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FLIGHT OPERATIONS &
TRAINING STANDARDS
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Getting to Grips with Cold Weather Operations

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INTRODUCTION

Cold weather operations result in specific challenges, and may have an influence on safety margins. These conditions can adversely affect aircraft performance, systems and structures.

This brochure is a guidance document that can be used as a resource for Airbus operators involved in cold weather operations. It provides a detailed understanding of the threats associated with cold weather, and specifies the essential knowledge and procedures to ensure both safety and operational performance.

It is essential to remember that icing is not limited to winter operations in the northern hemisphere. Therefore, constant vigilance and a good awareness of the situation are essential.

This brochure summarizes information from various documents from Airbus and the aviation industry. It is a supplementary resource that does not replace the Airbus manuals and regulations. In the case of a difference between the information in this brochure and that contained in the AFM, FCOM or any regulation, the manuals and regulatory documents always have priority.

Definitions

Anti-icing is a precautionary measure that protects treated surfaces from the accretion of frost and ice and the accumulation of snow and slush, for a limited period of time (holdover time).

Clear ice develops when flying in areas with high concentrations of supercooled water droplets, for example in cumuliform clouds and freezing rain. Clear ice forms when only a small part of the supercooled water droplets freezes on impact. The droplets freeze gradually as they flow back across the wing, and leave a smooth, hard, glossy, and transparent coating of ice over the wing surface, known as clear ice.
Clear ice can also develop in the case of precipitation on a cold-soaked aircraft on the ground. Clear ice is very difficult to visually detect, and may break loose during or after takeoff.

Cold soak: The wings of an aircraft are “cold-soaked” when they contain very cold fuel, due to a long flight at high altitude, or a refuel with very cold fuel. Cold-soaked wings depend on:
- The quantity and temperature of the fuel in the fuel tanks,
- The type and location of fuel tanks,
- The length of time at high altitude,
- The temperature of refueled fuel, and
- The time since refueling.

Contamination: All forms of frozen or semi-frozen deposits on an aircraft, for example frost, snow, slush or ice.

De-icing is a procedure that removes frost, ice, slush or snow from the aircraft. This may be achieved by mechanical methods, pneumatic methods, or the use of heated fluids.

De/Anti-icing is a procedure that combines both de-icing and anti-icing, and can be performed in one or two steps:
- One-step de-icing/anti-icing: Heated anti-icing fluid is used to de-ice the aircraft, and remains on the surfaces to provide anti-icing capability.
- Two-step de-icing/anti-icing: The procedure contains two different steps. The first step (de-icing), is followed by the second step (anti-icing), as a separate fluid application.

Dew point is the temperature at which water vapor starts to condense.

Drizzle (Metar code: DZ) is a uniform precipitation that has only small drops (diameter less than 0.5 mm (0.02 in) very near together. Drizzle appears to float while following air currents, but is different to fog droplets, because drizzle falls to the ground.

Fog is a visible aggregate of extremely small water particles (droplets) in the air. Fog reduces the horizontal visibility on the ground to less than one kilometer.

Freezing fog (Metar code: FZFG) is a fog formed of supercooled water droplets that freeze on contact with objects, and develops a coating of rime/clear ice.

Freezing rain (Metar code: FZRA) and freezing drizzle (Metar code: FZDZ) is rain or drizzle in the form of supercooled water droplets that freeze on impact with any surface.

Frost is a deposit of ice crystals that develops on the ground or other surfaces. Frost is formed by sublimation, when water vapor is deposited on a surface whose temperature is at or below freezing.

Glaze ice is a smooth coating of clear ice formed by the freezing of supercooled water droplets (e.g. freezing rain or freezing drizzle) on objects with a surface temperature below or slightly above 0 °C.

Hail (Metar code: GR) is a precipitation of particles of ice that fall either separately or grouped together. These particles are usually spheroidal, conical or irregularly shaped, with a diameter of 5 to 50 mm (0.2 to 2.0 inches).

Hoarfrost is a rough white deposit of crystalline appearance formed at temperatures below freezing point. It usually occurs on exposed surfaces on a cold and cloudless night. It frequently melts after sunrise: if it does not, an approved de-icing fluid should be applied in sufficient quantities to remove the deposit. Generally, hoarfrost cannot be removed by only brushing. **Thin hoarfrost** is a uniform white deposit of fine crystalline texture, that is thin enough to see surface features underneath, for example paint lines or markings.

Holdover time is the estimated time during which the anti-icing fluid prevents the formation of ice and frost and the accumulation of snow on the treated surfaces of an aircraft:

- With one-step de-icing/anti-icing: The Holdover Time starts when the de-icing/anti-icing starts.
- With two-step de-icing/anti-icing: The Holdover Time starts when the second step (e.g. anti-icing) starts.

Ice pellets (Metar code PL) is a precipitation of transparent ice particles, usually spheroidal or irregular, with a diameter of 5 mm (0.2 inch) or less. The pellets of ice usually bounce when they fall on hard ground.

Icing conditions occur when the OAT on the ground and for takeoff, or when TAT in flight, is 10 °C or below, and there is visible moisture in any form (for example clouds, fog with visibility of one mile or less, rain, snow, sleet and ice crystals).
Icing conditions also occur on the ground and for takeoff when the OAT is 10 °C or below when operating on ramps, taxiways, or runways where surface snow, standing water, or slush may be ingested by the engines or freeze on engines, nacelles, or engine sensor probes.

Precipitation is any liquid or solid water that falls from the atmosphere and reaches the ground.

Precipitation intensity is an indication of the quantity of precipitation collected per unit time. It is expressed as light, moderate or heavy. Intensity is defined in accordance with the type of precipitation, based either on rate of fall for rain and ice pellets, or visibility for snow and drizzle. The rate of fall criteria is based on time and does not accurately describe the intensity at a specific time of observation.

Rain (Metar code: RA) is a precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 inch) in diameter, or smaller drops, that in contrast to drizzle, are widely separated.

Rime ice is formed by the immediate freezing of supercooled droplets as they strike the aircraft. Therefore, rime ice may form only on the leading edges and not on the surfaces. It can generally be removed by brushing, but when surfaces and edges are covered, it is necessary to use an approved de-icing fluid. Rime ice appears rough, milky and opaque.

Runback ice forms when liquid water impacts the aircraft surface, flows off past the impact region, and then freezes. This can occur at near freezing temperatures with liquid water levels that are very high, or when thermal ice protection does not melt the impacting water.

Sleet, or “Rain and Snow Mixed” (METAR code RASN or SNRA), is precipitation composed of a mixture of rain and partially melted snow.

Slush is snow soaked with water, that spatters when stepped on firmly. Slush occurs at temperatures of approximately 5 °C (41 °F).

Snow (Metar code SN) is the precipitation of ice crystals, mainly branched in the form of six-pointed stars. At temperatures higher than about -5 °C (23 °F), the crystals are generally grouped together in snowflakes.

- **Dry snow** is snow that if compacted by hand, does not stay compressed when released. The wind can blow dry snow. Dry snow normally occurs when temperature is below freezing, and can be easily brushed off from the aircraft.
- **Wet snow** is snow that, if compacted by hand, stays compressed when released, and with which snowballs can be created. Wet snow normally occurs when the temperature is above freezing. Wet snow easily sticks to the aircraft structure, and therefore is more difficult to remove than dry snow.
- **Compacted snow** is snow that is compressed into a solid mass that cannot be additionally compressed, and will hold together or break up into chunks if picked up.

Snow grains (Metar code: SG) is a precipitation of very small white and opaque particles of ice. These particles are usually flat or elongated. Their diameter is less than 1 mm (0.04 inch). When the particles hit hard ground, they do not bounce or break.

Snow pellets (Metar code: GS) is a precipitation of white and opaque particles of ice. These particles are spherical or sometimes conical. Their diameter is about 2 to 5 mm (0.1 to 0.2 inch). Particles are easily crushed. They bounce and break on hard ground.

Supercooled water is a condition where water remains liquid at negative Celsius temperatures. Supercooled drops and droplets are unstable and freeze on impact.

Supercooled Large Droplets (SLDs) are water drops with a diameter above 50 micrometers (0.05 mm) that exist in a liquid form at air temperatures below 0 °C. SLDs include freezing drizzle drops and freezing raindrops.

Visible moisture occurs when there is fog, rain, snow, sleet, high humidity (condensation on surfaces) or ice crystals, or when taxiways or runways are contaminated by water, slush or snow.

ABBREVIATIONS

ACARS	Aircraft Communication Addressing and Reporting System
AFM	Airplane Flight Manual
AIP	Aeronautical Information Publication
AMM	Aircraft Maintenance Manual
AMP	Aircraft Maintenance Publication (A220 only)
AMS	Aerospace Material Specification
AOA	Angle Of Attack
AS	Aerospace Standard
ATC	Air Traffic Control
CDF	Centralized De-icing Facility
CRM	Crew Resource Management
EASA	European Union Aviation Safety Agency
EFB	Electronic Flight Bag
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAP	Final Approach Point
FCOM	Flight Crew Operating Manual
FCU	Flight Control Unit
FLS	FMS Landing System
FMS	Flight Management System
FPA	Flight Path Angle
FTP	Fuel Temperature Prediction
GBAS	Ground Based Augmented Systems
GIDS	Ground Ice Detection System
GNSS	Global Navigation Satellite System
GS_L	Pseudo Glide Slope (LPV) track
HOTDS	Holdover Time Determination System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
ISA	International Standard Atmosphere
ISI	In-Service Information
ISO	From the Greek word “isos”: International Organization for Standardization
LPV	Localizer Performance with Vertical Guidance
LWES	Liquid Water Equivalent System
MCDU	Multipurpose Control and Display Unit
MEA	Minimum En-route Altitude
METAR	METeorological Aerodrome Report
MSA	Minimum Sector Altitude
NOTAM	Notice to Airmen
OAT	Outside Air Temperature
PANS-OPS	Procedures for Air Navigation Services - Aircraft Operations
PEP	Performance Engineer’s Programs
PFD	Primary Flight Display
RNP	Required Navigation Performance
RNP AR	Required Navigation Performance with Authorization Required
RNP APCH	RNP Approach
SAE	Society of Automotive Engineers International
SBAS	Satellite Based Augmented System
SLS	Satellite Landing System
TAT	Total Air Temperature
TC	Transport Canada
VNAV	Vertical Navigation

A. Aircraft Icing on Ground

1. Causes

1.1. General

There are many weather conditions that can cause icing on the aircraft when on the ground. The main conditions are frost and precipitations that include for example snow, freezing fog, freezing drizzle, freezing rain and ice pellets.

A380 in Freezing Fog

Frost may form on the aircraft due to radiation cooling in the following conditions:

- Clear sky (because the heat loss from the surface of the earth is more significant when there are no clouds).
- The light is low, for example during the night, or in the shade (because the heat loss is more significant when there is no sun).
- No wind or light wind (because there is no or little heating via convection).

Due to the heat lost by radiation to the sky, the aircraft surfaces may become colder than the ambient air. If the temperature of the aircraft surfaces decreases below the frost point of the ambient air (the temperature below which water vapor deposits directly to ice crystals), frost will form on the aircraft surfaces.

Frost may also form due to conduction cooling (Refer to A.1.2).

Water, slush or snow on ramps, taxiways and runways may also contaminate the aircraft due to the wind, jet blast from other aircraft, or snow removal operations at the airport.

Possible Contamination due to Wind on the Ramp

In addition, the projection of slush or snow during taxi, takeoff or landing may result in contamination on the aircraft (e.g. flaps, slats and landing gear).

1.2. Icing due to Cold-Soaked Wings

Even when the OAT is several degrees above freezing, frost or more significantly, **clear ice**, can form on the under and upper sides of **cold-soaked wings** in the following conditions:

- The temperature of the aircraft structure is below 0° C (32° F).
- Moisture is visible (e.g. fog, rain, drizzle), or humidity is high.

This is because the moisture near the wing surface freezes. Heavy freezing was reported during drizzle or rain at temperatures up to +15 °C.

Wings can be cold-soaked due to contact with cold fuel or cold metallic parts (e.g. landing gear structure). This may occur in the case of refuel with cold fuel, or after a long flight at high altitude. Therefore, frost or clear ice due to cold-soaked wings mainly affects:

- The areas of the wing that contain fuel after flight (fuel tanks)
- The areas of the wing corresponding to metallic structures, for example areas above the spars and the structure of the main landing gear.

Frost above Landing Gear Structure

Frost above Fuel Tank

The following factors contribute to cold-soak:

- Temperature and quantity of fuel in the fuel tanks
- Type and location of fuel tanks
- Flight time at high altitude
- Temperature of re-fuelled fuel.

1.3. Ice Accretion on the Engines

In specific conditions defined in the FCOM (i.e. freezing fog, icing conditions with OAT and visibility below a certain threshold, depending on the engine manufacturer), ice may accrete on the fan blades, spinner or in the engine core while on ground with the engines running. This may occur even if the engine anti-ice is ON, because the engine anti-ice only prevents ice accumulation on the nacelle intake.

This type of ice accretion may occur even if the outside air temperature is above 0 °C: The acceleration of the air over the fan blades and spinner causes the air pressure to decrease (in accordance with Bernoulli's principle). This causes the air temperature to decrease, possibly below the freezing point of water, even if the OAT is above 0 °C. If there is moisture, water droplets come into contact with the sub-freezing surface of the fan blades or spinner, and freeze immediately. The same phenomenon may occur in the engine core (e.g. guide vanes).

Ice on Fan Blades and Spinner

The presence of ice may also be due to a frozen contaminant that melts (because the engine is hot), and freezes again after the engine cools down.

1.4. Ice Ridges

Ice ridges on the lower nose fuselage may appear during a long stay on ground in cold conditions. However, ice ridges may also appear when the melted ice or snow (due to probe and windshield heating) runs down and freezes again on the nose fuselage.

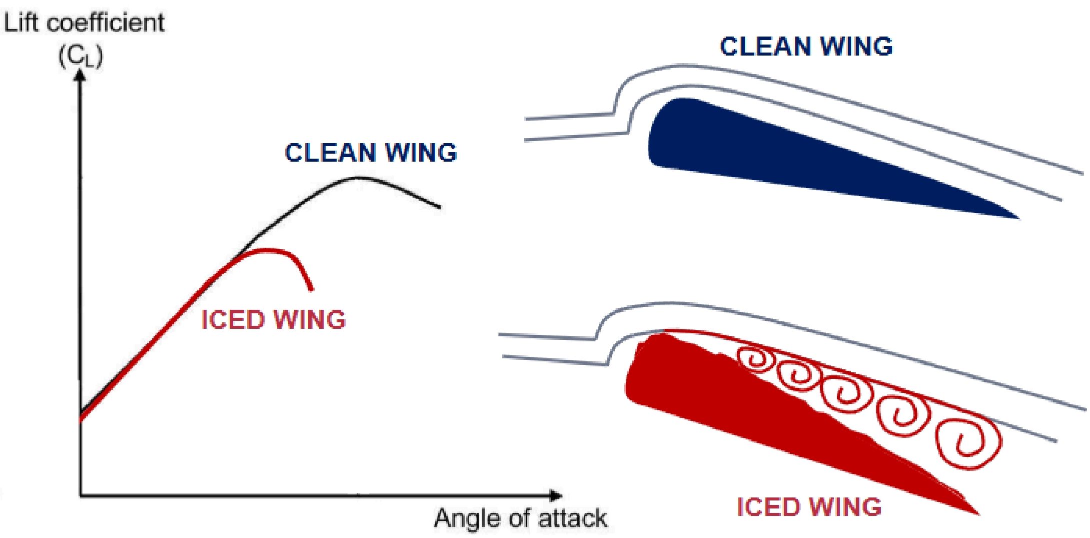
Ice Ridges on the Lower Nose Fuselage

2. Consequences

2.1. Degraded Aircraft Performance

Ice, snow, slush or frost accumulation on the external surfaces of an aircraft may significantly affect its flight characteristics.

The surface roughness created by these contaminants disturbs the smooth, laminar airflow over the wing. Even a thin layer of ice can have a very significant effect on the aircraft performance. This interference of the boundary layer reduces aerodynamic lift, increases drag (drag also increases due to contamination on the fuselage, landing gear, engines, etc), and negatively affects the stability and control of the aircraft. The maximum angle of attack is reduced, and the aircraft will stall at a lower angle of attack and a higher airspeed.



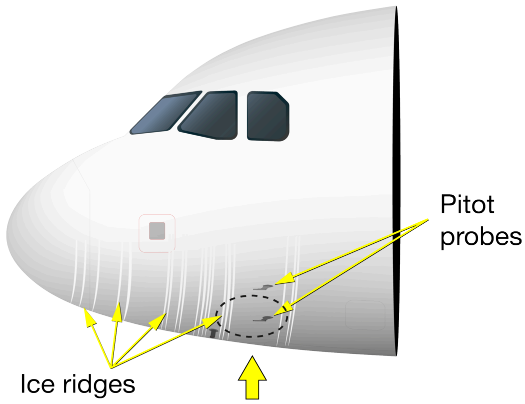
2.2. Mechanical Interference

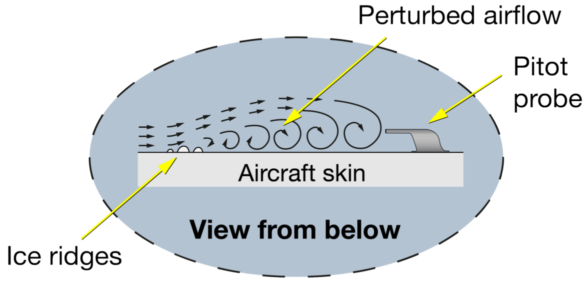
Freezing deposits may cause moving parts (e.g. flaps, elevators) to jam, and therefore restrict or prevent their movement.

2.3. Erroneous Sensor Data

Iced probes (e.g. Pitot probes, AOA probes, static probes, etc) may provide erroneous information, for example unreliable air data.

Unreliable air data may also be due to the airflow interference created by ice ridges on the lower nose fuselage.





2.4. Engine Damage or Flameout

The effects of ice accretion on the engine include fan unbalanced rotation, vibrations, fan blade damage, loss of thrust, compressor stall and flameout.

In addition, some ice may break away from the aircraft during takeoff, and it may be ingested by the engines. It may cause damage to the fan and compressor blades, or cause the engine to lose thrust or flame out.

3. The Clean Aircraft Concept

The previous paragraph describes all the hazards due to icing on the aircraft. Therefore, all the critical surfaces of the aircraft (leading edges, upper wing surfaces, vertical and horizontal stabilizers, all control surfaces) and the engines, etc. must be free of ice, snow or frost before takeoff. This is the **Clean Aircraft Concept** (i.e. aerodynamically clean).

As described in the FCOM, there are two exceptions to the clean aircraft concept:

- A thin layer of frost (up to 3 mm or 1/8 inch) on the underside of the wings in the area of the fuel tanks is acceptable. This is because the frost does not normally affect aerodynamic performance in this location.
- Thin hoarfrost is also acceptable on the upper surface of the fuselage.

The Clean Aircraft Concept is a fundamental, non-negotiable principle of flight safety. Regulations clearly indicate that operators must comply with the Clean Aircraft Concept. For example, EASA CAT.OP.MPA.250 indicates that *the commander shall* *only commence take-off if the aircraft is clear of any deposit that might adversely affect the performance or controllability of the aircraft*.

More generally, some regulations require operators to establish a Ground Icing Program. This is in order to establish the responsibilities, procedures, guidelines and processes (quality control, training and testing, emergency response plan, Safety Management System, etc.) necessary to safely operate in icing conditions on ground.

4. De-icing and Anti-Icing

4.1. General

As per the Clean Aircraft Concept, when contamination is detected it must be removed. The most common method is the application of de-icing and anti-icing fluids.

- De-icing Fluids: Application of heated fluids (typically Type I) to melt and wash away existing contamination.
- Anti-icing Fluids: Application of unheated, thickened fluids (Type II, III, or IV) on a clean surface to prevent subsequent contamination for a specific period (the Holdover Time).

De-icing/anti-icing can be performed at the gate (or near the gate, after pushback) or off-gate (Centralized De-icing Facility (CDF) or remote area near the runway).

4.2. De-Icing and Anti-Icing Fluids

De-icing/anti-icing fluids are also known as freezing point depressant fluids, because they lower the freezing point of the contaminant. De-icing/anti-icing fluids can be divided into two categories:

- Type I fluid (non thickened fluid)
- Type II/III/IV fluids (thickened fluids).

The fluids must comply with the specifications, for example:

- Aerospace Material Specification (AMS) 1424 (for Type I fluid), or AMS 1428 (for Type II/III/IV fluids) defined by the Society of Automotive Engineers International (SAE), or
- Equivalent specifications, such as defined by the International Organization for Standardization (ISO).

4.2.1. Type I Fluid

- Color: orange
- Relatively short Holdover Time

Type I fluids have a low viscosity that mainly depends on temperature. They are heated when applied, usually for de-icing purposes.

Type I fluids generally contain a high percentage of glycol (at least 80 %), that lowers the freezing point to negative ambient temperatures. Other components include water, corrosion inhibitors and wetting agents. The purpose of the wetting agents is to form a uniform film over the surfaces of the aircraft.

Because Type I fluids are not thickened, they easily flow off the treated surfaces, leaving only a marginal protective layer. This layer is not usually sufficient for prolonged protection. It is the mixture of heat and the spray pressure, instead of any chemical reaction with glycol, that makes the fluid appropriate as a de-icing fluid. Type-I fluids can also be used as an anti-icing fluid, but the holdover time is limited.

Treatment with Type I Fluid

4.2.2. Types II/IV Fluids

- Type II color: white/pale straw (yellowish)
- Type IV color: green
- Relatively long Holdover Time

Similarly to Type I fluids, Type II/IV fluids also mainly contain glycol and water. The main difference is that Type II/IV fluids contain a **thickening agent**. The increased viscosity enables Type II and IV fluids to form a thick protective layer (the holdover protection). Therefore, **Type II and IV fluids have better anti-icing properties than type I fluids** (i.e. the associated Holdover Time is higher).

This protective advantage is important during freezing precipitation and/or long taxi times. In general, Type IV fluids provide longer protection than Type II and III fluids.

The viscosity of Type II and IV fluids depends on shear force. When the aircraft does not move, or moves at low speed during taxi, the viscosity is high. But when shear force applies (for example airflow during takeoff), the viscosity rapidly decreases. This causes the fluids to flow off the wing before rotation, so that the aircraft performance is not affected. Therefore, the protection of the anti-icing fluid (Holdover Time) ends:

- When the aircraft takes off (i.e. the anti-icing fluid does not protect against icing in flight), or
- When frozen deposits start to form or accumulate on treated aeroplane surfaces, that indicates the loss of performance of the fluid (refer to A.4.2.4).

4.2.3. Type III Fluid

- Type III color: Bright yellow
- Type III has a much lower viscosity than Types II & IV.
- Type III fluids do not have a better Holdover Time than Type II and IV.

The Type III fluid provides a better anti-icing protection, compared to Type I.

Even if Type III fluid also contains a thickener, its viscosity is lower compared to Type II and IV. Therefore Type III fluid is designed for use on aeroplanes with low rotation speeds (regional aircraft), because the fluid flows off more easily.

4.2.4. Fluid Failure

Anti-icing fluids offer limited protection. As freezing precipitation continues to fall, it is absorbed by the fluid layer. This gradually dilutes the glycol, and increases the freezing point of the fluid.

A fluid is considered to "fail" when it can no longer absorb moisture, and begins to freeze. Fluid failure generally occurs first at the wingtips, leading and trailing edges of the wing. Visually, a failed fluid may lose its glossy appearance, and become opaque or slushy. An accumulation of frozen precipitation follows. **The aircraft must not take off in this condition.**

4.2.5. Residues

In the case of repetitive applications of thickened fluids (e.g. Type II/IV), there may be an accumulation of dried fluid in aerodynamically quiet areas, for example cavities and gaps. These residues may rehydrate in high humidity conditions (e.g. precipitation, washing, etc.), and freeze below 0 °C (the residue has a low glycol content, because the glycol evaporated). This may cause flight controls to jam on small commuter aircraft with unpowered flight controls.

Airbus did not receive reports of in-service events due to fluid residues. Be aware that the Maintenance Planning Document requires routine zonal inspections of the aircraft. These inspections already check for contamination, and will therefore identify if there are any dry or rehydrated fluid residues.

For more information refer to Airbus ISI article 30.00.00001 - Potential impact of frozen re-hydrated de/anti-icing fluid residues on flight controls.

4.2.6. Catalytic Oxidation

Carbon material naturally reacts with oxygen to turn into CO_2. This natural reaction occurs at a very low rate, not perceivable at ambient temperature. However, its speed or rate significantly increases with temperature. This is referred to as thermal oxidation.

Catalytic oxidation is a severe oxidation that occurs when there is a catalyst (particularly alkali metals, like potassium). Catalytic oxidation lowers the temperature at which thermal oxidation becomes perceivable. The following table compares the thermal and catalytic oxidations rate:

Temperature	Time to reach 5 % weight loss = 25 % loss of strength	
	Thermal oxidation	**Catalytic oxidation**
25 °C	7.5 x 10^{18} years	3.6 x 10^{18} years
400 °C	3 years	33 days
500 °C	14 days	15 hours
600 °C	12 hours	45 minutes
700 °C	49 minutes	4 minutes

Analyses demonstrated that the catalytic oxidation of carbon brakes is mainly due to runway de-icing products. When the potassium or sodium is absorbed by the carbon, it does not go away. Catalytic oxidation can continue after the winter is finished, and may result in a local loss of carbon density. This decrease in material strength may result in the rupture of the disk.

For more information refer to ISI article 32.42.00003 - Carbon brakes catalytic oxidation - runway de-icing products impact.

4.2.7. Holdover Time

The Holdover Time is the **estimated** time during which the anti-icing fluid prevents the formation of ice and frost and the accumulation of snow on the treated surfaces of an aircraft.

The Holdover Time starts:

- For one-step de-icing/anti-icing: when the de-icing/anti-icing starts
- For two-step de-icing/anti-icing: when the second step (e.g. anti-icing) starts.

The Holdover Time does not end in the case of intermittent precipitation (i.e. there is no Holdover Time credit due to the fact that the precipitation temporarily stops). Even if the precipitation stops, the fluid diluted due to precipitation continues to flow off the aircraft due to gravity. It is not possible to determine how much anti-icing fluid remains on the wing. Holdover Times under these conditions are not evaluated.

The Holdover Time ends:

- When the aircraft starts to take off (anti-icing fluids protect the aircraft on ground only, until a specific airspeed during takeoff).
- When frozen deposits start to form or accumulate on treated aircraft surfaces, that indicates the loss of performance of the fluid.

The Federal Aviation Administration (FAA) and Transport Canada (TC) regularly update and publish the Holdover Time tables, for different fluids and prevailing conditions.

The Holdover Time tables are referred to as Holdover Time **guidelines**, because Holdover Time cannot be precisely determined. Holdover Time guidelines are ranges of time, rather than exact times. This is because there are many factors that have an influence on the Holdover Time, for example wind, humidity, temperature of the aircraft surfaces (i.e. aircraft skin temperature below the OAT), or jet blast from other aircraft.

Therefore:
- The flight crew should use their own assessment in order to establish the Holdover Time, and may need to adjust the value published in the Holdover Time guidelines.
- The use of the Holdover Time does not imply that it is safe to take off in the prevailing conditions, even if the Holdover Time is not exceeded. The Holdover Time tables alone are not sufficient to ensure that the aircraft is free of contaminants (except for some regulations). A pre-takeoff check is necessary (refer to A.5.8.1).

Under specific meteorological conditions, anti-icing may be ineffective. Holdover Time guidelines do not include guidance for the following types of precipitation:
- Hail
- Moderate and heavy freezing rain
- Heavy snow
- Ice pellets and small hail (the standardized test protocol used to develop the Holdover Time is not applicable due to the physical characteristics of ice pellets and small hail). However, there is a dedicated test protocol, in order to publish guidelines known as "allowance times". The principle of allowance times is the same as holdover times: they indicate the estimated times for an aircraft to take off after de-icing/anti-icing. Allowance times are available for Type III fluids and some Type IV fluids (Ethylene Glycol and Propylene Glycol).

An alternative to Holdover Time tables is a Liquid Water Equivalent System (LWES). An LWES is an automated system for weather measurement that determines the Liquid Water Equivalent (LWE) rate in conditions of frozen or freezing precipitation. The LWES includes a Holdover Time Determination System (HOTDS). Based on the LWE, the HOTDS then provides the flight crew with near real-time Holdover Time, for example via ACARS or EFB.

However, the weather data from the LWES must not be the only source of information used to determine if it is safe to take off. Flight crews must still consider METAR reports and visual observations.

4.3. Other De-Icing Methods

In addition to de-icing fluids, there are other de-icing methods, for example:
- Hot water (depending on the OAT)
- Forced air (alone or mixed with de-icing fluid) at low or high pressure
- Broom (with soft bristles to prevent damage to the aircraft skin)
- Hot air blower (e.g. for engine de-icing)
- Engine ice shedding procedure (refer to A.5.7.3).

4.4. Roles and Responsibilities

4.4.1. De-Icing/Anti-Icing Crew

The ground crew involved in the de-icing/anti-icing process must be trained and qualified. SAE Aerospace Standard (AS) 6286 describes the standards for training and qualification for de-icing/anti-icing.

The **De-Icing/Anti-Icing Operator** (also referred to as de-icer, sprayer or "Spray Man") performs the de-icing/anti-icing, and is responsible for the correct and entire de-icing/anti-icing treatment of the aircraft.

The **De-Icing/Anti-Icing Coordinator** (also referred to as de-icing manager or "Ice Man") coordinates and manages the de-icing operation and/or works as a team leader in de-icing. This qualification is mainly designed for the coordination of de-icing operations at remote and/or centralized de-icing facility areas.

The **Pre-/Post De-Icing/Anti-Icing Inspector** performs the contamination check (refer to A.5.2) and the post de-icing/anti-icing check (Refer to A.5.6.1 and A.5.8.2).

Depending on qualifications and the organization of the de-icing/anti-icing provider, the same person can perform several tasks (e.g. treatment and inspection, or coordination and inspection).

4.4.2. Flight Crew and Cabin Crew

The **Captain** is responsible for the compliance with the Clean Aircraft Concept. Therefore, it is the responsibility of the Captain:

- To decide if de-icing/anti-icing (or additional de-icing/anti-icing) is necessary
- To accept the aircraft after de-icing/anti-icing.

Similarly to the ground crew, the flight crew must be trained in order to ensure that they have an entire and up-to-date knowledge of the de-icing/anti-icing procedures and policies.

The **cabin crew** is responsible for the communication to the flight crew of any safety critical information, as soon as applicable. This includes information about surface contamination. Cabin crew training should include awareness of the effects of frozen surface contaminants, and the requirement to inform the flight crew of any observed surface contamination. The identification of icing is important, in order to be able to communicate with the flight crew about the ice contamination before and during flight.

4.4.3. Other Stakeholders

Depending on the Operator's organization and airport facilities (i.e. off-gate de-icing/anti-icing), other stakeholders may include the apron control, de-icing/anti-icing pad control, ATC, flight dispatchers, etc.

5. Procedures

This section describes the main operational procedures associated with de-icing and anti-icing on ground. Airport specific procedures are published in local Aeronautical Information Publication (AIP) or NOTAM. SAE AS 6285 describes the standards for the de-icing/anti-icing processes.

Maintenance procedures for aircraft servicing and protection in cold weather are available in the A220 Aircraft Maintenance Publication (AMP), A300-600/A310/A320 family/A330/A340/A380 Aircraft Maintenance Manual (AMM) and A350 Line Maintenance.

In addition, maintenance best practices and recommendations during cold weather are available in the A220-ISI-00-00-017 (A220) and ISI 12.31.00014 (All Airbus aircraft except A220).

5.1. Preliminary Cockpit Preparation

In conditions with a risk of engine ice accretion, the flight crew checks the logbook to know the taxi-in time of the previous flight. The purpose is to determine the maximum taxi time before the engines are accelerated (refer to A.5.7.3).

5.2. Contamination Check

The contamination check, performed by the flight crew, or by other trained and approved qualified personnel, is an external visual inspection of the aircraft, in order to identify if there is any frozen contamination. It determines the requirement for de-icing/anti-icing.

This visual inspection must take into account all critical parts of the aircraft, and must be performed from locations that offer a clear view of these parts. Particularly, these parts include:

- Wings (leading edges included)
- Vertical and horizontal stabilizers
- All control surfaces
- Slats and flaps
- Fuselage
- Landing gear
- Probes
- APU
- Engines (inlet, spinner, fan blades, etc). Take into account the fact that due to the airflow in the engine, ice may form on the rear side of the fan blades. In addition to a visual inspection, check that the fan is free to rotate.

Ice on the Rear Side of the Fan Blades

Notes:
- Frost must not be considered as a minor contaminant. Similarly to snow or ice, it is a safety threat due to the adverse effect on aircraft performance and flight characteristics (refer to A.2.1).
- Radiation cooling or conduction cooling due to cold-soaked wings may cause the temperature of the wing surfaces to be several degrees below the OAT (refer to A.1.1 and A.1.2). Therefore, frost may form even if the OAT is several degrees above 0 °C. Therefore, the contamination check should not be based on the prevailing OAT only. Be aware also that radiation cooling depends on materials, therefore frost on the aircraft may appear at different times.
- It is critical to understand that the airflow during takeoff will not blow the contaminant off the wings.
- Aircraft contamination is not necessarily symmetrical. This is due to wind variation, adjacent buildings, etc.
- Clear ice and ice ridges may be difficult to see, particularly on a white fuselage during night time.
- A Ground Ice Detection System (GIDS) is a system used during aircraft ground operations to inform ground crews or flight crews about frozen contamination on aircraft surfaces. GIDS can be used in addition to the contamination check, but must not be used as the primary method to perform the contamination check.

5.3. Clear Ice Check

Clear ice can form due to cold-soaked wings (refer to A.1.2). **It is very difficult to detect** during walkaround, particularly in low lighting, and when the wing is wet. The leading edge may not feel particularly cold. Clear ice may not be detected from the cabin either, because wing surface details can be seen through the clear ice.

Clear Ice

In addition, there may be clear ice below a layer of snow, slush or anti-icing fluid. Because clear ice is very difficult to detect during walkaround, a tactile inspection of the critical surfaces by touching the surface with the hands, may be necessary.

Tactile Inspection

Another method to detect clear ice is the use of a Ground Ice Detection System (GIDS).

5.4. Approaching the De-Icing/Anti-Icing Area (Off-Gate De-icing/Anti-icing only)

The de-icing/anti-icing area is often congested with aircraft, equipment and personnel. Visibility may be low and the surface may be slippery. Taxi with vigilance in order to avoid a collision. If they are not sure, the flight crew must stop the aircraft.

5.5. De-Icing and Anti-Icing

5.5.1. Communication

The flight crew may inform the passengers and the cabin crew of the requirement to de-ice/anti-ice.

Before treatment, the flight crew establishes communication with the de-icing/anti-icing crew, in order to:

- Confirm that the aircraft is configured for de-icing/anti-icing
- Confirm the de-icing/anti-icing method
- Confirm the type of fluid(s) and fluid mixture ratio, if applicable
- Communicate any aircraft type-specific information.

Communication is very important, particularly during off-gate de-icing/anti-icing (coordination to position the aircraft, to configure the aircraft, etc.). Maintain continuous two-way communication with the de-icing/anti-icing personnel during de-icing/anti-icing.

5.5.2. De-Icing

When frozen contamination is detected, the aircraft must be **de-iced**.

Both left and right sides of the aircraft must receive the same (i.e. same amount and type of fluid, same mixture) and symmetrical de-icing treatment, even if the contamination is only on one side.

In some situations (e.g. frost or ice limited to localized areas on cold-soaked wings) a full de-icing is not necessary. It is then possible to de-ice only the contaminated areas. Holdover Time is not applicable in this case. Both left and right sides of the aircraft must receive the same and symmetrical de-icing treatment.

The spray nozzle should not be too far from the aircraft surface, in order to minimize the heat loss. Do not apply de-icing fluid on the engine air intakes and exhausts. This is to avoid corrosion and contamination of the bleed air system. Use hot air to remove frozen contaminants from the engines.

Do not apply de-icing fluid on the landing gear (brakes, wheels, etc). This is to prevent corrosion and carbon contamination and the associated risk of catalytic oxidation (refer to A.4.2.6). Use hot air to remove frozen contaminants from the landing gear.

In addition, do not apply the de-icing fluid on the following areas (depending on aircraft type and aircraft configuration):

- The probes and sensors (Pitot, TAT, AOA, etc) and ice detectors (if installed)
- The cockpit windshield and lateral windows
- The flight crew emergency escape hatch (A220 only)
- The cabin doors and windows
- The APU air intake and exhaust. On A220, A350 and some A320, the APU air intake is located on the upper area of the tail cone. Make sure that the de-icing/anti-icing personnel is aware of this, in order to avoid the ingestion of de-icing/anti-icing fluid by the APU.
- The outflow valves
- All other air intakes and outlets.

For additional information, refer to FCOM, A220 AMP, A300-600/A310/A320 family/A330/A340/A380 AMM and A350 Line Maintenance.

5.5.3. Anti-Icing

If outside conditions may result in the accumulation of contaminants (snow, etc) on the aircraft surfaces at the time of takeoff, the aircraft surfaces must be **anti-iced**.

The application of anti-icing protection means that **for a period of time** (Holdover Time) ice, snow or frost will not adhere to, or accumulate on aircraft surfaces. This is achieved by the application of anti-icing fluids.

If both anti-icing and de-icing are required, the procedure may be performed in one or two steps. The second step is performed before the fluid that was sprayed during the first step freezes, usually within 3 minutes after the end of the first step. The selection of a one or two step process depends on weather conditions, available equipment, available fluids and the required Holdover Time.

For appropriate anti-icing protection, undiluted anti-icing fluid should be sprayed uniformly and in sufficient quantity, in order to ensure sufficient thickness. The treated surfaces should be clean or already de-iced. For maximum anti-icing protection, undiluted Type II, III or IV fluid should be used.

Both left and right sides of the aircraft must receive the same complete and symmetrical anti-icing treatment. Apply the anti-icing fluid from the front to the rear. Because the Holdover Time is limited in time, both of the following apply:
- Anti-icing should be performed as near to the takeoff time as possible
- The flight crew should evaluate the taxi time before takeoff.

Similarly to de-icing fluid, anti-icing fluid must not be sprayed on probes, APU air intake and exhaust, etc. (Refer to A.5.5.2). In addition, do not apply anti-icing fluid on the radome and the fuselage area forward of the doors 1L and 1R. For additional information, refer to FCOM, A220 AMP, A300-600/A310/A320 family/A330/A340/A380 AMM and A350 Line Maintenance.

Do not apply a new layer of anti-icing fluid on top of an existing layer of anti-icing fluid. The initial anti-icing layer may freeze at the end of the holdover time. In addition, the viscosity and the aerodynamic performance of the fluid may be affected, and this will cause the fluid to flow incorrectly during takeoff. If a new anti-icing protection is necessary, the aircraft must be de-iced first.

5.6. After Treatment

5.6.1. Post Treatment Check

The post treatment check, performed by qualified personnel, is an external visual inspection of the aircraft that is performed immediately after de-icing/anti-icing. It ensures that all treated surfaces are no longer contaminated. If there is any remaining contamination, another de-icing is necessary (followed by another post treatment check).

The post treatment check, performed from observation points that are at an appropriate elevation, includes all parts of the aircraft that were treated. To ensure that there is no clear ice on suspected areas, a tactile inspection may be necessary (refer to A.5.3).

5.6.2. Anti-Icing Code

After anti-icing, a qualified person provides the flight crew with information about the fluid treatment. The "**anti-icing code"** is the standardized format. It contains the following elements:
- Fluid type (i.e. Type I, II, III or IV)
- Fluid brand (except for Type I) (optional)
- Fluid concentration in the fluid/water mixture (except for Type I). For example, "75" means 75 % of fluid and 25 % of water.
- Local time at start of anti-icing
- Date (optional)
- The statement "post de-icing/ant-icing check completed".

Example: TYPE II / MANUFACTURER BRAND X / 75 / 2235 / 27FEB26 / POST-DE-ICING/ANTI-ICING CHECK COMPLETED

The anti-icing code is also a confirmation that the aircraft is free of contamination.

If two different companies are involved in the de-icing/anti-icing treatment and post de-icing/anti-icing check, the anti-icing code must not be provided before the post de-icing/anti-icing check is completed.

The flight crew then uses the anti-icing code to determine the Holdover Time based on other elements, for example the precipitation type and intensity, OAT and flaps configuration.

5.6.3. Departure from the De-Icing/Anti-Icing Area

Before the flight crew start an engine (if applicable), reconfigure or move the aircraft, they must ensure that all de-icing/anti-icing operations are completed and that all personnel and equipment are clear of the aircraft. The flight crew must have a clear understanding of when and where they can exit the de-icing/anti-icing area.

It is important to correctly reconfigure the aircraft, in accordance with the FCOM. For example, on A320/A330/A340/A350/A380, if the DITCHING pb-sw remains ON after de-icing/anti-icing, it will cause a lack of pressurization in flight, that will ultimately trigger the CAB PRESS EXCESS CAB ALT alert.

5.7. Taxi

5.7.1. Situational Awareness

After treatment, the flight crew maintains awareness of the conditions (weather, jet blast, etc.) that may affect the aircraft, in order to evaluate if the applied Holdover Time is still appropriate (the applicable Holdover Time may change if prevailing conditions change).

Cabin crew can help the flight crew, because they have a better view of the wings from the cabin.

The flight crew maintains awareness of:

- The remaining time before the Holdover Time expires
- The remaining time before the engine acceleration, if in conditions with a risk of engine ice accretion (refer to A.5.7.3).

Taxi time may be longer than usual due to weather conditions.

5.7.2. Specific Precautions

Increase the distance from the previous aircraft, in order to avoid contaminants blown into the engines. Maintain flaps retracted in order to prevent contamination of the slats/flaps mechanism.

Taxi at reduced speeds, because the taxiway may be slippery. Avoid large tiller inputs to minimize the risk of skidding during turns. It may be more appropriate to use differential braking and/or thrust, instead of the nosewheel steering. Be aware that anti-skid is not available below 10 kt (or 20 kt, depending on aircraft type), and that engine anti-ice increases ground idle thrust.

5.7.3. Engine Ice Accretion and Ice Shedding

As explained in A.1.3, in specific conditions defined in the FCOM (i.e. freezing fog, icing conditions with OAT and visibility below a certain threshold, depending on the engine manufacturer), ice may accrete while on ground with the engines running:
- On the fan blades,
- On the spinner, or
- In the engine core.

The FCOM publishes the maximum taxi time in this type of icing conditions, and an ice shedding procedure that sheds (i.e. that removes) the ice from the engine. The ice shedding procedure contains an acceleration of the engine to a specific N1 value, and depending on aircraft type and engine type, a hold time at that N1:
- The acceleration of the engine mechanically sheds the ice, as the centrifugal forces increase and the fan blades slightly flex.
- The hold time thermally sheds the remaining ice (particularly on static structures like, for example the inlet guide vanes), because the fan airflow temperature increases due to higher pressure.

The ice shedding process may not be uniform, and this may cause a temporary fan imbalance and vibrations. The vibrations should stop when the fan is clear of ice.

5.8. Before Takeoff

5.8.1. Pre-Takeoff Check (in the Holdover Time)

As indicated in A.4.2.7, the Holdover Time tables alone are not sufficient to ensure that the aircraft is free of contaminants (except for some regulations). A pre-takeoff check shortly before takeoff (and in the Holdover Time) is necessary as a final confirmation that the aircraft is free of frozen contaminants.

The pre-takeoff check, under the responsibility of the Captain, includes all of the following:
- Assess if the applied Holdover Time is still appropriate and is not exceeded.
- Check that the wings or representative surfaces (*) of the aircraft are free of frozen contaminants. This check is usually performed from inside the aircraft (cockpit and/or cabin), but may be performed from outside the aircraft, for example if the Captain requires the assistance of qualified ground personnel.

(*) A representative surface is a portion of the aircraft that the flight crew can observe from inside the aircraft, in order to determine if the critical surfaces are also contaminated. This concept is not used in the Airbus procedures.

5.8.2. Pre-Takeoff Contamination Check

The pre-takeoff contamination check is an inspection of the critical surfaces for contamination. It is usually performed from outside the aircraft, by qualified ground personnel. The pre-takeoff contamination check is necessary if:
- The pre-takeoff check (Refer to A.5.8.1) does not enable the flight crew to evaluate the condition of the aircraft critical surfaces, or

- The applied holdover time is exceeded.

If the flight crew is not sure about the condition of the aircraft after the pre-takeoff contamination check, or if the pre-takeoff contamination check cannot be performed, another treatment is necessary (in this case, as explained in A.5.5.3, the previous treatment must be removed, before a new de-icing/anti-icing treatment is applied).

5.9. Takeoff

Depending on regulations, if a pre-takeoff contamination check is performed, the aircraft must take off within five minutes. If it is not possible to take off within five minutes, the aircraft must return for de-icing/anti-icing.

As indicated in A.4.2.7, the weather data from the LWES must not be the only source of information used in order to determine if it is safe to take off. Flight crews must still consider METAR reports and visual observations.

If the flight crew is not sure about the condition of the aircraft, they must not take off.

In conditions with a risk of engine ice accretion (refer to A.5.7.3), a final engine acceleration may be necessary before takeoff (depending on the aircraft type and engine manufacturer).

5.10. After Landing

The flaps and slats may be contaminated due to icing conditions during the approach or due to a contaminated runway or taxiway. In this case, do not retract the flaps until after engine shutdown, and after the ground crew confirmed that flaps and slats are clear of obstruction due to ice.

In conditions with a risk of engine ice accretion (refer to A.5.7.3), the flight crew maintains awareness of the remaining time before the engine acceleration.

5.11. When Parked

In conditions with a risk of engine ice accretion (refer to A.5.7.3), the flight crew records the total taxi-in time in the logbook. If an engine acceleration was performed during taxi-in, the flight crew only records the taxi-in time since the last engine acceleration.

6. Human Factors

6.1. Human Limitations

De-icing and anti-icing are not only technical or logistical tasks. De-icing and anti-icing also rely on human performance. History and safety data indicate that human factors often contributed to incidents or accidents during de-icing/anti-icing, due to for example:

- Time pressure: delays, high pressure to meet takeoff slots, to take off before the Holdover Time expires
- Environmental stressors:
  - For de-icing/anti-icing personnel: weather conditions (e.g. low visibility, precipitation, cold, wind), engine danger areas, exposure to glycol and noise, proximity with aircraft and vehicles, slippery surface.
  - For the flight crew: weather conditions (e.g. low visibility), restricted view of surroundings from the cockpit, proximity with aircraft and vehicles, slippery surface, radio frequency changes, tasks interruptions.
- Physiological stressors: fatigue, stress
- Cognitive bias:
  - Expectation bias (to see what one expects to see): for example, to determine that the wing is clean, just because the aircraft was de-iced.
  - Plan continuation bias (to maintain the original plan despite the change in conditions).
- Communication errors (e.g. misunderstanding).

6.2. Competencies

De-icing/anti-icing is a complex operation, in a difficult environment. Stakeholders are physically at different locations. Everyone involved in the de-icing/anti-icing process (refer to A.4.4) should work together as a single and coordinated team. Therefore, **teamwork** and **Crew Resource Management** (CRM) are essential.

Team members should have a **shared mental model** (i.e. a shared understanding of the dynamics of the de-icing/anti-icing process) and a **shared situation awareness** (i.e. a shared understanding of the environment). To achieve this, each team member should for example:
- Know the team mission (apply the Clean Aircraft Concept, refer to A.3)
- Know the responsibilities and tasks of each team member (refer to A.4.4) and how they are related.
- Communicate correctly. Communication should be standardized (e.g. use of read-back, call-sign, ICAO phraseology, etc.) and short, to prevent problems with understanding.

A shared mental model and shared situational awareness enable successful:
- Coordination of the team members
- Monitoring and awareness of the team activities and performance
- Anticipation of the actions of others
- Identification of problems and threats (threats and errors management)
- Decision making and problem solving.

The flight crew must apply **leadership** via the development of a "psychologically safe" environment where the ground crew or cabin crew feel comfortable reporting problems. Another important skill is **assertiveness**. Any person who is not sure or has a concern should be able to speak up. Authority gradient or time pressure must not be an obstacle. It is important to stand firmly against expectations and requests that the aircraft should leave on time. The possible resulting decision (i.e. request a pre-takeoff contamination check or a tactile inspection, return for another de-icing/anti-icing, etc) may delay the aircraft but may be the safest option.

B. Aircraft Icing in Flight

1. Icing Principles

1.1. Atmospheric Physics

Water is a well-known component of atmospheric air. Clear air includes water vapor in very variable proportions based on the air temperature. Saturation vapor density is the maximum possible mass of water vapor possible in a specific volume of space. It is about 0.5 g/m3 at - 30 °C and 5 g/m3 at 0 °C. Any quantity of water beyond the saturation conditions will be seen under the form of water drops or ice crystals, that form clouds.

Saturation conditions may be exceeded by two processes:

- First, via the lifting of warm air. Air lifting may be caused by meteorological instability or orography. Instability is associated with weather systems, perturbations or large quantities of clouds. The orographic effect is due to wind blowing on a mountain.
- Second, via the rapid cooling of the lower air layer during a night with clear sky.

In both of these conditions, the quantity of water initially in the air mass may become beyond the saturation conditions at the new (lower) temperature. Additional water precipitates in the form of droplets or ice crystals.

In supercooled liquid water the icing phenomenon occurs because the water does not always turn to ice at or below 0 °C. Water at a negative Celsius temperature may remain liquid: it is referred to as **supercooled liquid water**. But supercooled drops and droplets are unstable. This means that they can freeze suddenly if they hit, or are hit by an object, particularly if the object is at a negative temperature. This is the basic mechanism for ice forming on aircraft and engine surfaces exposed to supercooled liquid water.

The results of the above are the following:

- The range of OAT for airframe icing in supercooled liquid water icing is: slightly positive °C, down to -40 °C, although at -40 °C most or all of the water is most probably in the form of ice crystals. This can be translated into altitudes: at mid latitudes, altitudes where severe icing is most likely to occur are around FL 100 down to the ground.
- Due to variations in temperature conditions around the airframe, a slightly positive OAT does not protect the aircraft from severe icing.
- Accumulation of ice (icing) occurs on the "penetrating" or protruding parts of the airframe: nose, wing or fin, or tailplane leading edges, engine intakes, antennas, hinges, etc.

1.2. Meteorology

Supercooled water can be found in many clouds in the atmosphere, provided the temperature is below and not too far from freezing. Very convective clouds like big Cumulus or Cumulonimbus are typical examples. Except for the possible effects of hail, Cumulonimbus are a special icing threat, because contrary to all other icing clouds, icing conditions can be encountered outside the cloud body, for example under the anvil. Anvils often generate freezing drizzle or freezing rain. The precipitation under an anvil can cause severe icing. At tropical latitudes, this may happen at such high altitudes and outside air temperatures that no supercooled liquid water icing should normally be expected. Therefore, flying under the anvil of a Cumulonimbus should be avoided.

Layers of stratiform clouds, **absolutely regardless of their thickness**, can display high quantities of freezing drops, that include freezing drizzle. This is because despite their stratus appearance, they include some limited but continuous convective activity, and this makes them a perfect location to generate freezing drizzle. Meteorology provides categories of supercooled water drops based on their diameter in microns or drop size:

- 0 to 50 µm: standard super cooled droplets. They stay aloft and make clouds.
- 50 to 500 µm: freezing drizzle.
- 500 to 2000µm: freezing rain. They fall down and result in clear ice.

Cloud physics indicate that no cloud is ever made of a single drop size. A cloud can be described by its spectrum of droplets. It is considered that most usual supercooled clouds contain a spectrum of droplets between 0 and 50 µm, with a peak at around 20 µm. When there is freezing drizzle, the spectrum is not changed a lot, but there is another smaller peak, at approximately 200 µm, with very few drops in-between. However, most of the water content remains in the lower part of the spectrum (i.e. large droplets are much fewer than the 20 µm ones).

There is a risk of icing. Low level stratus and other gray clouds may have a high water content.

This type of cumulus congestus may hide severe intermittent icing.

Although the gray clouds contain supercooled liquid water, the situation is too windy to be a significant icing threat, except inside the cumulonimbus

This type of thick stratus that looks like thick soup with a mountain blockage, may be a threat for icing.

1.3. Accretion of Ice Shapes in Flight

Many parameters affect the icing process:

- Air temperature (OAT or SAT)
- Aircraft speed or Total Air Temperature (TAT)
- Aircraft size
- Type of cloud
- Type of precipitation
- Liquid water content of the air mass
- Liquid water drop size distribution
- Possible ice crystals
- Total water content of the air mass
- Local temperature and heat capacity of the aircraft skin
- Type of de-icing or anti-icing system.

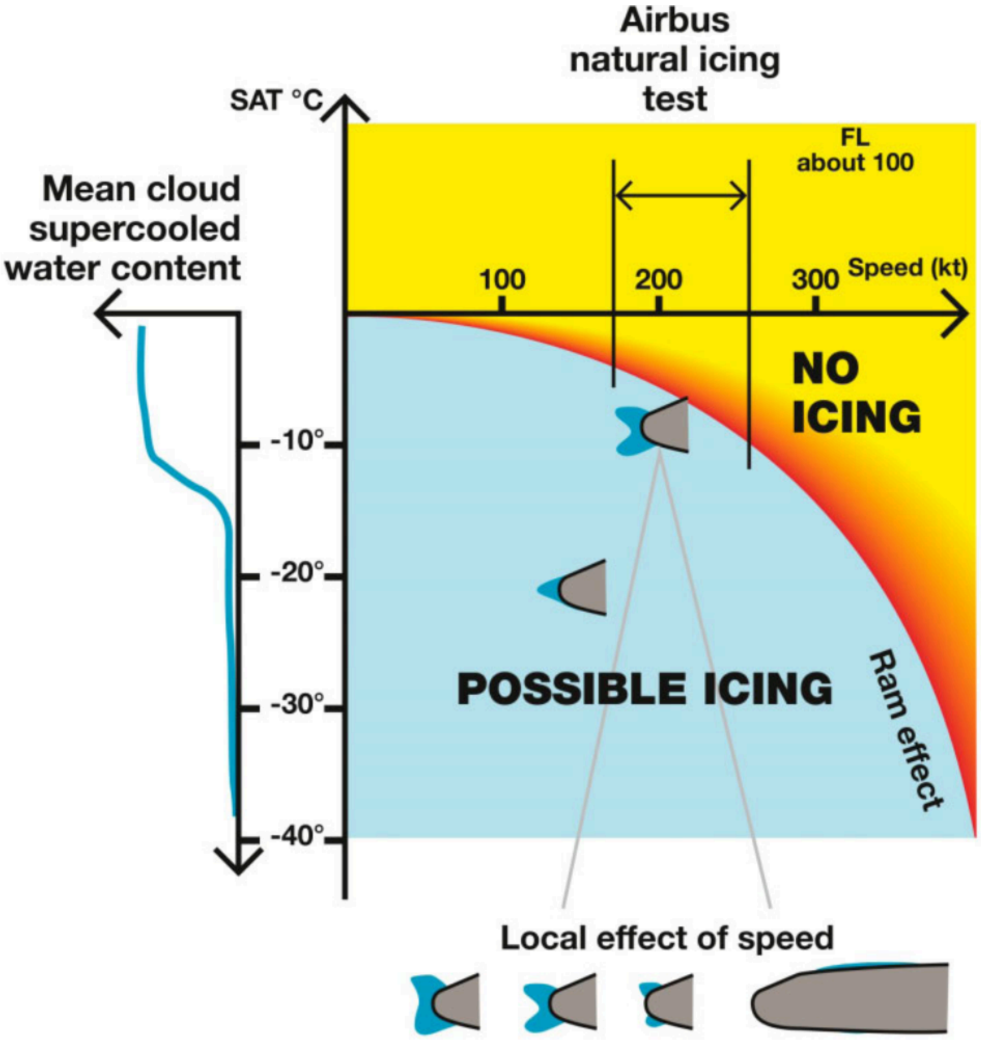
For example, one of the effects of aircraft speed is kinetic heating, or the ram effect. At 250 kt, the kinetic heating results in a TAT approximately 10 °C warmer than the SAT. Kinetic heating is sometimes referred to as temperature recovery, because it **naturally** heats the leading edge and therefore to some degree protects it from icing (at 250 kt, this occurs as long as the outside air is above - 10 °C).

The individual influence of the parameters listed above creates a difficult theoretical problem. The various influences are not additive. There are various shapes that include:

- A pure moon arc attached to the leading edge, or
- A double horn, or
- A flat, grooved plate downstream of the leading edge (known as runback ice), or

- “Shark teeth” that point toward the airflow and are created aft of the leading edge.

The graph below provides an idea of the various types of shape that may be encountered in clouds with icing conditions, from 0 °C down to -40 °C (below -40 °C, there is no supercooled water).

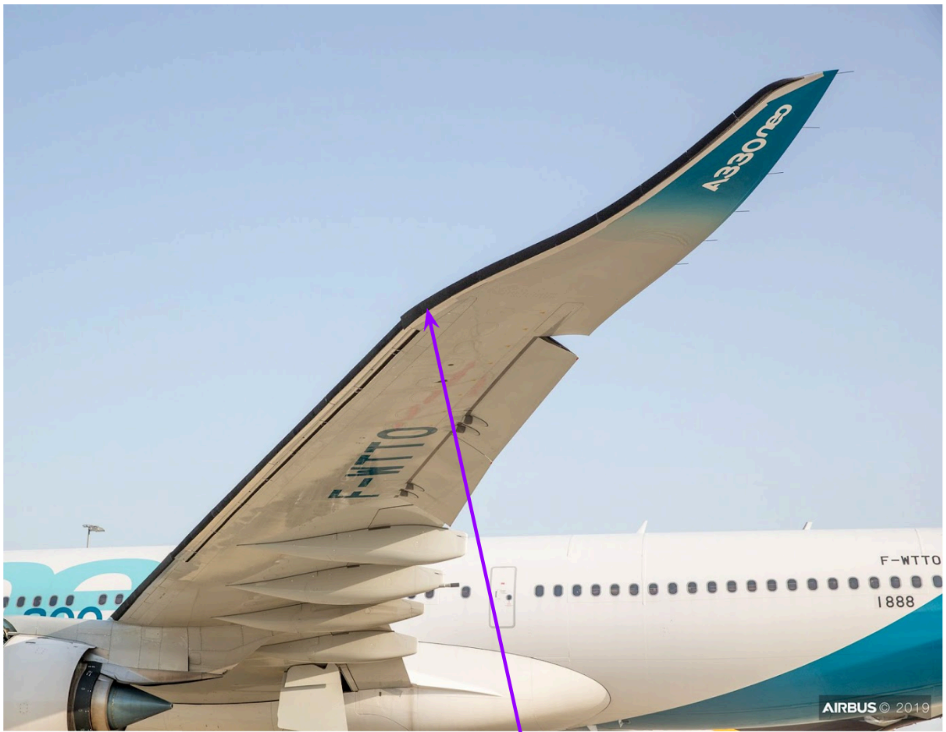


The various types of shape indicate how complex the ice accretion process may be. In this context, it is very difficult to describe, categorize and anticipate ice shapes. Therefore, the design and certification of ice protection systems are based on a "worst case" scenario.

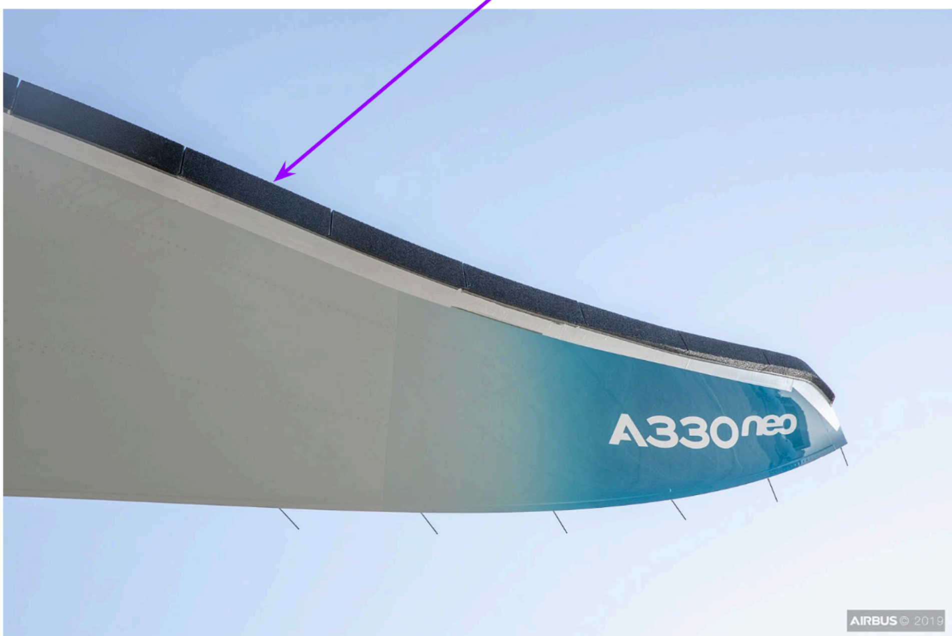
1.4. Aerodynamics

Any type of ice accretion is an obstacle to smooth airflow. Any obstacle slows down the airflow and creates turbulence that will degrade the lifting performance of the wing (Refer to A.2.1).

However, contrary to icing on ground, the aircraft is certified to fly in icing conditions. The anti-ice system protects a part of the wing leading edge and the engine intake, and icing on not protected parts does not significantly affect aircraft performance and flight characteristics.
Because it is not possible to take into account all the possible ice shapes, Airbus procedures are based on the ice shapes that are considered to have the largest effect on the aircraft, as tested in flight with artificial ice shapes.



Artificial Ice Shapes



As a result, the minimum speeds are defined in order to keep acceptable margins in terms of maneuverability against the real stall speed with ice accretion. On Fly-By-Wire aircraft, the alpha protection system takes into account ice shapes. **This means that the aircraft remains protected in case of ice accretions**.

2. In-Flight Ice Protection

2.1. Ice Protection Methods

2.1.1. Hot Bleed Air

Ice protection systems based on hot bleed air are referred to as anti-ice systems, because they are usually switched on before accretion occurs. The heated surfaces then prevent icing. All Airbus wing and nacelle (engine intake) anti-ice systems are based on hot bleed air from the engines.

Ice protection systems based on hot bleed air can also be used to remove light accumulations of ice. However, these systems cannot be considered de-icing systems that are fully appropriate, because the quantity of energy required to evaporate ice accretion is very high.

- **Wing Leading Edges**
  Large aircraft, for example Airbus aircraft, are significantly less at risk of icing than smaller aircraft. This is due to the size and thickness of their wings: thick wings collect less ice than thin ones. Therefore it is not necessary to anti-ice the full wingspan.

  The heat flux is computed in order to compensate for outside air cooling (known as forced convection) and to melt the possible ice. When rapid cooling due to airspeed does not occur, the heat flux may cause damage to the slats via overheating. Therefore wing anti-ice is inhibited on the ground.

  Horizontal and vertical stabilizers also have leading edges where ice accretion can occur, but they are not anti-iced. This is because they both have large margins relative to their maximum required performance. Both are demonstrated to comply with certification targets with ice shapes.

- **Engine Air Intakes**
  Hot bleed air is used to anti-ice the nacelle air intake. This protects the fan blades from damage caused by the ingestion of ice.

  Engine anti-ice is not inhibited on ground, due to both of the following:
  - The engine intake is not affected by overheating.
  - Ice accretion on the engine may occur at OAT above 0 °C (refer to A.1.3).

2.1.2. Electrical Heating

Electrical heating is usually used where small amounts of ice are encountered, or on small surfaces like turboprop air intake.

On Airbus aircraft, equipment that includes static probes, pitot probes, AOA probes, cockpit windows and wastewater drain masts are electrically anti-iced.

2.1.3. Mechanical De-icing Boots

Mechanical boots are de-icing systems designed to remove ice accretion. They are usually used on propeller aircraft. The boots are rubber tubes that are installed on the leading edges of the wing. As soon as ice accretion occurs, the boots are inflated by pressurized air in order to break the ice. De-icing boots are not used on Airbus aircraft.

2.2. Procedures For Flight In Icing Condition

The AFM and FCOM indicate that **icing conditions** occur when the OAT (on the ground and for takeoff), or the TAT (in flight) is 10 °C or below, and there is visible moisture in any form (for example clouds, fog with low visibility of one mile or less, rain, snow, sleet, ice crystals).
Icing conditions also occur on the ground and for takeoff when the OAT is 10 °C or below when operating on ramps, taxiways, or runways where surface snow, standing water, or slush may be ingested by the engines or freeze on engines, nacelles, or engine sensor probes.

On A300-600/A310/A320/A330/A340/A350/A380, when icing conditions are encountered:

- The flight crew must set the engine anti-ice to ON.
- The flight crew may set the wing anti-ice to ON, in order to prevent ice accretion on the wing leading edge.
- The flight crew must turn on the wing anti-ice if there is confirmation of ice accretion, for example ice on the visual indicators or on the wipers.

On A220, the flight crew sets the engine and wing anti-ice to AUTO, in order to take advantage of the automatic mode. In this case, engine and wing anti-ice is automatically controlled by the ice detection system (refer to B.2.3.2).

The flight crew should avoid extended flight in icing conditions with the slats extended. This is because ice accretion may cause damage to the slats when they are retracted.

If there is confirmation of ice accretion and to take into account ice formation on not heated structures, V_{LS} (V_{REF} on A220) must be increased for specific flaps setting (depending on aircraft types), as described in the FCOM.

2.3. Ice Detection

2.3.1. Visual Ice Indicator

The visual ice indicator provides the flight crew with confirmation of ice accretion.

	A220	A300/A310	A320 Family	A330/A340	A350	A380
Nb Installed	0	0	1	1	2	2

Visual Ice Indicator (A350)

2.3.2. Ice Detection System (If Installed)

The definition of icing conditions, as “visible moisture and less than 10 °C TAT” is conservative. When icing conditions occur (as per the definition), it does not necessarily mean that there is ice accretion on the aircraft. In addition, there are situations where the icing conditions, as per the AFM definition, are difficult to identify (e.g. at night).

All A220/A330/A340/A350/A380 are equipped with an ice detection system. It is optional on the A320 family.

The ice detection system operates in flight only, and provides the flight crew with an additional indication of icing.

The ice detection system has two ice detectors that measure ice accretion. The ice detector has an airfoil-shaped part that stands out in the airflow, so that the probe perpendicularly sticks out in the airflow beyond the boundary layer. An internal heating device de-ices the probe, to enable subsequent ice detection.

Ice Detector (A220)

The ice detection system informs the flight crew if the quantity of ice accretion on a detector is more than a specific threshold. The flight crew then sets the engine or wing-anti ice to ON (except on A220, because the ice detection system automatically sets the engine and wing anti-ice to ON).

The ice detectors do not indicate how much ice accretion there is on the critical surfaces of the aircraft. The detectors are installed on the lower part of the nose fuselage, an area very sensitive to ice accretion. The correlation between ice accretion at this sensitive location and ice accretion (and accretion rate) on critical aircraft surfaces (e.g. the engines inlets and the slats), are tested and validated in flight and wind tunnel testing.

C. Performance and Handling Qualities on Contaminated Runways

Takeoff and landing on a contaminated runway requires specific considerations, particularly due to the large variations in methods for runway condition reporting between regions, countries and even airports. In addition, the aircraft performance results provided to pilots are calculated based on simplified, controlled and perfect scenarios, that do not indicate real situations on the runway. Neither the observation and measurement of the runway condition, nor the physical effects on the aircraft are a perfect science. Therefore, some conservatism is required in order to take into account any situation. However, it is also important to keep in mind that over-conservatism may result in excessive penalties for operations.

It is obvious that the braking performance is strongly affected by a slippery runway. However the loss in acceleration and in aircraft lateral controllability must also be considered.

1. What Is a Contaminated Runway?

Pilots who are not familiar with winter conditions can easily feel too relaxed about safety by the way performance data is presented: a few distinct contaminant types clearly described in terms of depth and density, associated with a number, that are considered to be constant for each runway third.

Unfortunately, Mother Nature is rarely so easily categorized. In addition, while weather can generally be forecast with good accuracy, that includes chronology, the runway surface conditions with natural contamination is difficult to anticipate. Runway surface conditions depend on various factors that include state changes due to aircraft traffic, surface temperature effects, chemical treatment, or run-off and removal.

For more information on aircraft performance on contaminated runways, refer to Getting to Grips with Aircraft Performance.

2. Specific Reporting

In addition to the SNOWTAM, the air traffic controller may provide information on the runway conditions in the form of a Pilot Report or PiRep of Braking Action (BA).

PiReps of BA are information reported by the crew based on the behavior of the aircraft during the landing.
PiReps can be evaluated from:

- Pilots personal assessment
- Automatic assessment performed by the aircraft, through the Braking Action Computation Function (BACF).

PiReps communicated to the pilots in approach should always include the time and emitter of the report that includes the airline and the aircraft type. PiReps of Braking Actions usually use the terminology: GOOD / MEDIUM / POOR.

2.1. Pilots Personal Assessment

These reports are individual understandings that may be affected by a number of factors that include:

- If the pilot is familiar with contaminated runways
- If the pilot is familiar with this specific type of condition
- The type of aircraft
- The use of deceleration devices.

It is also easy for a pilot to incorrectly consider the aerodynamic and reverse thrust deceleration forces as braking forces. In addition, a flight crew can only evaluate the portion of the runway they used. Therefore, a PiRep may not take into account a runway end that is less used, and that may have different contamination characteristics compared to other parts of the runway. However, these personal reports are still important because they often (but not always) provide the most updated information available under dynamic weather, and associated runway surface conditions. In countries where PiReps of Braking Action are transmitted to following traffic, it is the responsibility of the pilot who performs the In-Flight landing performance assessment to determine if the transmitted information can be considered reliable or not. PiRep is also called Pilot Braking Action Report (PBAR).

2.2. Braking Action Computation Function (BACF)

Airbus developed an aircraft function (currently available as an option for A320 and A330 family aircraft) that uses onboard data to identify the braking action the aircraft encountered during landing.
The basic principle of the function is, after landing, to use the data measured by the aircraft during its landing roll to identify the braking action level. By using the aircraft performance model, it is possible to tell the difference between the parts of deceleration coming from aerodynamics, thrust reverse, and wheel-braking.

The comparison of the wheel braking performance to the performance models for standardized “reference” runway conditions enables the software to identify the braking action(s) that the aircraft experienced.
By design this system is only able to evaluate the runway condition when the antiskid is activated. Therefore, the BACF evaluates the portion of the runway when the aircraft deceleration demand is high.
After landing, the flight crew may directly check the braking action report on a dedicated MCDU page. The flight crew may use this information with their own observations as part of their Pilot Report (PIREP) of Braking Action back to Air Traffic Services.

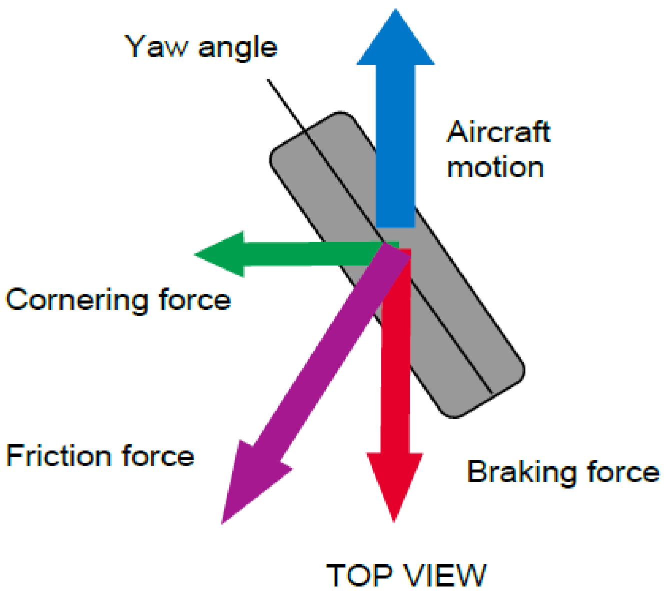
ACARS data sent to the ground systems with the results, provides digital data about the braking actions reported across a fleet of aircraft, throughout their route network.
BACF reports are also referred to as Aircraft Braking Action Reports (ABAR).

3. Aircraft Directional Control

The previous section analyzes the impact of the reduction of the friction forces on aircraft braking performance. The reduction of friction forces also significantly reduces aircraft directional control.
The effect of the crosswind component on a slippery runway should also be considered.

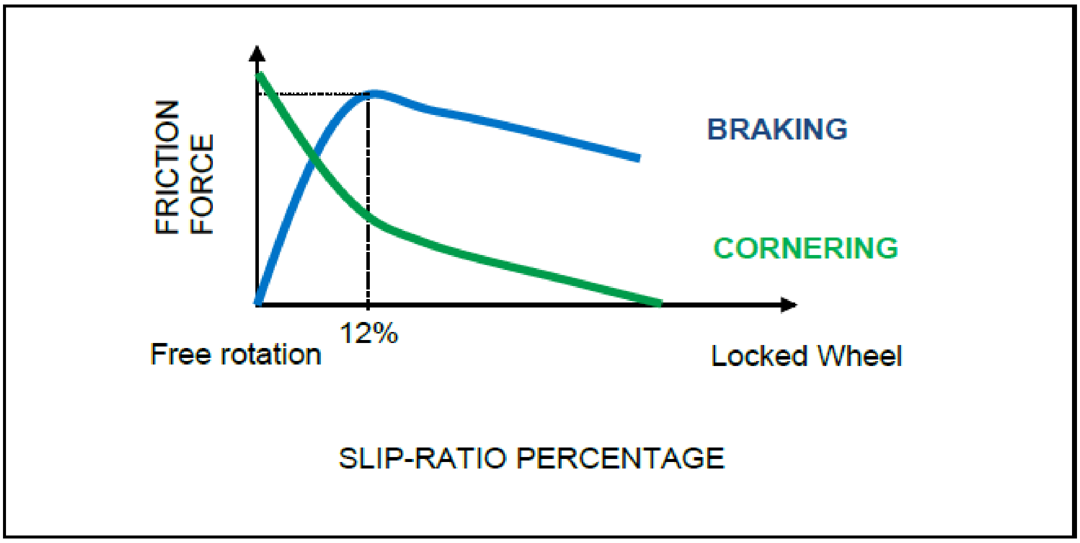
3.1. Influence of Slip Ratio

When a rolling wheel is yawed, the force on the wheel can be split in two directions: One in the direction of wheel motion, the other perpendicular to the motion. The force in direction of the motion is the well-known braking force. The force perpendicular to the motion is known as the side-friction force or cornering force.
Steering capability is obtained via the cornering force.

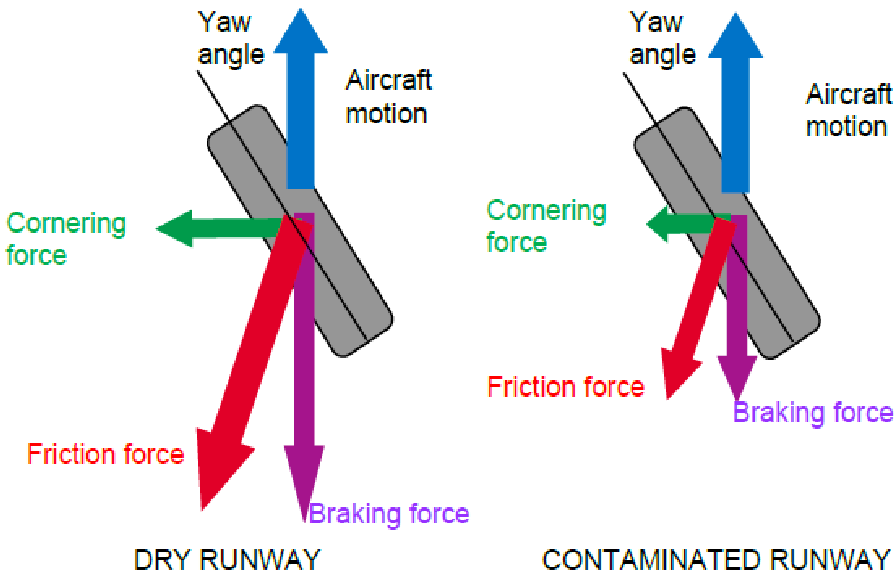


Maximum cornering effect is obtained from a free-rolling wheel. On the other hand, a locked wheel produces a small cornering effect.
For braking performance, we can recall that a free-rolling wheel produces no braking. In other words, maximum steering control is obtained when brakes are not applied. Therefore there must be some compromise between cornering and braking.

The following diagram illustrates this principle:



The above diagram illustrates that when maximum braking efficiency is reached (i.e. around 12 % slippage), a significant part of the steering capability is lost.
This is not a problem on a dry runway where the total friction force, split in braking and cornering, is high enough. It may however be a problem on a slippery runway, where the total friction force is significantly reduced. In some critical situations, the pilot may have to decide between braking and controlling the aircraft. It may not be possible to obtain both at the same time.



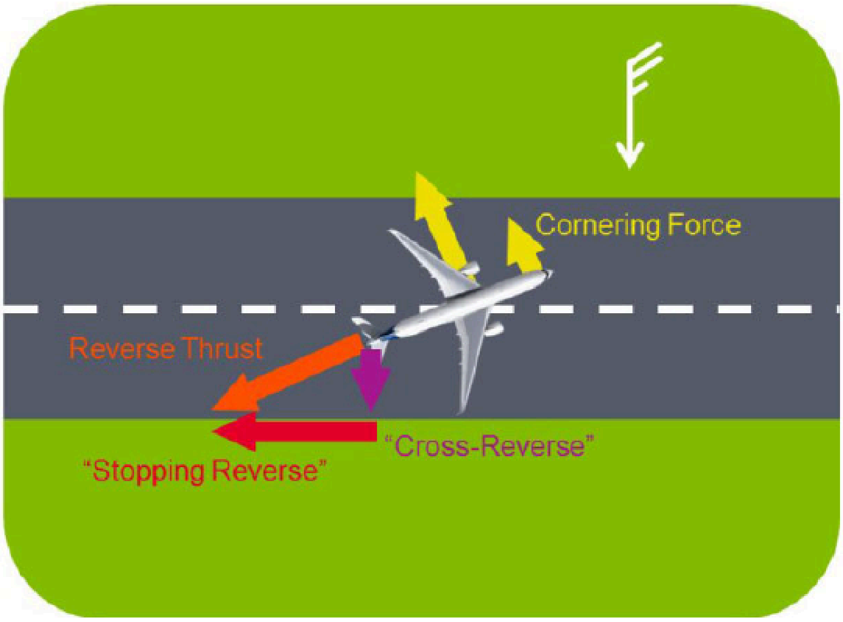
3.2. Influence of Wheel Yaw Angle

The cornering force also depends on the wheel yaw angle. The wheel yaw angle is defined as the angle between the wheel and its direction of motion. The cornering force increases with the yaw angle, however, if the wheel is yawed too much, the cornering force rapidly decreases.
The wheel yaw angle that provides the maximum cornering force depends on the runway condition, and reduces when the runway is very slippery. It is around 8 ° on a dry runway, 5 ° on a slippery runway and 3 ° on an icy runway.

3.3. Ground Controllability

During a crosswind landing, or aborted takeoff, cornering force is the primary way to maintain the aircraft in the width of the runway.
In a crosswind situation, the aircraft crabs. That is, the nose of the aircraft is not aligned with the runway axis.
The wind component can be split in two directions: crosswind and head/tail wind. Similarly, the thrust reverse component is split in a component parallel to the runway centerline, that stops the aircraft, and in a component perpendicular to the runway. For the purpose of this example, let us refer to it as cross-reverse.

These two forces, crosswind and cross-reverse, push the aircraft off the runway. The cornering forces induced by the main wheel and the nose wheel must balance this effect.



In this type of situation, the release of the brakes will enable more cornering force to be developed, and will therefore recover aircraft directional control.
During the use of the autobrake, LOW mode provides more cornering force than MED mode.

4. Crosswind

4.1. Demonstrated Crosswind

A demonstrated crosswind is indicated in the Airplane Flight Manual (AFM). The words **demonstrated crosswind** are intentionally selected to express that this is not always the maximum crosswind that the aircraft is able to manage. It refers to the maximum crosswind that was **encountered** during the flight test campaign, and for which sufficient recorded data is available.
It is also intentional that **demonstrated crosswind is not indicated in the Limitations section** (unless specific limitations apply to engine operations), but in the Performance section of the AFM.

The demonstration of crosswind capability is performed on dry or wet runways, and it is usually considered that the reported values are similarly applicable to dry or wet runways.

In fact, the information in the AFM is an indication of what was encountered during certification flight tests, to provide guidance to operators to establish their own limitations. FAR/CS 25 requires this information to be provided.

The maximum crosswind for automatic landing is defined in the Limitations section of the AFM. In this case, it must be understood as a limitation. This is the limitation of the system.

4.2. Effect of Runway Contamination

It is a fact that a runway friction coefficient that is poor will affect both braking action and the capability to sustain high crosswind components. Airbus publishes recommendations, based on calculations and operational experience, in order to develop guidelines on the maximum crosswind for these types of runway conditions.
The Limitations section of the FCOM indicates the maximum recommended crosswinds related to the runway braking action that is estimated. The table below is an example provided in the A320 FCOM:

MAXIMUM RECOMMENDED CROSSWIND ON WET AND CONTAMINATED RUNWAYS

Runway Surface Conditions		Maximum Crosswind for Takeoff (Gust included)	Related Landing Performance		Maximum Crosswind for Landing (Gust included)
Runway State or / and Runway Contaminant	**AIREP[1]**		**RWYCC[2]**	**Level**	
Damp **Wet** Up to 3 mm (1/8") of water **Slush** Up to 3 mm (1/8") **Dry snow** Up to 3 mm (1/8") **Wet snow** Up to 3 mm (1/8") **Frost**	**Good**	39 kt	**5**	**GOOD**	38 kt
Compacted snow OAT at or below -15 °C	**Good to Medium**	29 kt	**4**	**GOOD TO MEDIUM**	29 kt
Dry snow More than 3 mm (1/8"), up to 100 mm (4") **Wet snow** More than 3 mm (1/8"), up to 30 mm (6/5") **Compacted snow** OAT above -15 °C **Dry snow over compacted snow** **Wet snow over compacted snow** **Slippery wet**	**Medium**	25 kt	**3**	**MEDIUM**	25 kt
Standing Water More than 3 mm (1/8"), up to 13 mm (1/2") **Slush** More than 3 mm (1/8"), up to 13 mm (1/2")	**Medium to Poor**	20 kt	**2**	**MEDIUM TO POOR**	20 kt
Ice (cold & dry)	**Poor**	15 kt	**1**	**POOR**	15 kt

(1) *AIREP: Special Air Report of Braking Action*

(2) *RWYCC: Runway Condition Code*

D. Fuel Freezing

1. Introduction

On some specific routes, fuel freezing limitations may be a concern. When very low temperatures are expected, the dispatch or flight plan may be affected, and have economic effects. Some routes may not be flown under severe temperature conditions with any fuel type.
Similarly, when very low temperatures are encountered in flight, specific crew procedures may be necessary.
This chapter provides a review of various characteristics associated with fuel freezing limitations.

2. Fuel Temperature Prediction Software

2.1. Principles

The Fuel Temperature Prediction (FTP) software relies on external data sources to obtain:

- Navigation data (waypoints, distance, time)
- Weather data (temperatures)
- Performance data (altitude, speed, fuel on board).

This data determines the nominal fuel distribution and movement during the flight, and simulates the effect of the various processes of heat exchange, for example:

- Convection
- Radiation
- External heat sources
- Mass transfer.

The result is a detailed output of the fuel temperatures in each tank at each waypoint, a summary that indicates:

- If the flight can be dispatched under the specific conditions
- If any manual transfers were triggered during the simulation
- What the lowest predicted/expected temperature in each tank is.

This information enables the dispatcher to decide in an informed manner, which areas may need to be avoided on a critical flight.

2.2. Operating Modes

The FTP can be used in two ways depending on the source of the navigation, weather and performance data:

- The Flight Plan Analysis
- The Sector Analysis.

2.2.1. Flight Plan Analysis

The Flight Plan Analysis uses an operational flight plan of the airline (or pilot log) as a data source for the computation. The current basic implementation is included in the Performance Engineer's Programs (PEP) software suite. An important feature is found in the different types of flight plans (formats and providers) to be imported. To manage this, the FTP environment in PEP is designed to accept a standard XML (eXtensible Markup Language) format. The FTP accepts the two following XML formats for the flight plan input:

- XML ARINC 633 standard
- XML Airbus standard.

Operators can contact the provider of their flight planning system to have flight plans in the ARINC 633 XML format. In addition, the modification of the airline pilot log to an XML format requires the development of a customized tool.

All the necessary information (e.g. required input formats, functionality) for this module is provided in the Performance Programs Manual (PPM) for PEP-FTP.

The Airbus Flight Planning (FLIP) computation results in a specific output and can be directly imported to the user interface of PEP-FTP. Then, the same type of analysis can be performed as for a Flight Plan Analysis.

2.2.2. Sector Analysis

The Sector Analysis is designed to help evaluate how cold fuel problems affect a city pair on a statistical basis. For this option, the computation is based on a simplified model:

- The routing is based on a Great Circle distance.
- The performance on the route is established with the Airbus Flight Planning (FLIP) module of PEP.
- For the statistical weather data, FTP uses the NOAA GUACA database (National Oceanic and Atmospheric Administration - Global Upper Air Climatic Atlas), collected from historical weather data obtained in the 80’s and 90’s from the ECMRWF (European Centre for Medium Range Weather Forecasts). Unfortunately, this database is no longer updated, and this means that the use of the Sector Analysis Module can no longer be used.

Therefore, Airbus recommends that operators use the “Flight Plan Analysis” module to check the possibility of fuel freezing.

2.3. Applicability

The FTP module of PEP is available for the following Airbus aircraft types:

- A319/A320/A321
- A330/A340
- A380.

The design of the A350 fuel tank optimizes thermal exchanges. This design was validated with polar flights, where more than a 20 ℃ margin against the fuel freezing point was measured. Because of this design of the fuel tank, the FTP module is not required for the A350 aircraft.

E. Effect of Low Temperature on Altimetry

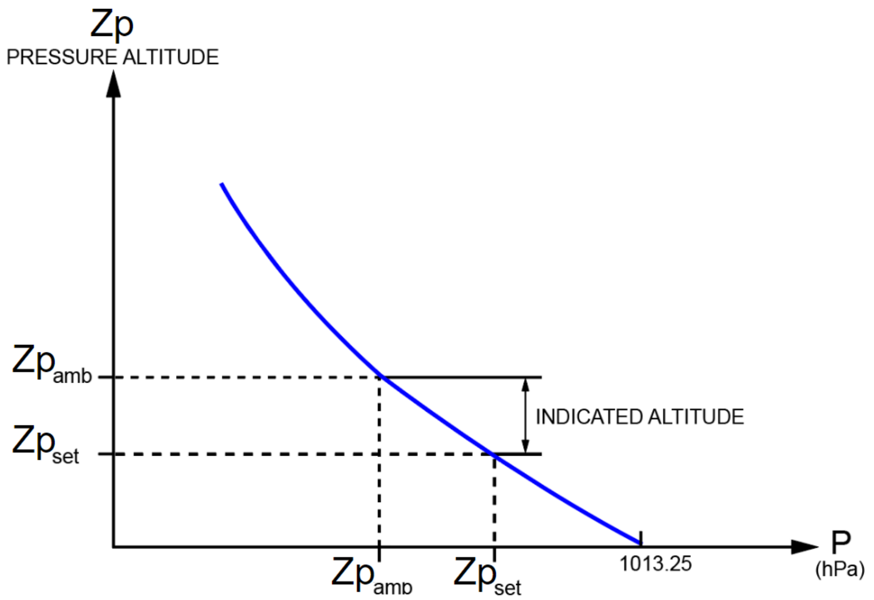
1. Altimetry Principles

The International Standard Atmosphere (ISA) is a mathematical model that determines the density, static pressure and temperature at any point of the atmosphere.

The static probes of the aircraft measure the static pressure of the atmosphere. With the ISA model, it is therefore possible to use this static pressure to obtain the corresponding altitude, known as pressure altitude (Zp).

Based on a calibration in accordance with the ISA model, the PFD and the standby instrument (if installed) display the vertical distance between:

- The pressure altitude Zp_{amb} that corresponds to the static pressure measured by the static probes.
- The pressure altitude Zp_{set} that corresponds to a reference pressure that the flight crew selected (1013 hPa, QNH or QFE, if the QFE option is installed).



2. Effect of Low Temperature

When the temperature is below ISA, the air is more dense. This causes the vertical distance between isobaric surfaces (surfaces of constant air pressure) to decrease and be nearer to the ground.

Therefore, when the temperature is below ISA, the true altitude of the aircraft is lower than the indicated altitude (because the altitude displayed in the cockpit is based on the measured air pressure and a calibration on the ISA model). This may affect terrain and obstacle clearance.

For more information, refer to Getting to Grips with Aircraft Performance.

3. Correction for the Effects of Low Temperature

3.1. Definition

The term "correction" refers to the value that the flight crew adds to the published minimum altitudes or heights, in order to take into account the effects of low temperature.

The correction applies for example to:
- Minimum En Route Altitude (MEA) and Minimum Sector Altitude (MSA)
- Procedure turn minimum altitude (as applicable)
- Final Approach Fix (FAF) and Final Approach Point (FAP) minimum altitude
- Missed approach altitude
- Barometric minima (except if the chart takes into account the effects of low temperature. Refer to E.5.3 and E.5.4).

3.2. General

When the atmospheric temperature may be significantly below ISA, it is the responsibility of the Operator to establish a policy about the correction for the effects of low temperature.

In accordance with the ICAO Annex 6 (Operation of Aircraft), the Captain is responsible for the safety of the aircraft and all crew members, passengers and cargo on board. This includes terrain and obstacle clearance.

The ICAO Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM) Doc 4444 indicates that when necessary, the applicable minimum vectoring altitude must include a correction for the effects of low temperature. However, except for the minimum vectoring altitude, other minimum flight altitudes may be published without any correction. In addition, vectoring may occur where a minimum vectoring altitude is not established. Therefore, **it is important to be aware that the ATC may assign an altitude or level that is not corrected for low temperature**. Terrain and obstacle clearance may not be sufficient.

The procedures in the PANS-ATM do not relieve the Captain of their responsibility to ensure that any clearance issued by ATC is safe. The Captain is always responsible for terrain and obstacle clearance. This responsibility is not transferred to the ATC, even during radar vectoring or direct routing (the ATC is responsible to provide clearances that assist the Captain to operate safely).

If an ATC clearance to an altitude does not ensure sufficient terrain and obstacle clearance, the Captain must request an alternative ATC clearance to a higher altitude. Even when the ATC applies a correction for the effects of low temperature, the correction may be based on a temperature that is not low enough for the current conditions.
The flight crew may also ask the ATC for the applicable minimum flight altitude, lowest usable flight level or minimum vectoring altitude, and if the ATC applied a correction for the effects of low temperature to these levels (if so, the flight crew may also ask the coldest temperature taken into account).

3.3. Types of Corrections

Several types of corrections for the effects of low temperature are available (e.g. approximate, tabulated or accurate correction). In any case, the objective is the same: to maintain sufficient terrain or obstacle clearance.
For more information, refer to the ICAO Procedures for Air Navigation Services - Aircraft Operations (PANS-OPS) Doc 8168 volume III.

3.4. Operational Considerations

The following points need to be considered:

- The correction is a value that the flight crew adds to the published minimum altitudes or heights. Therefore:
  - **The flight crew must not change the barometric reference setting to correct for the effects of low temperature**.
  - The flight crew increases the altitude of the aircraft only if the aircraft is below the corrected minimum altitude.
- The application of corrections larger than necessary may cause operational difficulties (e.g. ILS glide interception from above, reduction of separation with other aircraft).
- The manual determination of the corrected minimum altitudes may increase workload, particularly during approach. On A300-600 with EPIC avionics and A220, the flight crew may use the FMS TEMP COMP page to compute the corrections. Another possibility is to use an EFB software.

4. Temperature Compensation

4.1. Definition

The term “temperature compensation” refers to the capability to automatically adjust the vertical flight path in order to take into account the effects of temperature.

Temperature compensation does not relieve the flight crew from correcting the published minimum altitudes for the effects of low temperature.

4.2. A300-600 with EPIC Avionics and A220

On these aircraft, the flight crew may activate the temperature compensation function of the FMS. The FMS profile is then adjusted in accordance with the OAT that the flight crew entered in the FMS. In vertically managed mode, the FMS profile enables the aircraft to fly the same trajectory as in standard ISA temperature.

The temperature compensation of the FMS profile does not change the barometric aircraft altitude on the PFD (or altimeter on A300-600).

4.3. All other Airbus Aircraft

Except A300-600 with EPIC avionics and A220, the FMS has no temperature compensation function.

4.3.1. FMS Landing System (FLS)

If installed on A320/A330/A340/A350/A380, the FLS enables the flight crew to fly for example VOR, NDB or RNP approaches with LNAV or LNAV/VNAV minima similarly to an ILS. To do so, the FMS computes a final approach path, referred to as the FLS beam. The FLS beam is temperature compensated for temperatures below the ISA temperature: when the temperature at destination (that the flight crew entered in the FMS) is below the ISA temperature, the computation of the FLS beam and the associated vertical guidance is corrected with the entered temperature. The temperature compensation of the FLS beam does not change the barometric aircraft altitude on the PFD.

5. Focus on the Approach Phase

With or without FMS temperature compensation, in vertical selected or managed mode, the aircraft altimetry is based on barometric pressure. Therefore, when the temperature is significantly below ISA, the published minimum altitudes or heights always need to be corrected (except if the chart takes into account the effects of low temperature. In this case the minimum OAT is indicated on the chart. Refer to E.5.3 and E.5.4).

Note: For ILS CAT II/III, there is no requirement to correct the minima, because they are based on radio altitude (measured by the radio altimeters).

5.1. ILS CAT I, GLS, RNP APCH with LPV Minima

- For ILS, vertical guidance is based on the glide slope signal.
- For GLS (if installed on A320/A330/A350/A380), vertical guidance is based on the GNSS position with a correction from a ground station, also known as Ground Based Augmented System (GBAS).
- For RNP APCH with LPV minima, vertical guidance is based on the GNSS position, with a correction from geostationary satellite constellations, also known as Satellite Based Augmented System (SBAS). The vertical guidance is ensured by the SLS (if installed on A320/A330/A350/A380), VNAV (A220) or GS_L (only on A300-600 with EPIC avionics).

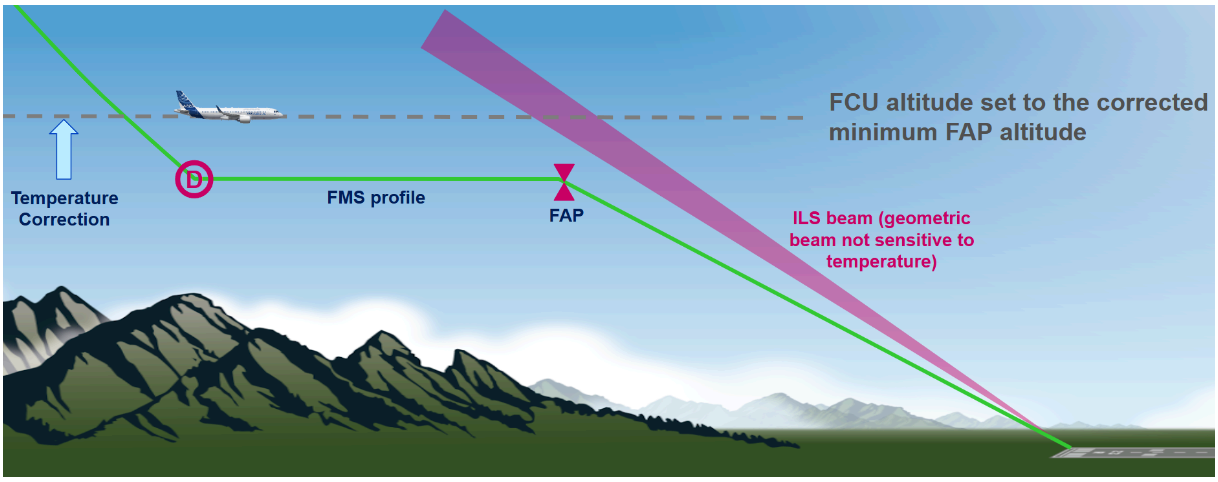
Because vertical guidance during final approach is not based on barometric pressure, the flight crew can follow the ILS(GLS)(SLS)(VNAV)(GS_L) guidance in the case of low temperature. However, this guidance applies to the final approach only.

5.1.1. A300-600 with EPIC Avionics and A220

For appropriate vertical guidance during initial and intermediate approach, the flight crew activates the temperature compensation function of the FMS.

5.1.2. All other Airbus Aircraft

When the temperature is below the ISA, the FMS vertical profile may be too low because it is not temperature compensated. As an example, the illustration below indicates that the aircraft altitude is adjusted (via the FCU) so that the aircraft does not fly below the corrected minimum FAP altitude of an ILS approach:



5.2. VOR, NDB AND RNP APCH WITH LNAV MINIMA

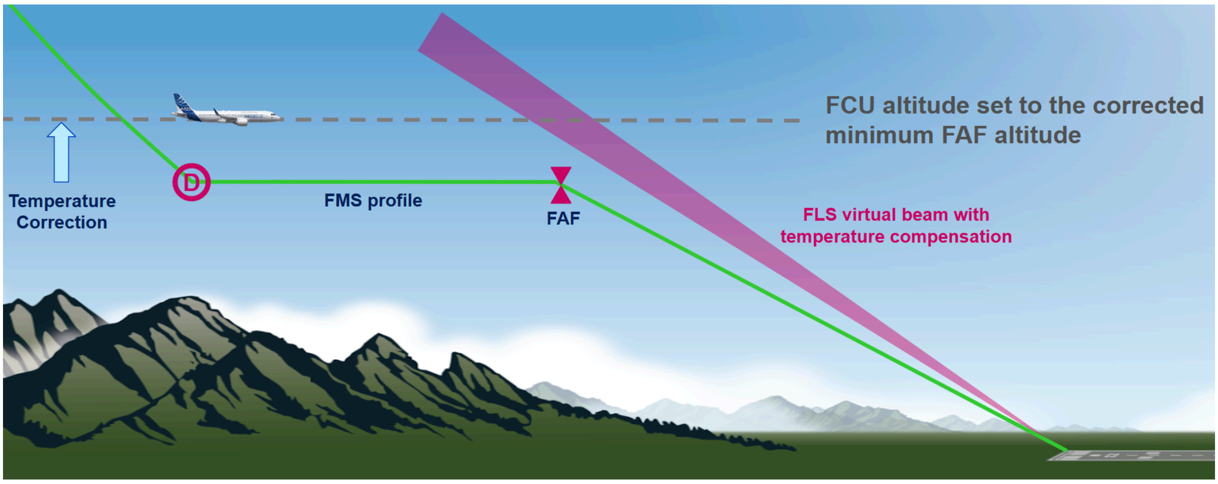
5.2.1. A300-600 with EPIC Avionics and A220

For appropriate vertical guidance, the flight crew activates the temperature compensation function of the FMS.

5.2.2. All other Airbus Aircraft

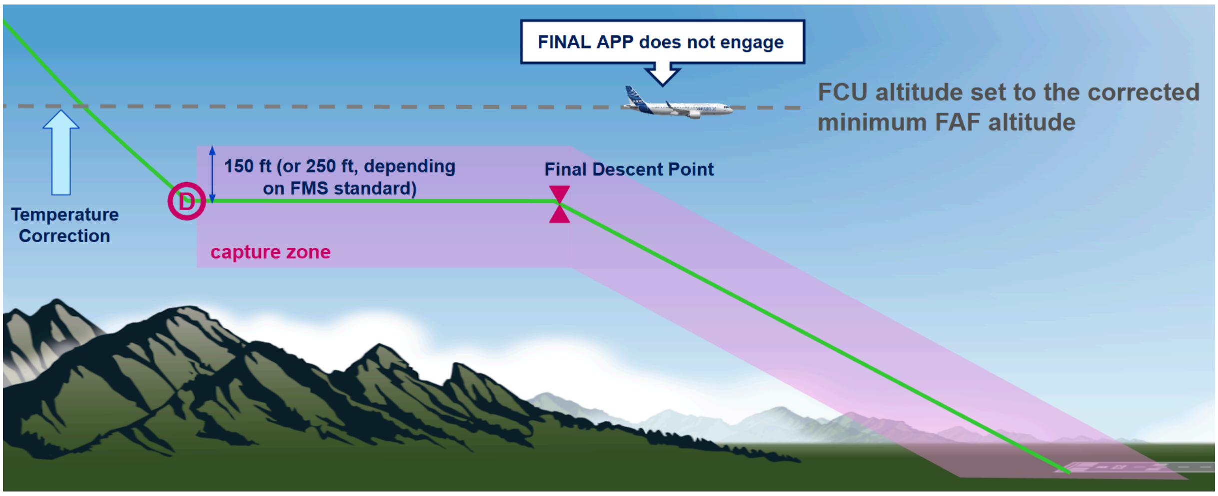
- **When the FLS is Used**

  As explained in E.4.3.1, the FLS beam is temperature compensated. Therefore, in the case of low temperature, the flight crew can follow the FLS guidance during final approach. However, there is FLS guidance during the final approach only. The FMS vertical profile may be too low in other segments of the approach, because it is not temperature compensated. As an example, the illustration below shows that the aircraft altitude is adjusted (via the FCU), so that the aircraft does not fly below the corrected minimum FAF altitude:



- **When the FLS is not Used**
  This paragraph applies to aircraft without FLS, or aircraft that cannot use FLS on specific approaches (e.g. due to the geometry of the approach).

  The FMS vertical profile is not temperature compensated. In managed guidance mode (e.g. FINAL APP mode for A320/A330/A340, APP-DES for A350, P.DES mode if installed on A300-600/A310), the aircraft follows the FMS vertical profile, that may be too low in the case of low temperature. However, a correction via the FCU may cause the FINAL APP(APP-DES)(P.DES) mode not to engage. This is because the aircraft may be above the capture zone of the vertical FMS profile. On A320/A330/A340, this occurs if at the FMS Final Descent Point, VDEV is more than 150 ft (or 250 ft, depending on the FMS standard), as indicated below:



In addition, it is not authorized to apply altitude corrections to the final approach segment of the FMS flight plan (by the manual modification of the altitude constraints). In order to use FINAL APP(APP-DES)(P.DES) mode, it is recommended to check the obstacle clearance and define a minimum OAT for the entire approach (including initial, intermediate and final approach segments):

- If the OAT is above this defined minimum OAT, the flight crew can fly the approach with FINAL APP(APP-DES)(P.DES) mode and without temperature correction.
- If the OAT is below this defined minimum OAT, the flight crew cannot fly the approach with FINAL APP(APP-DES)(P.DES) mode. They must revert to selected mode (and apply temperature corrections).

5.3. RNP APCH WITH LNAV/VNAV MINIMA

The approach chart indicates a minimum OAT that ensures obstacle clearance in the final approach segment. Therefore, there is no requirement to correct the minima when the temperature is above the minimum OAT. However, this minimum OAT does not take into account the other segments of the approach.

5.3.1. A300-600 with EPIC Avionics and A220

For appropriate vertical guidance during initial and intermediate approach, the flight crew activates the temperature compensation function of the FMS. In addition, this enables the aircraft to fly the approach even if the temperature is below the minimum OAT published on the approach chart (in this case, the minima must be corrected).

5.3.2. All other Airbus Aircraft

- **For Aircraft with FLS**

- If the OAT is above the minimum OAT published on the approach chart:
  The minimum OAT on the chart ensures obstacle clearance in the final approach segment only. The FMS vertical profile may be too low in other segments of the approach, because it is not temperature compensated. Refer to E.5.2.2 for an example during the intermediate approach segment.

- If the OAT is below the minimum OAT published on the approach chart:
  As explained in E.4.3.1, the FLS beam is temperature compensated. This enables the aircraft to fly the approach even if the temperature is below the minimum OAT published on the approach chart (in this case, the minima must be corrected).
  However, there is FLS guidance during the final approach only. The FMS vertical profile may be too low in other segments of the approach, because it is not temperature compensated. Refer to E.5.2.2 for an example during the intermediate approach segment.

- **A320/A330/A340 without FLS, A300-600/A310 without EPIC Avionics**

  The FMS vertical profile is not temperature compensated. Therefore, without FLS, the flight crew cannot fly the approach if the temperature is below the minimum OAT published on the approach chart.

  Even if the temperature is above the minimum OAT published on the approach chart, obstacle clearance is ensured in the final approach segment only. The FMS vertical profile may be too low in other segments of the approach, because it is not temperature compensated. However, a correction via the FCU may cause the FINAL APP mode (A320/A330/A340) or P.DES mode (A300-600/A310) not to engage. Refer to E.5.2.2 for an illustration of the capture zone on A320/A330/A340.

  In addition, it is not authorized to apply altitude corrections to the final approach segment of the FMS flight plan (by the manual modification of the altitude constraints). In order to use FINAL APP(P. DES) mode, it is recommended to check the obstacle clearance, and define a minimum OAT for the entire approach (this includes initial and intermediate approach segments):

  - If the OAT is above this defined minimum OAT, the flight crew can fly the approach with FINAL APP(P.DES) mode and without temperature correction.

- If the OAT is below this defined minimum OAT, the flight crew cannot fly the approach (it is not permitted to fly RNP APCH with LNAV/VNAV minima with selected FPA mode).

5.4. RNP AR

Similarly to RNP APCH with LNAV/VNAV minima, the RNP AR approach chart indicates a minimum OAT that ensures obstacle clearance in the final approach segment. Therefore, there is no requirement to correct the minima when the temperature is above the minimum OAT. However, this minimum OAT does not take into account the other segments of the approach.

5.4.1. A300-600 with EPIC Avionics and A220

For appropriate vertical guidance during initial and intermediate approach, the flight crew activates the temperature compensation function of the FMS. In addition, this enables the aircraft to fly the approach even if the temperature is below the minimum OAT published on the approach chart (in this case, the minima must be corrected).

5.4.2. A320/A330/A340/A350/A380

The FMS vertical profile is not temperature compensated. Therefore, the flight crew cannot fly the approach if the temperature is below the minimum OAT published on the approach chart.

Even if the temperature is above the minimum OAT published on the approach chart, obstacle clearance is ensured in the final approach segment only. The FMS vertical profile may be too low in other segments of the approach, because it is not temperature compensated. However, a correction via the FCU may cause the APP-DES mode (A350/A380) or FINAL APP mode (A320/A330/A340) not to engage. Refer to E.5.2.2 for an illustration of the capture zone on A320/A330/A340.

In addition, it is not authorized to apply altitude corrections to the final approach segment of the FMS flight plan (by the manual modification of the altitude constraints). In order to use APP-DES(FINAL APP) mode, it is recommended to check the obstacle clearance and define a minimum OAT for the entire approach (this includes initial and intermediate approach segments):

- If the OAT is above this defined minimum OAT, the flight crew can fly the approach with APP-DES(FINAL APP) mode and without temperature correction.
- If the OAT is below this defined minimum OAT, the flight crew cannot fly the approach (it is not permitted to fly an RNP AR approach with selected FPA mode).