ZFW	-

OFP REV JAN 20 - 15 34 21 - ACCEPTED
EXPORTED AT Jan 20, 2020 18:21

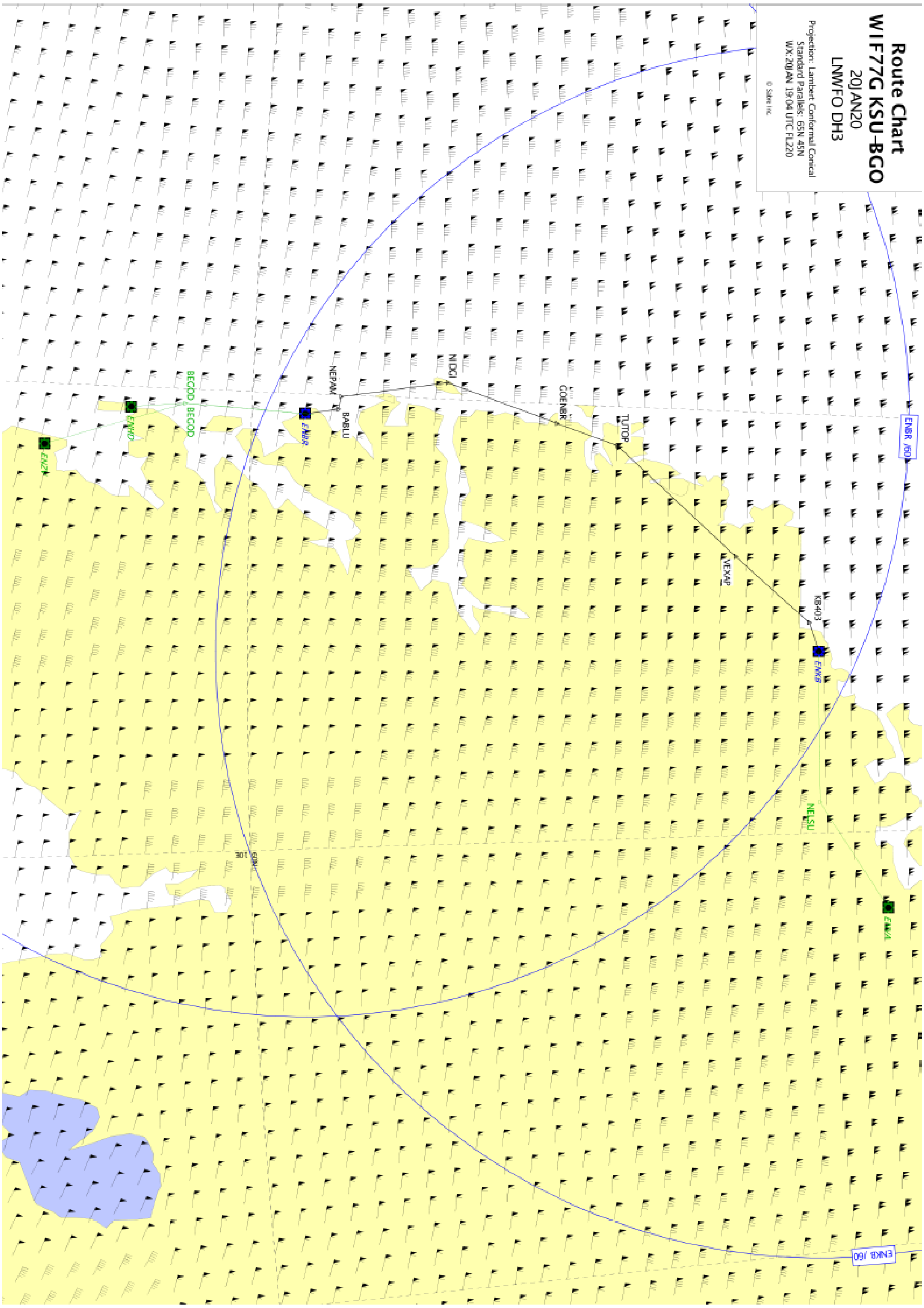
PLACEHOLDER FOR ATC FLIGHT PLAN

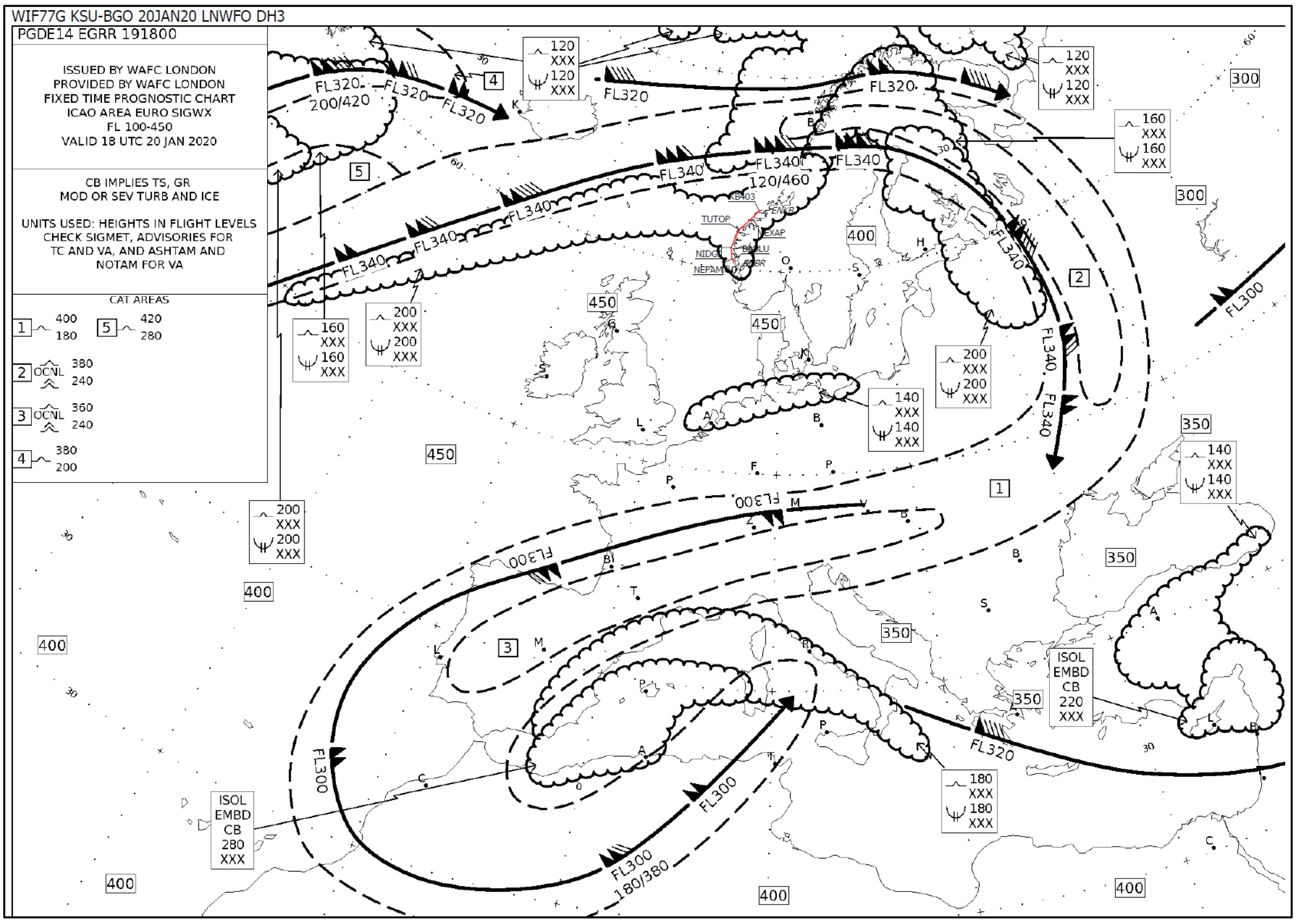
ATC NOT AVAILABLE

```
WF577 20JAN20 KSU-BGO

ENKB -KSU - KRISTIANSUND-KVERNBERGET
07/25  2390
SA 201520Z  24036G51KT 9999 BKN015 11/07 Q1014 RMK WIND 745FT
25059G79KT=
FT 201400Z  2015/2022 25030G45KT 9999 -RADZ FEW006 BKN015 TEMPO
2015/2022 4000 RADZ BKN008=

ENBR -BGO - BERGEN FLESLAND
17/35  2990
SA 201520Z  17015KT 9999 8000N -DZRA SCT003 BKN007 07/07 Q1031
TEMPO 2500 -DZRA BR OVC004 RMK WIND 1200FT 20021KT=
FT 201100Z  2012/2112 19015KT 6000 -RA SCT007 BKN010 TEMPO
2012/2104 2000 DZRA BR BKN004 BECMG 2016/2018
23018G32KT
BECMG 2101/2103 31012KT FEW015 BKN025=

ENVA -TRD - TRONDHEIM/VAERNES
09/27  3000
SA 201520Z  28021KT 9999 FEW020 BKN025 10/07 Q1012 TEMPO
28028G38KT 4000 -DZRA BR BKN008 RMK WIND 670FT
29034G49KT=
FT 201100Z  2012/2112 24008KT 9999 -RA FEW012 BKN018 TEMPO
2012/2023 4000 RADZ BKN009 BECMG 2012/2014 25020KT
TEMPO
2014/2017 26025G35KT BECMG 2017/2019 27030G45KT TEMPO
2100/2112 4000 SHRASNGS BKN020CB=

ENHD -HAU - HAUGESUND KARMOY
13/31  2120
SA 201520Z  17009KT 9999 VCSH BKN014 08/07 Q1033=
FT 201400Z  2015/2022 22012KT 9000 -RA SCT008 BKN015 TEMPO
2015/2018 BKN008=

ENZV -SVG - STAVANGER/SOLA
11/29  2450 18/36  2710
SA 201520Z  16007KT 9999 SCT014 BKN022 08/06 Q1034 TEMPO
BKN014=
FT 201157Z  2012/2112 24008KT 8000 -DZRA SCT007 BKN015
TEMPO 2012/2016 2500 RADZ BR BKN003
TEMPO 2016/2024 4000 BR BKN008
BECMG 2021/2023 25018KT
TEMPO 2100/2106 26022G32KT 2000 DZRA BR BKN006
BECMG 2106/2108 32012KT=

ENAL -AES - ALESUND VIGRA
06/24  2310
SA 201520Z  23031G42KT 5000 SHRA FEW002 SCT006 BKN018 09/08
Q1019=
FT 201400Z  2015/2023 23032G45KT 9000 -RA SCT008 BKN015 TEMPO
2015/2023 3000 RADZ BR BKN006=

ENOL -OLA - ORLAND
15/33  3000
SA 201520Z  25037G50KT 9999 FEW008 BKN012 OVC020 10/08 Q1011
TEMPO 3000 RADZ BKN008=
FT 201100Z  2012/2112 24037KT 9000 -RA FEW010 BKN015 TEMPO
2012/2020 25040G55KT 3000 RADZ BKN008 BECMG 2018/2021
25027KT TEMPO 2020/2112 27032G45KT SHRA SCT012CB
BKN020=

ENOR -     - NORWAY FIR
WS 201530Z  D07 VALID 201600/202000 ENVN-
ENOR NORWAY FIR SEV ICE FCST WI N6500 E01145 - N6650 E01300 -
```

```
N6725
E01400 - N6650 E01550 - N6500 E01430 - N6500 E01145 FL050/170
STNR
NC

ENSV -     -
WA 201515Z  B07 VALID 201600/202000 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N5905 E00730 - N5845 E00545 -
N6055
E00440 - N6200 E00500 - N6200 E00730 - N5905 E00730
3000FT/FL150
STNR NC

ENBD -     -
WA 201520Z  C05 VALID 201600/202000 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N6200 E00500 - N6300 E00400 -
N6500
E00605 - N6500 E01415 - N6400 E01400 - N6200 E01210 - N6200
E00500
3000FT/FL180 STNR NC
```

WindTempChart_LambProj




WIF77G KSU-BGO 20JAN20 LNWFO DH3
PGDE14 EGRR 191800
ISSUED BY WAFC LONDON
PROVIDED BY WAFC LONDON
FIXED TIME PROGNOSTIC CHART
ICAO AREA EURO SIGWX
FL 100-450
VALID 18 UTC 20 JAN 2020
CB IMPLIES TS, GR
MOD OR SEV TURB AND ICE
UNITS USED: HEIGHTS IN FLIGHT LEVELS
CHECK SIGMET, ADVISORIES FOR
TC AND VA, AND ASHTAM AND
NOTAM FOR VA
CAT AREAS
1 400 180
5 420 280
2 OCNL 380 240
3 OCNL 360 240
4 380 200
FL320
200/420
FL340
120/460
FL300
180/380
ISOL
EMBD
CB
280
XXX
ISOL
EMBD
CB
220
XXX

WF577 >> ENKB >> ENBR >> Jan 20, 2020 18:25

Weather

DEPARTURE:

ENKB - KSU - KristiansUnd

METAR:

201750Z 24029G44KT 6000 SHRA FEW002 SCT015 BKN022 09/07 Q1013 RMK WIND 745FT 25050G73KT=

TAF:

201700Z 2018/2022 25030G45KT 9999 -RADZ FEW006 BKN015 TEMPO 2018/2021 26040G58KT 4000 RADZ BKN008=

DESTINATION:

ENBR - BGO - Bergen

METAR:

201750Z 19011KT 2500 DZ VV003 08/08 Q1030 BECMG 25015G25KT TEMPO 3500 DZ BR RMK WIND 1200FT 23015KT=

TAF:

201700Z 2018/2118 21015KT 6000 -RA SCT005 BKN010 TEMPO 2018/2104 25020G32KT 2000 DZRA BR BKN004 BECMG 2102/2105 31012KT FEW015 BKN025=

DESTINATION ALTERNATE 1:

ENHD - HAU - Haugesund

METAR:

201750Z 20009KT 9000 BKN012 08/07 Q1032=

TAF:

201700Z 2018/2022 24012KT 9000 -RA SCT008 BKN015 TEMPO 2018/2020 BKN008=

DESTINATION ALTERNATE 2:

ENZV - SVG - Stavanger

METAR:

201750Z 19007KT 9999 BKN013 08/07 Q1033 TEMPO BKN008=

TAF:

201700Z 2018/2118 19008KT 9999 BKN015 TEMPO 2018/2024 3000 BR BKN008 BECMG 2020/2022 25018KT TEMPO 2100/2106 26022G32KT 2000 DZRA BR BKN006 BECMG 2104/2106 32012KT=

DESTINATION ALTERNATE OPTION:

ENAL - AES - Alesund

METAR:

201750Z 23032G45KT 6000 SHRA SCT006 BKN014 09/08 Q1018=

TAF:

201700Z 2018/2023 23032G45KT 9000 -RA SCT008 BKN015 TEMPO 2018/2021 3000 RADZ BR BKN006 BECMG 2021/2023 27020G30KT=

OFP REV JAN 20 - 15 34 21 - ACCEPTED

EXPORTED AT Jan 20, 2020 18:21

WF577 >> ENKB >> ENBR >> Jan 20, 2020 18:25

DESTINATION ALTERNATE OPTION:
ENML - MOL - Molde

METAR:
201750Z 24023KT 9999 RA FEW010 SCT015 BKN025 09/08 Q1017=
TAF:
201700Z 2018/2022 27030G40KT 9999 -RA BKN018 TEMPO 2018/2022 4000 RADZ BKN012=

DESTINATION ALTERNATE OPTION:
ENTO - TRF - Sandefjord

METAR:
201750Z 22008KT CAVOK 06/05 Q1027 NOSIG=
TAF:
201700Z 2018/2118 22012KT CAVOK PROB40 TEMPO 2018/2106 26018G28KT=

DESTINATION ALTERNATE OPTION:
ENGM - OSL - Oslo

METAR:
201750Z 21011KT CAVOK 05/02 Q1023 NOSIG=
TAF:
201700Z 2018/2118 21010KT CAVOK PROB30 TEMPO 2018/2103 25015G25KT=

DESTINATION ALTERNATE OPTION:
ENCN - KRS - KristiansAnd

METAR:
201750Z 23008KT 200V270 9999 BKN019 08/05 Q1032=
TAF:
201700Z 2018/2022 23012KT 9999 FEW012 BKN020 TEMPO 2018/2022 26015G25KT BKN014=

TAKE-OFF ALTERNATE:
ENVA - TRD - Trondheim

METAR:
201750Z 26024G34KT 7000 -RA FEW020 BKN025 09/07 Q1011 TEMPO 27030G45KT 4000 RADZ BR BKN008 RMK WIND 670FT 27026G39KT=
TAF:
201700Z 2018/2118 27025G35KT 9999 -RA FEW012 BKN018 TEMPO 2018/2118 27035G45KT TEMPO 2018/2023 4000 RADZ BKN009 TEMPO 2100/2118 4000 SHRASN BKN020CB=

OFP REV JAN 20 - 15 34 21 - ACCEPTED
EXPORTED AT Jan 20, 2020 18:21

WF577 >> ENKB >> ENBR >> Jan 20, 2020 18:25

ENROUTE:

ENKB - KSU - KristiansUnd

METAR:

201750Z 24029G44KT 6000 SHRA FEW002 SCT015 BKN022 09/07 Q1013 RMK WIND 745FT 25050G73KT=

TAF:

201700Z 2018/2022 25030G45KT 9999 -RADZ FEW006 BKN015 TEMPO 2018/2021 26040G58KT 4000 RADZ BKN008=

ENROUTE:

ENBR - BGO - Bergen

METAR:

201750Z 19011KT 2500 DZ VV003 08/08 Q1030 BECMG 25015G25KT TEMPO 3500 DZ BR RMK WIND 1200FT 23015KT=

TAF:

201700Z 2018/2118 21015KT 6000 -RA SCT005 BKN010 TEMPO 2018/2104 25020G32KT 2000 DZRA BR BKN004 BECMG 2102/2105 31012KT FEW015 BKN025=

OFP REV JAN 20 - 15 34 21 - ACCEPTED

EXPORTED AT Jan 20, 2020 18:21

WF577 >> ENKB >> ENBR >> Jan 20, 2020 18:25

Sigmets

ENROUTE:

ENOR - null

SIGMET:

C06 VALID 201500/201900 ENVV-
ENOR NORWAY FIR SEV TURB FCST WI N6500 E01050 - N6310 E00730 -
N6245 E01130 - N6350 E01400 - N6500 E01400 - N6500 E01050 SFC/FL180
STNR NC

SIGMET:

B05 VALID 201500/201900 ENVV-
ENOR NORWAY FIR SEV MTW FCST WI N5945 E00730 - N6000 E00620 - N6200
E00500 - N6200 E00730 - N5945 E00730 SFC/FL180 STNR NC

SIGMET:

D08 VALID 201700/201900 ENVN-
ENOR NORWAY FIR SEV TURB FCST WI N6500 E01120 - N6715 E01250 -
N6700 E01630 - N6500 E01415 - N6500 E01120 SFC/FL080 STNR WKN

SIGMET:

D07 VALID 201600/202000 ENVN-
ENOR NORWAY FIR SEV ICE FCST WI N6500 E01145 - N6650 E01300 - N6725
E01400 - N6650 E01550 - N6500 E01430 - N6500 E01145 FL050/170 STNR
NC

ENROUTE:

ENBD - null

SIGMET:

C05 VALID 201600/202000 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N6200 E00500 - N6300 E00400 - N6500
E00605 - N6500 E01415 - N6400 E01400 - N6200 E01210 - N6200 E00500
3000FT/FL180 STNR NC

ENROUTE:

ENSV - null

SIGMET:

B07 VALID 201600/202000 ENVV-
ENOR NORWAY FIR MOD ICE FCST WI N5905 E00730 - N5845 E00545 - N6055
E00440 - N6200 E00500 - N6200 E00730 - N5905 E00730 3000FT/FL150
STNR NC

OFP REV JAN 20 - 15 34 21 - ACCEPTED

EXPORTED AT Jan 20, 2020 18:21

Appendix C Dialog with De Havilland

Questions from NSIA and reply from De Havilland received 2 April 2020:

1. Flight operations in SLD conditions – Have Bombardier done research on how the engine behaves in conditions with Super Cooled Large Droplets? If not, have you considered to do so?

    The basic answer is that to our knowledge there are no aircraft certified for use in SLD conditions because there are no means to verify test (practically) results in the real environment. We do describe how a crew can detect Severe Icing (AFM Sect 4.7) and direct them to exit those conditions (AFM Sect 4.7.3.5). From our perspective, the crew witnessed both conditions for detection of Severe Icing. As part of the post Roselawn accident in the US, we conducted extensive handling tests with ½" quarter round behind the leading edge boots to simulate "run back" ice and concluded that our wing was robust enough to negate any problems of the sort.

2. Use of weather radar to detect icing – There is limited information about the use of the weather radar to detect ice in the Honeywell user manual. The pilots in Widerøe seem not to use the radar for this purpose and mostly use it to detect and avoid turbulence in connection with CB activity. The AIBN would like to know Bombardier's view regarding the use and ability of weather radar to detect and avoid severe icing conditions. Especially SLD conditions.

    De Havilland are not aware of any guidance material stating that conventional weather radar can be used to detect and avoid SLD conditions. We are aware of statements indicating weather radar can be used for detection of freezing rain where there may also be SLD conditions associated with cloud formation producing the rain, however, the same guidance material is quite clear that airborne weather radar is not effective where droplet sizes are less than 500 microns due to very low radar reflectivity at the wavelength of existing weather radars. Reference FAA Advisory Circular 91-74B, "Airborne weather radar cannot, however, detect drizzle-size drops or cloud-size drops, and therefore should not be relied upon to detect icing in clouds or freezing drizzle. It also lacks the ability to detect small, ice crystals that have little to no liquid water present that can be in heavy concentrations near convective weather systems."

3. Informing other operators – To our knowledge this kind of incident has not happened with the Dash-8 before. (Inflight icing of this severity ending with dual engine flame-out) Does Bombardier plan to inform other Dash-8 operators or at least operators that may encounter the same conditions?

    We are currently checking through our old documentation to understand if we have passed this information on to our Operators in the past. We are preparing additional information package for transmittal. We will certainly re-emphasize the need to monitor the signs for severe icing and immediate exit when those conditions are detected.

4. Mitigating actions – In this early stage of the investigation we have discussed possible mitigating actions for Widerøe. One action discussed is to paint part of the engine intake in a dark color to make visual detection from the cockpit of ice buildup in the intake inside the boots easier. Is this something you would consider being useful?

    De Havilland do not consider it to be advantageous to monitor for ice build-up aft of the protected area of the engine intake. The indication of severe icing conditions is the accretion of ice on the propeller spinner aft of the spinner nose toward the blades and on the cockpit side windows aft of the leading edge. Crews are expected to monitor these identified areas of *the aircraft during any flight in icing and be prepared to exit the conditions immediately upon detection of ice accretion on the indicated areas.*

Questions from the NSIA and reply from De Havilland received 10 October 2021:

NSIA knows that the aircraft entered an area with severe icing during flight, and that the ice catch was substantial. The engines flamed out shortly after the crew observed ice shedding from the aircraft. The NSIA believe that ice from this shedding got ingested into the engines. The investigation is left with three possibilities where the ice came from.[38]

1. Ice was ingested in the engines from other parts of the aircraft than the engine. This ice would bypass the compressor inlet and possibly clog the bypass door. Ice would then build up from the aft and forward, until it would be sucked into the compressor.

   We consider it highly unlikely for this scenario to be feasible. The only ice shed locations upstream of the engine are the propeller blades, perhaps the spinner, although this would be almost impossible, the nacelle intake lip, potentially the nacelle intake duct if the aircraft is operated outside of Appendix C icing (see point 2 below), and the engine adapter heater. Ice building up in the lower cowl plenum far enough the be ingested into the engine would need to be so substantial that the airframe ice would be of primary concern in such an encounter.

2. Ice build-up on the side walls of the air intake, due to runback. This would create sheets of ice loosening and be sucked right up in the compressor inlet. This is similar to the Nova Scotia incident in 2001, where the crew reported seeing ice build-up in the intake just prior to the flameout. Since it was observed from the cockpit, it can be assumed that the build-up was on the side walls as the lower bowl is not visible.

   Note that I do not believe that it is possible to see clear ice building up in the nacelle inlet. Irrespective, I also do not believe that the aircraft involved in the Nova Scotia event has been exposed to icing conditions outside of Appendix C envelope. Any conditions creating runback in the lower cowl inlet would create similar runback on the airframe. The aircraft has been certified and tested to operate in Appendix C icing conditions. Operation outside of the Appendix C icing conditions would likely result in ice building up in different areas, rendering the ice protection systems less effective.

3. If the intake boots were completely covered with ice, lumps of ice would break free when entering milder air masses and the result would be similar to option 2. and lumps of ice would be sucked into the compressor inlet, but possibly not as serious.

   The larger the ice fragments breaking off the intake lip, particularly clear higher density ice, the less likely they are to bypass the inertial separator and be ingested into the engine.

4. Based on the data collected after the Nova Scotia incident, did you see cases where ice was being picked up in the air inlet as the crew had reported during climb in the Nova Scotia incident?

   After the Air Nova (later Jazz) flameout, the Operator painted the “ski ramp” a dark green to enable the crew to see an airborne build up of ice, however it was our opinion that any ice forming on that surface in flight would be clear and as such could still not be identified as ice by the crew.

[38] *At a later stage of the investigation, the NSIA sent another email to De Havilland to clarify some additional aspects. The first section, containing three questions, concerns how ice could have entered the engine, and the following section contains four follow-up question.*

5. What is the De Havilland’s current position on the risk of ice building up inside the air inlet?

   *We realize that the nacelles can “catch” ice but haven’t experienced anything that causes us concern when the aircraft is operated within the “certified” icing envelope. The instructions included in AOM 653 include a tactile inspection of the Bypass Door area (This are **MUST** be clear before flight). The Auto Ignition system was intended to relight the engine should any unforeseen flameout occur.*

6. We understand that the crew action when unintentionally entering severe icing is to leave the area at once. Even then, the risk of being exposed for some time is present. Have you evaluated to inform operators of the possibility of engine flameouts due to icing?

   I can find no records of an such documentation other than the AFM Sect 4.7.3 instructions.

7. In the last email (sent 2 April 2020) you mentioned that you were preparing an information package on the subject for operators. Was that finalized and distributed?

   De Havilland sends out an In Service Activities Report (ISAR) in the summer each year reminding Operators of Icing Protection for the Type(s). A copy of the latest is attached.[39]

[39] *The NSIA has read the above-mentioned ISAR, but was unable to find any relevant information about engine failure due to icing.*

Appendix D AOM No 653

Z2

Regional Aircraft
123 Garratt Blvd.
Downsview, Ontario, Canada M3K 1Y5

de Havilland Dash 8

All Operator Message No. 653

ATTN:	Director/Manager of:	Maintenance Engineering Quality Control Flight Operations	
		DATE:	30 MAR 01
ATA:	0240	MODEL:	Dash 8 100/200/300

SUBJECT: Occurrence Advisory – Dual Engine Flameout During Taxi

REFERENCE:
/A/ Service Letter DH8-12-006 Revision "D"
/B/ Approved Flight Manual, Section 4.7 Para 4.7.2.1 Normal Procedures
/C/ Approved Flight Manual, Section 2.6 Para 2.6.6 Limitations

The following message is being sent to all de Havilland Dash 8 100/200/300 Operators and Bombardier Aerospace Regional Aircraft Field Service Representatives.

This message contains information requiring attention and/or action. Please ensure timely and appropriate distribution within maintenance and flight operations departments.

DISCUSSION:

One Operator recently experienced a two-engine flameout during taxi for take-off. Digital Flight Data Recorder data confirmed that the right engine quit, followed shortly thereafter by the left engine.

Prior to the occurrence the aircraft had been parked on the ramp for approximately three hours in heavy blowing snow. The lower engine cowl intake plugs were not installed during the station stop. The aircraft was deiced/anti-iced and taxied for departure. During taxi the right engine lost power and subsequently stopped. While waiting for clearance to taxi back to the terminal, the left engine lost power and stopped.

The flameouts are believed attributable to a heavy buildup of partially frozen contaminant in the engine's air intake becoming ingested by the engine during taxi. The Flight Crew had not inspected the engine air intakes for contamination before departure. The intake bypass doors were "open" during the entire ground stop.

A post occurrence inspection of the aircraft several hours later by government aircraft accident investigation authorities and the operator revealed that a substantial amount of slush and snow was still present in the lower cowl air intake of each engine.

The Limitations Section of the Approved Flight Manual (A.F.M.), paragraph 2.6.6 requires the engine intake bypass doors open and engine ignition in "Manual" or "Auto" at any time that the icing conditions as defined in paragraph 2.6.6 are encountered.

DH8 Service Letter 8-12-006 Revision "D" states:

> Through the icing experience of one operator it has been discovered that ice can accumulate in the engine air intake, immediately ahead of the bypass door. If this ice accumulation is not removed it can build forward of the nacelle plenum and potentially cause an engine power interruption. As a result of these events, the operator has implemented the following procedure:
>
> Tactile inspections of the engine intakes must be completed during all station stops when icing conditions exist. If icing conditions are encountered in-flight or icing conditions exist or have existed on the ground, an inspection to ensure that the engine air intakes are clear, must be performed. A visual inspection of the intake may **NOT** identify ice that has formed in the nacelle plenum. With the intake bypass doors "OPEN", reaching inside the plenum chamber will identify any ice, slush or "other" contaminant buildup. This area **MUST** be clear before flight.

Operators may wish to implement a similar practice during operation in icing conditions.

Currently there are two means of providing protection from inadvertently accumulating ice and snow in the lower cowl intake area while the aircraft is moored/parked.

Engine Air Intake Covers

Engine Air Intake Covers are designed to provide protection from foreign objects. There is a new sponge rubber cover available which replaces the original urethane foam type. The new covers provide a better form fit around the cowl lip, resulting in a very reliable seal. Operators in climates where unfavorable weather conditions prevail are recommended to purchase this type.

This new Engine Air Intake Cover is available from Tronair, When ordering, be sure to stipulate the "sponge rubber type", as the P/N remains the same: 99-8032-6000.

Engine Air Intake Boots

In addition to the new sponge rubber Engine Air Intake Covers, Tronair are introducing an optional Air Intake Boot to provide additional protection against contamination. This boot is made of a heavy vinyl that is resistant to engine and hydraulic oils. The boot fits over the air intake covers and is held on by elastic and adjustable straps with nylon straps with nylon hooks that attach to the lower cowl hinge openings. This boot is an optional piece of equipment only, P/N 99-8111-6000.

Please direct responses and inquiries to your Bombardier Aerospace Regional Aircraft Field Service Representative or the Technical Help Desk in Toronto at telephone (416) 375-4000 or facsimile (416) 375-4539 or e-mail: thd@dehavilland.ca.

Jim Donnelly, Manager Product Safety, and Martin Elliott, Director, In-Service Engineering, Bombardier Aerospace Regional Aircraft.

Appendix E Internal recommendations

Recommendations and actions following Widerøe's internal report

1. The company should ensure that pilots receive a notification on their iPad (Aviobook) when the Norwegian Meteorological Institute issues a significant weather forecast.

   Measure: […] Our experts' assessment is that it will not be possible to develop an appropriate notification system in the app, since the app is worldwide and the user would then receive notifications of SIGMETs and AIRMETs most of which would be irrelevant, and this would defeat the object of the notification. The solution whereby the crew make active use of the enroute chart to look for significant weather phenomena is considered adequate.

2. It is recommended that the company enter into a dialogue with Avinor with a view to having AIRMET and SIGMET notifications visualised graphically in Aviobook in future.

   Measure: […] JEPPESEN will release a new version of its app FD PRO this month. In this version, all SIGMETs will be included and visualised on enroute charts.

3. The simulator at CAE OSL should be upgraded to the same configuration as Widerøe's Dash-8 100, 200 and 300 aircraft as regards auto ignition.

   Measure: The simulator has been updated to include auto ignition.

4. It is recommended that the company raise awareness among its pilots about special weather phenomena that can cause severe icing conditions, how pilots can identify such phenomena and when the 'Flight in severe icing conditions' procedure should be applied.

   Measure: Training base developed through a CBT. The planned measure will be implemented in the course of 2021.

5. It is recommended that the company raise awareness among its pilots about the importance of making active use of the weather radar in relation to the aircraft's configuration.

   Measure: […] Fleet Office has prepared a basis for and provided concrete input for training, including both OPC/PC and Line-Check. The pilots' awareness is expected to improve through line checks going forward.

6. The company should provide simulator training focusing on flameout with relight in all segments of flight.

   Measure: The topic has been added to OPC and is followed up in a safety case.

7. The company should raise the pilots' awareness of challenges associated with flying in particularly demanding areas, with a focus on icing and future climatic changes. Challenges relating to humid air that is mechanically lifted, mountain waves and fronts. Special areas more prone to icing. Prospects concerning icing related to climate change.

   Measure: Fleet Office has established cooperation with the Norwegian Meteorological Institute / aviation weather service for access to the weather phenomena known to give rise to moderate/severe icing in Norway. Based on this information, an overview of icing conditions in Norway is prepared, supplemented by the experience and expertise of

Widerøe's pilots. In the Winter Bulletin 2020/21, all Widerøe pilots were encouraged to provide written feedback on this. The information obtained from the feedback received will be collected and categorised before the final document is published. The form of publication and the document owner remain to be decided. The simulator has been configured and approved with a new icing model. This was done in accordance with EASA CS-FSTD(A) issue 2 (Certification Specifications for Aeroplane Flight Simulation Training Devices). Widerøe has been the responsible SME (Subject Matter Expert). A new qualification certificate was issued in September 2020. All instructors will be trained in the module by OPC 01/21. Training base developed through a CBT. The planned measure will be implemented in the course of 2021.

8. The company should ensure that its pilots have the equipment necessary to carry out a satisfactory inspection of the air inlets on Widerøe's Dash 8 aircraft. Steps, lights, mirrors, etc. The equipment must be easy to access and use.

   Measures: A decision has been made to order about 40 new mirrors – W8P25617 – in accordance with the established follow-up ordering procedure.

9. The company should consider whether the interior of the air inlets (lower cowling) should be painted a darker colour than white to facilitate the detection of accumulating ice/snow. It should also consider introducing procedures to ensure a smooth interior surface in the air inlet.

   Measure: We have considered the recommendation made following the investigation. We cannot see that the colour of the cowling intake would make much difference. The important thing is the surface's structure and ability to prevent ice accumulation. Our focus will be on regular cleaning and, if relevant, painting/polishing the surface. We will therefore introduce active surface cleaning in connection with the aircrafts' A checks. We will also look at the possibility of having the surface polished and painted when the cowling is in the workshop for repairs.

10. The company should consider whether to upgrade its fleet of DHC-8-100/200/300 aircraft with CSI 826930 (basis for enlarging drain holes). A task for regular inspection of drain holes should also be introduced

    Measure: The technical department has consulted De Havilland concerning other operators' experience of CSI 82693. (Enlarge duct assembly drain hole) […] The recommendation was not to carry out this CSI, as no data exist that support any positive effect compared with the current system.

Appendix F Operational directive

OPERATIONAL DIRECTIVE			37-2021
APPLICABLE TO:	OM-B DHC-8 1/2/300	OM-B DHC-8 Q400	Reissue
ISSUE DATE: 23.01.2021		EFFECTIVE DATE: 07.12.2021	

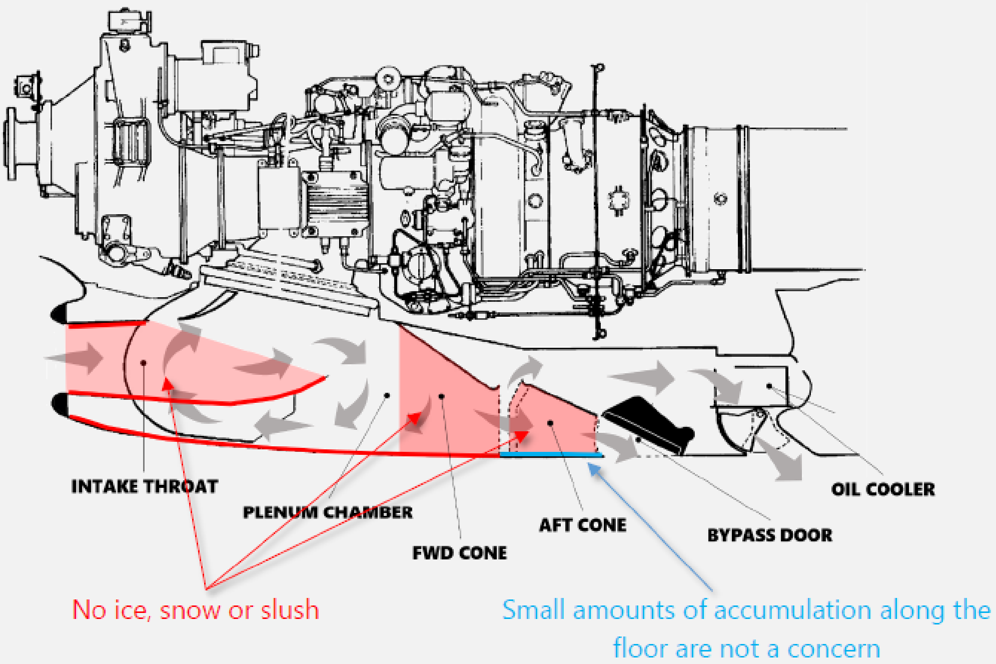
SUBJECT **Inspection of Engine Air Inlets**

APPROVER Ole Støre — Fleet Chief Pilot Dash 8

BACKGROUND

The Dash 8 aircraft have been designed, tested and certificated for flight into icing conditions. Depending on how severe the weather conditions are during flight, ice is expected in the nacelle intakes. The inlet will allow small to medium-sized pieces of ice to enter the engine, without consequence, as the engines are designed and tested according to Airworthiness Standards.

However, progressive ice accumulation in multiple flight segments or on the ground is a particular concern that must be addressed through company policies, procedures, and maintenance practices. Under such circumstances, ice can progressively accumulate in the engine air intake, both in the intake throat and immediately ahead of the bypass door. If this ice accumulation is not removed, it can potentially cause an engine power interruption.



As a result of actual occurrences, Widerøe has implemented the following inspection procedures for the engine nacelles. Stepladders required for inspection are found at every third gate at all major network destinations, and close to the parking position at the regional airports. If in doubt, a request for information on the actual location of the stepladder can be made to the ground service provider.

2.11 Operational Guidance Material

Pre-flight in Cold Weather *OM-B 2.11.8.11 (DHC-8-1/2/300) / 2.11.9.8 (DHC-8 Q400)*

[...]

Engine Air Inlets

Contaminants like rain, slush and snow may pool in the bottom of the engine intake immediately ahead of the bypass door and form an ice sheet that is hard to detect. If this ice accumulation is not removed, it can build up forward of the nacelle plenum and potentially cause an engine power interruption.

Therefore, tactile inspections of the engine intakes must be performed during all extended ground stops when icing conditions (slush/snowfall) exist on the ground, or if moderate-to-severe icing conditions were encountered in flight. A visual inspection alone may not identify ice formed in the nacelle plenum, which could result in engine flameout. The inspections must be performed even if the intake covers have been fitted during ground stops.

NOTE While an extended ground stop cannot be precisely defined, the following guidelines apply:

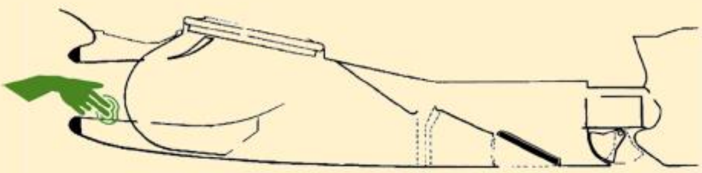
- A regular turnaround, where the crew remains on board, is not considered an extended ground stop;
- Changing aircraft may be considered an extended ground stop when leaving one aircraft and walking through the terminal to another. Moving directly from one aircraft to another over the tarmac may not be considered an extended ground stop. The intensity of precipitation and wind magnitude/direction must also be considered.
- An aircraft parked overnight is always considered as an extended ground stop.

A visual inspection of the intake may be conducted using a mirror/electronic device and is part of all preflight inspections. The tactile inspection required above must be conducted by using a stepladder to reach inside the aft plenum chamber to identify any ice, slush or other contaminant buildups by following the procedures below:

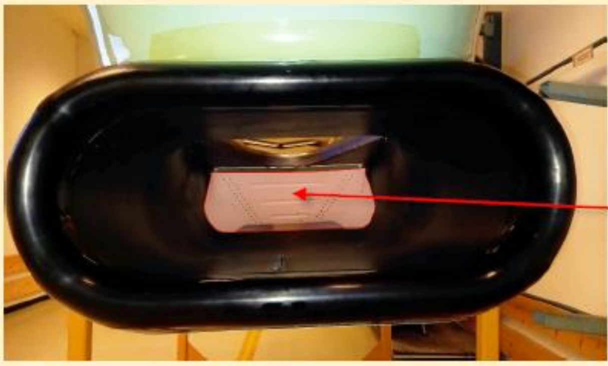
1. Open both intake bypass doors using the 'Engine Intake Bypass' switchlight on the 'Ice and Rain Protection Panel'. The bypass doors are DC-powered and will function whenever the aircraft is powered up.
2. Ensure that a flight crew member remains in the flight deck to guard the position of the bypass doors during the inspection.
3. Using a stepladder to gain sufficient access, perform visual and tactile inspections of both intakes behind the intake lips checking for residual ice or slush that may melt and accumulate on the ramp. Ensure no contamination has built up in this area. Verify the drain holes are clear and free from debris.

Visual inspection

Tactile inspection



No ice, slush or snow

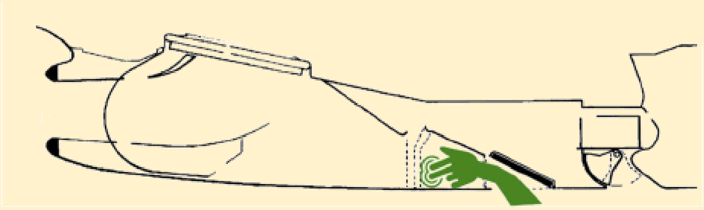


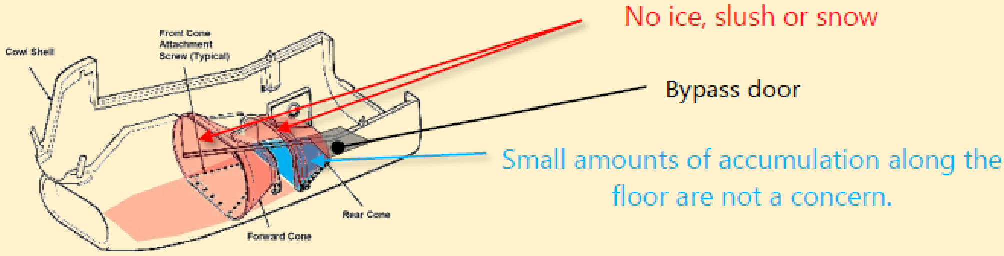
No ice, slush or snow

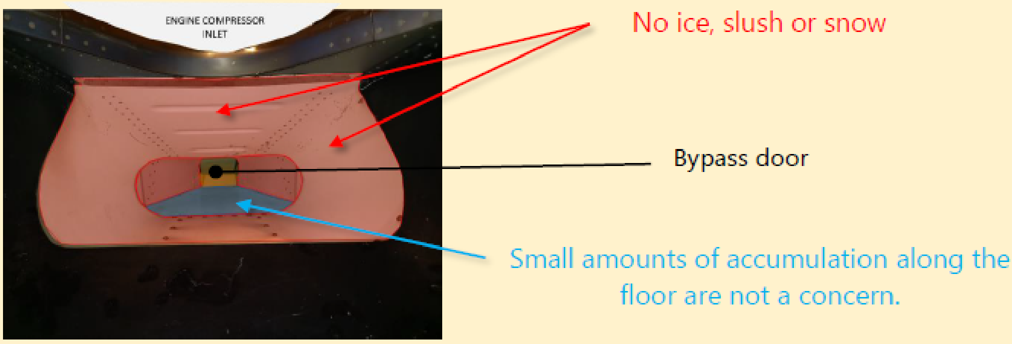
4. Using the inspection mirror and a stepladder, visually check the nacelle plenums bypassing the mirror up to and partially into the opened intake bypass doors. Via the opened intake bypass doors, reach inside the aft plenum chamber to identify any ice, slush, snow or other contaminates. Snow must be completely clear from the surfaces of the forward and aft cone and around the bypass door. In the Aft Cowl, small amounts of accumulation on the floor and along the intersection between the floor and walls of the lower cowl are not a concern. Verify the drain holes are clear and free from debris.

Visual inspection

Tactile inspection







This directive is valid until removed from AvioBook and IQSMS

5. If snow, slush or ice is found, contact MOC (7551 3607) for technical assistance to remove the contaminants according to maintenance procedures. Except for slush and snow that can be removed by a gloved hand (no equipment), pilots or ground personnel shall not attempt to remove contaminants inside the nacelles.
6. On the DHC-8 Q400, close the bypass doors before engine start.