Docket No. SA-533

Exhibit No. 2-BBB

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C.

ATR Cold Weather Operations Guide (Be Prepared for Icing)

(77 Pages)

ATTACHMENT
53

Cold Weather Operations

ATR Flight Operations Services

Be prepared for icing

Edition 2009

An Alenia Aeronautica and EADS joint venture

ATR

Important notice

This brochure is intended to provide general information regarding flying in icing conditions.
In no case it is intended to replace the operational and flight manuals for ATR aircraft.
In all events, the procedures describe in the Aircraft Flight Manual shall prevail over the information contained in this document.

Printed on 100% recycled paper using vegetable inks

All efforts have been made to ensure the quality of the present document.
However do not hesitate to inform ATR Flight Operations support of your comments at the following address: **flight-ops-support@atr.fr**

The Flight Operations Support team

Introduction

From the early days of aviation, icing has been one of the most frightening of atmospheric phenomenas. Today it remains a major concern for commuter aircraft particularly during takeoff and landing despite anti-icing and de-icing systems. Due to their flight level and speed, turboprop aircraft fly where icing conditions are most likely to occur.

For this reason, pilots of such aircraft must pay attention to clues leading to ice accretion. They must keep in mind that adverse weather conditions play significant causal roles in nearly one third of all aircraft accidents, including general aviation. Among them, more than 20% are directly related to icing.

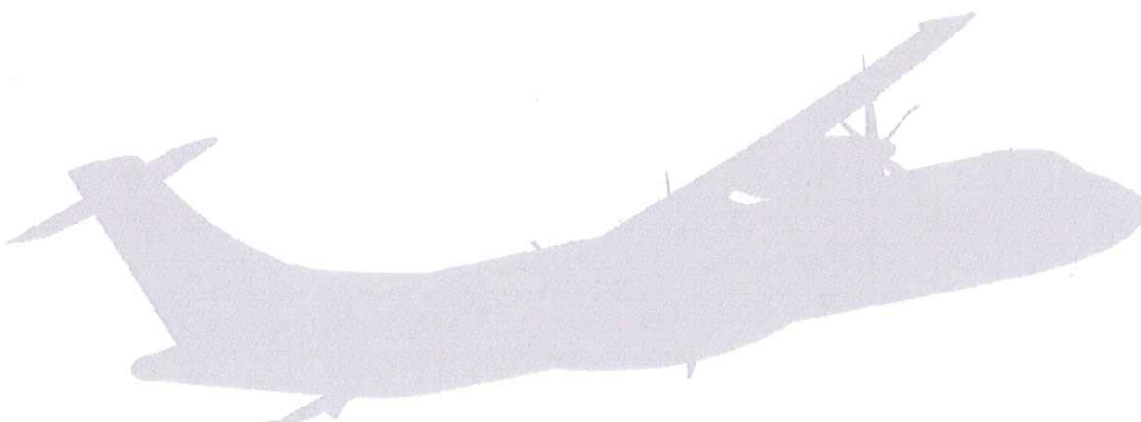
The Cold Weather Operations brochure intends to provide ATR operators with an understanding of ATR aircraft operations in cold weather conditions, and develop such aspects as:

- the icing meteorological phenomena
- the systems available to prevent and to control the ice accumulation
- the performance loss due to ice contamination on the aerodynamic surface of the aircraft
- the procedures to apply on ground and during flight when facing icing conditions.

This current release of the Cold Weather Operations brochure introduces the Aircraft Performance Monitoring (APM) system, offering operators an ongoing upgrade to their flight safety: ATR has developped the APM to enhance the **severe icing conditions detection**. This system includes low speed warning devices that enhances crew awareness, in case of severe icing threat. The APM functionalities are detailed in the chapters *Aicraft Ice Protection Systems* and *Procedures.*

Contents

A. Weather revision on icing



1. What is icing?

Icing is defined by any deposit or coating of ice on an object caused by the impact of liquid hydrometeors usually supercooled. This phenomenon generally occurs first on parts exposed to relative wind (i.e. probes, antennas, leading edge...)

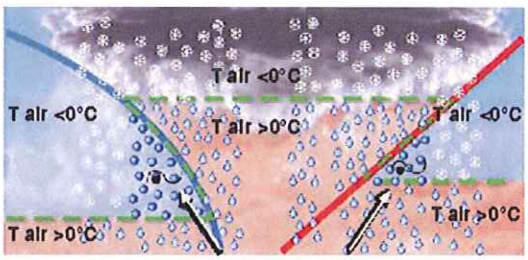
Supercooled water is a physical state where liquid water exists below its normal freezing point without freezing.

2. Build up process

Ice can form by three processes described below. At least one of them is involved whatever the weather situation.

2.1. Supercooled water droplets

Large quantities of supercooled water are present in the atmosphere, basically in clouds and freezing precipitation.



Ice deposits on airframe are directly related to supercooled water concentration in atmosphere, size of droplets and precipitation intensity.

This phenomenon appears when it is raining in very cold air.

Freezing rain

2.2. Freezing of liquid water

This case occurs when liquid water, at positive temperature remains on exterior parts of the airplane, typically scratch on skin, landing gear case, probes and control surfaces gap.

This water is very likely to freeze as soon as the aircraft enters a very low temperature atmosphere after uncompleted snow removal on ground for instance.

2.3. Condensation from vapor to ice

This is a transition from the vapor phase directly to the solid phase.

This phenomenon is likely to occur outside the clouds in a high moisture atmosphere on an aircraft with particularly cold skin. This case typically happens while aircraft is descending from its cruise flight level.

2.4. Types of accretion

This classification refers to the aspect of the accretion. It depends on several factors among them:

- Quantity of supercooled water droplets (Liquid Water Content)
- Size of droplets (diameter and distribution)
- Environment
- Outside Air Temperature (OAT)

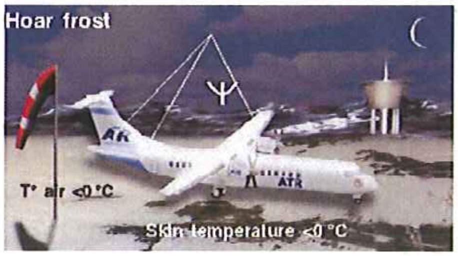
2.4.1. Hoar frost

Deposit of ice, which generally assumes the form of scales, needles, feathers or fans and which forms on objects whose surface is sufficiently cooled, to bring about the direct sublimation of water vapor contained in the ambient air.

Build up process

Condensation, that is to say direct transformation of vapor to ice. This phenomenon occurs with negative temperatures. Ice accretion appears on ground with a parked plane or in flight, particularly during descent with a cold airplane.

Associated weather conditions



On ground

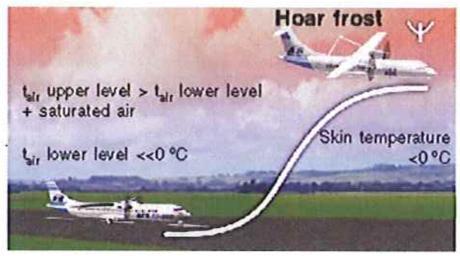
Anticyclonic conditions in winter, with clear night skies and little wind, can cause a sharp drop in ground temperature, which leads to formation of hoar frost on an aircraft parked outside overnight.

As whole airframe upper surfaces may be affected, the aircraft has to be cleaned of any ice accumulation prior to take-off.

In flight

Hoar frost can form on an aircraft, which was parked in a cold area and quickly climbs to a warm moist atmosphere.

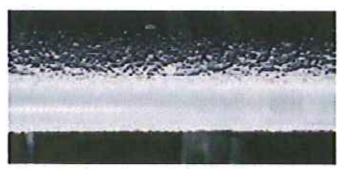
It can also form on an aircraft which has flown in a cold area and quickly descends into a warm moist atmosphere. Air in contact with the cold aircraft skin freezes quickly producing hoar frost.



Consequence

Hoar frost generally leads to light icing conditions with little effects on aerodynamic qualities.

2.4.2. Rime ice



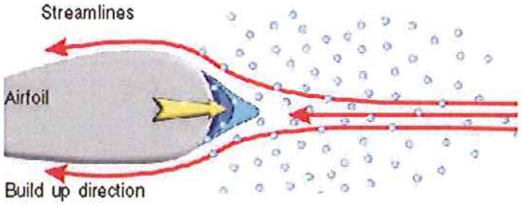
Rime ice on a leading edge

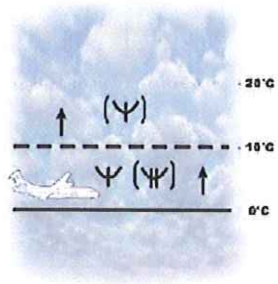
Rime ice has a milky, opaque appearance. It forms when the liquid water droplets freeze on impact. This usually occurs at low temperature or when the liquid water content is low.

Build up process

Fast freezing process of very small-supercooled water droplets in stable clouds layer.

This kind of icing builds up on parts exposed to the relative wind. The capture of little air bubbles during the freezing process gives rime ice its opaque aspect. The accretion grows up forward.





Associated weather conditions

Rime ice builds up in stable clouds layer like As and Ns of cold and warm fronts of polar fronts.

Consequence

Rime ice also builds up in radiation fog at negative temperature in high pressure area in winter.
Rime ice formations generally conform with the shape of the airfoil leading edge, causing less disruption in the airflow at sufficiently low AOA and therefore fewer handling and performance problems than clear ice.

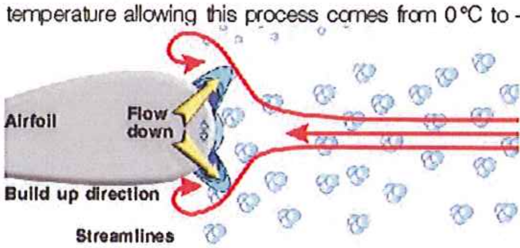
2.4.3. Clear ice

Clear ice can be lumpy and translucent or clear and smooth.

Clear ice on a leading edge

Build up process

Slow freezing of supercooled water droplets in stable or unstable clouds with high liquid water content. The range of temperature allowing this process comes from 0°C to –10°C.



At impact a supercooled water droplet spreads on the airplane skin and freezes, conforming plane shapes.

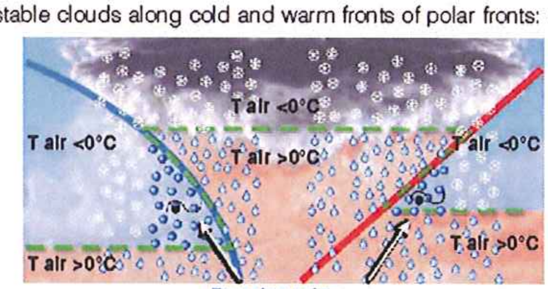
No air bubbles are captured during the process giving clear ice a compact texture and a transparent aspect.

This kind of icing generally grows up backward, conforming plane shapes or with a double horn shape.

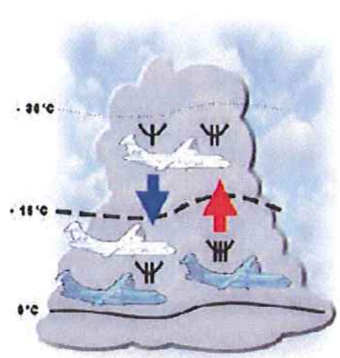
Associated weather conditions

Clear ice forms in cloud layers with high liquid water content:

- Very unstable clouds along cold and warm fronts of polar fronts: cumulonimbus and very unstable altocumulus



Freezing rain

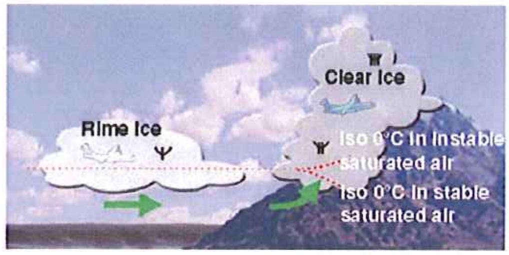


- Orographic lifting: Cb and very unstable Ac

  The orographic effect of a range of hills is likely to increase uplift in cloud so that the concentration and size of the supercooled water droplets are increased.

- Convective clouds and rear of depression.

- Dense fog and stratus
- Due to the high disparity of droplet size inside a cloud layer, ice accretion is a non-homogeneous process. Thus rime ice and clear ice accrete alternatively forming mixed ice.

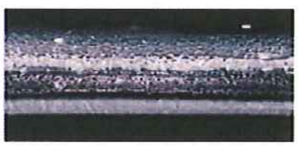


Consequence

The relatively slow freezing process can lead to the formation of horns and other shapes that can dramatically disrupt airflow and lead to substancial decrements in performance and handling. Clear ice accretion is very dangerous and is generally associated with severe icing conditions.

2.4.4. Mixed ice

Mixed ice forms at conditions between rime and clear ice in that it may form horns or other shapes that disrupt airflow and cause handling and performance degradations.



Mixed ice on a leading edge

2.4.5. Glaze

Glaze ice is very close in shape, texture and aspect to clear ice. The essential difference lies on the freezing mechanism.

A smooth compact deposit of ice, generally transparent, formed by the freezing of supercooled drizzle droplets or rain drops on aircraft skin with a temperature slightly above 0 °C

Build up process

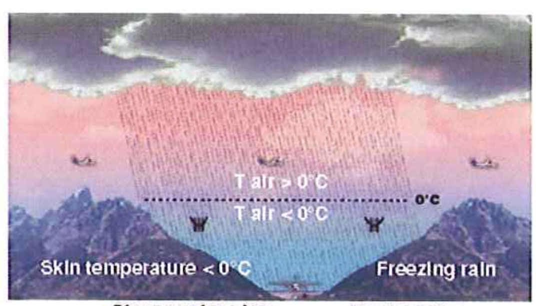
Glaze builds up through a condensation process of drizzle or raindrop. At impact a big supercooled water droplet spreads on the aircraft skin and freezes, conforming to plane shapes.

Glaze could also build up on a aircraft with a very cold skin under rain at positive temperature. In this case, the phenomenon has a short duration.

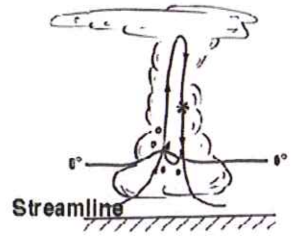
Associated weather conditions

Presence of supercooled precipitations is a regular phenomenon along frontal surfaces:

- Glaze accretion area is wider under warm front
- The higher the temperature difference between cold and warm air, the thicker the glaze accretion area
- Glaze accretion areas are more dangerous in winter than in summer
- Glaze accretion areas are likely to appear inside occlusions



- In winter on ground or at low level, freezing rain can form when the rain follows an anticyclonic period. Air close to the surface in valleys remains very cold, freezing rain is formed when water droplets pass through this layer.



Special case: glaze in Cb. Due to lifting currents inside the cloud, supercooled precipitations could strike a plane flying above freezing level from the bottom.

Consequence

Glaze is likely to induce severe icing. This type of icing is not only dangerous because the speed of accretion is fast, but also because the entire airframe is affected.

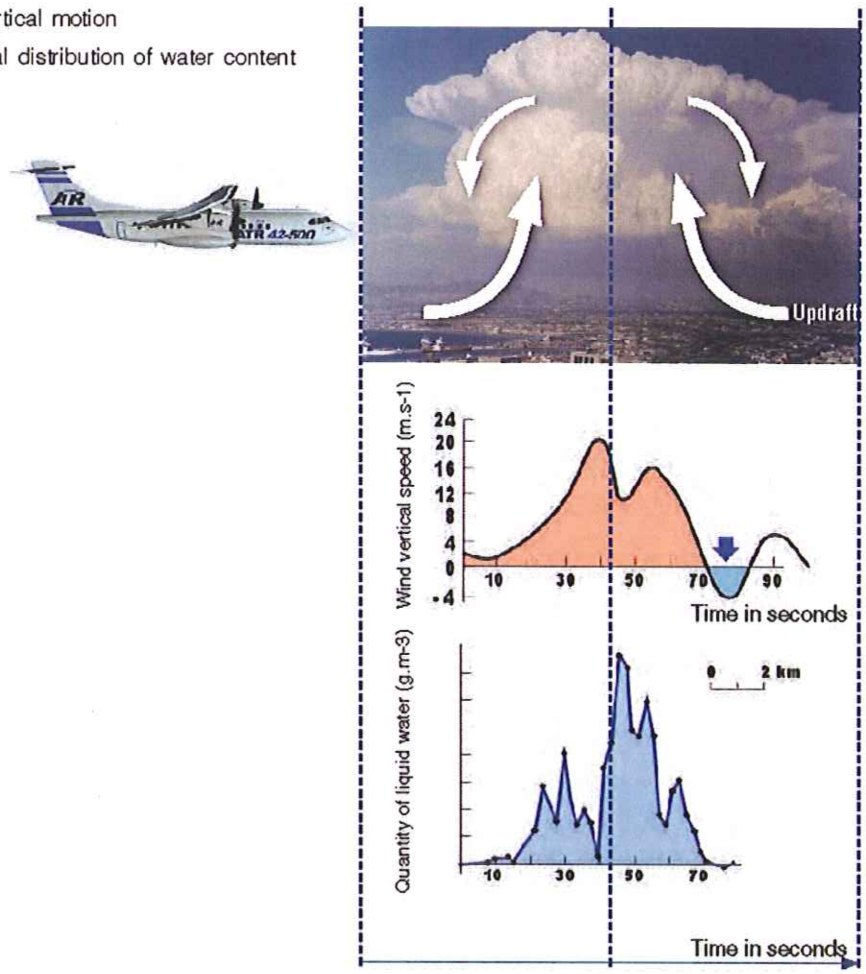
In this situation the de-icing system is inefficient.

2.5. Factors affecting the severity of icing

Icing intensity is directly related to the supercooled water quantity available.

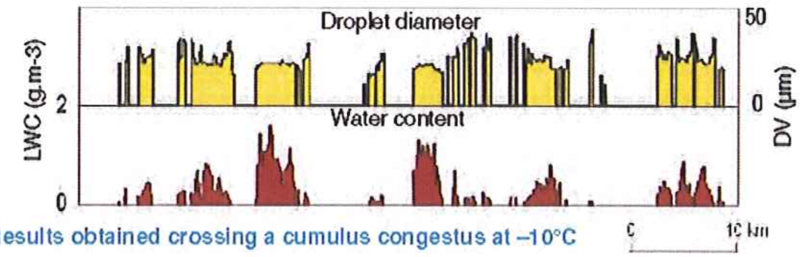
In addition, the speed of accretion is linked to the size of the supercooled water droplets, which depends on several factors among them:

- Cloud type
- Air in vertical motion
- Horizontal distribution of water content



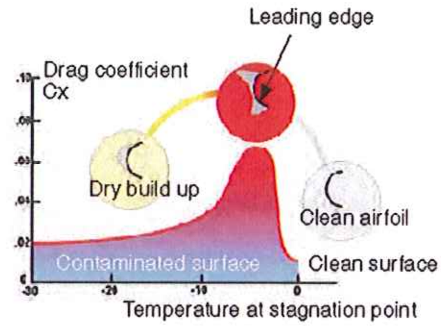
Note: The stronger the updrafts, the more the atmosphere contains liquid water. The previous diagrams show this phenomenon.

Consequently if an aircraft flies through such an area while in icing condition, ice accretion will be important.



Results obtained crossing a cumulus congestus at –10°C

Nevertheless, the speed of accretion, the shape and the texture depend on the speed of the aircraft through the medium.



Sudden increase of the drag

3. Icing classification

Two kinds of classifications are relevant:

- The first one quantifies the severity as a function of the atmosphere and is used by meteorologists.
- The second one connects synoptic charts to practical solutions.

3.1. Quantitative classification

Lets have a look at the standard water content of some typical atmospheric mediums.

Medium	Water content in g/m³
Fog	0.1 to 2
Stable clouds	0.2 to 0.5
Unstable clouds	1 to 3

Nevertheless the water content of clouds is a non-uniform value.

The following table shows the relationship between the supercooled water content in the atmosphere and the icing potential as it is presented on weather charts.

Symbol	Supercooled water content in g/m³	Corresponding clouds
Light	Less than 0.6	As, Ns, stable Sc Fog and light St Quite stable Ac
Moderate	From 0.6 to 1.2	Dense fog Dense St Ns Ac, unstable Sc, Cu, Cb
Severe	Above 1.2 Out of certification	Exceptional fog and St Very unstable Ac, Cu, Cb Heavy freezing rain

This table shows also that a same type of cloud could lead to different intensity of icing.

Flight tests have demonstrated that the most favorable temperatures for icing are:

- From 0 °C to –10 °C in stable clouds with an important decrease in intensity under –18 °C
- From 0 °C to –15 °C in unstable clouds, but presence of ice down to –30 °C

Ice accretion varies widely depending on the severity of icing: from less than 1 cm per hour to several cm per minute in Cb, Cu or heavy freezing rain.

3.2. Severity of ice

To standardize the reporting of the severity of icing encounters, 4 levels of icing severity have been defined:

- Trace icing
- Light icing
- Moderate icing
- Severe icing

The definitions used by the FAA are under review and may change under a new rulemaking initiative (review in 2002). Check the AIM 7-20 for the current definitions. Because its definition implied that it was not hazardous to flight, the term "trace ice" has been eliminated from the proposed FAA definitions.

Trace icing

Ice becomes perceptible. Rate of accumulation is slightly greater than the rate of sublimation.

Pilot action recommendation:

Monitor the situation, the icing severity could increase.

Light icing

Light ice indicates that the rate of accumulation is such that occasional use of ice protection systems is required to remove or prevent accumulation (1 cm in 15-60 minutes).

The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour). If in rime conditions, the accumulation on the leading edge appears as a band several centimeters wide. If clear or glaze, roughened edges may start to appear.

Pilot action recommendation:

This is a potentially hazardous condition. Either activate the ice protection system or exit the conditions.

Moderate icing

Moderate ice indicates that frequent use of ice protection systems is necessary to remove or prevent ice (1 cm in 5-15 minutes).

Unless actions are taken, substancial amounts of ice will build up on the airfoil. At this intensity, the rate of accumulation may present a problem even with short encounter.

Pilot action recommendation:

This is a potential hazardous condition. Activate the ice protection systems to control ice accretion while exiting the conditions.

Severe icing

Severe icing indicates that the rate of accumulation is so fast that ice protection systems fail to remove the accumulation of ice (1 cm in less than 5 minutes). The crew need to exit this condition immediately.

Severe icing is usually a product of clear or mixed icing encounter. Severe icing occurs most frequently in areas where the air has high content of liquid water or there are very large droplets.

Pilot action recommendation:

Immediate pilot action is required. Performance and handling may be seriously affected after only a few minutes exposure. Activate the ice protection system and work to **exit the conditions immediately.**

4. Some typical clouds

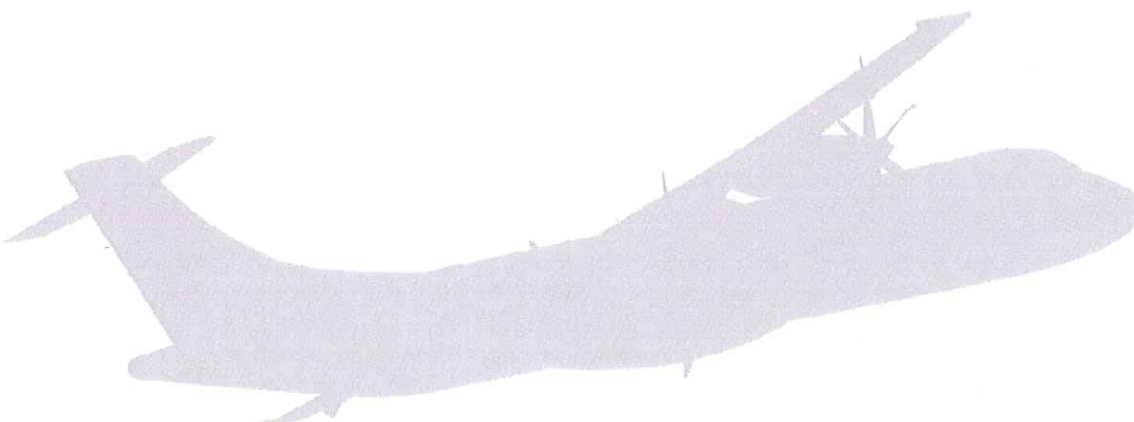
This situation is prone to icing. Low level stratus and other grey clouds may have a high water content.

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

This type of cumulus congestus may hide severe intermittent icing.

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

B. Weather documentation



Weather analysis is one of the most important aspects of flight preparation. It may become critical for particularly demanding conditions where potential icing conditions could be encountered. Typical weather forecast provided to pilots at flight preparation includes several documents which will be discussed in the following chapter.

1. Available means

TAF, METAR, SPECI and TREND collection

The crew should collect such information for all airports of interest including the ones along the planned route. These information might be essential in deciding whether the flight has to be re-planned via another route.

Sigmets and Airmets collection

This will alert the crew of areas of forecast or reported moderate and severe icing.

Significant weather charts collection

This is an invaluable mean for assisting the crew in forecasting possible areas of icing conditions or precipitation.

Snotams

These information will complete the picture and assist the crew in developing any alternate or contingency plan.

2. TAF/METAR/SPECI/TREND interpretation

TAFs are meteorological forecasting at airports.

METARs are routine meteorological observations at airports. Usually they are issued each 30 or 60 minutes.

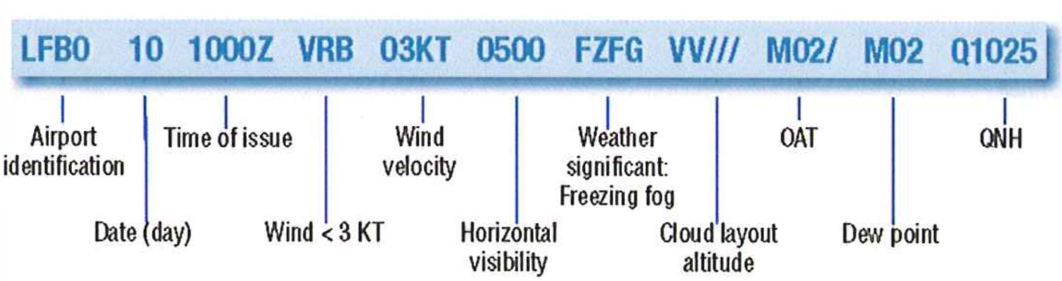
SPECIs are special meteorological observation reports. They are issued at a given airport if:

- Meteorological conditions are worse than the last METAR
- Meteorological conditions have improved and improvement has lasted for at least 10 minutes

TREND is a section included in a METAR or a SPECI providing information on the evolution of meteorological conditions. It is issued if a variation of wind, visibility, weather or cloud phenomenon is expected. The validity of a trend is 2 hours starting from the associated METAR or SPECI time.

Example of METAR message

This METAR is the typical example of ground icing conditions in winter:
low visibility with moisture, freezing fog and OAT below 5°C.



Example of TAF message

LFBO 150500Z 150615 360 03KT 0800 FZFG OVC002

- LFBO — Airport identification
- 150500Z — Date (day) / Time of issue
- 150615 — Validity (on the 15th between 06 and 15 TU)
- 360 — Wind direction
- 03KT — Wind velocity
- 0800 — Horizontal visibility (800 m)
- FZFG — Weather significant: Freezing fog
- OVC002 — Cloud layer altitude

3. AIRMET/SIGMET

AIRMET

In-flight weather advisories concerning phenomena of operational interest to all aircraft and potentially hazardous to aircraft having limited capabilities. AIRMETs are issued every six hours with amendments as needed and cover moderate icing, moderate turbulence, sustained surface winds of 30 knots or more, extensive mountain obscuration, and widespread areas of ceilings less than 1000 feet and/or visibility less than 3 miles.

SIGMET

In-flight weather advisory concerning phenomena of an intensity and extent that concerns the safety of all aircraft. SIGMETs cover severe and extreme turbulence, severe icing, volcanic ash and widespread dust or sandstorms that reduce visibility to less than 3 miles. CONVECTIVE SIGMETs advise of thunderstorms that are potentially hazardous to all aircraft. Information contained in SIGMETs depends on the cruise level:

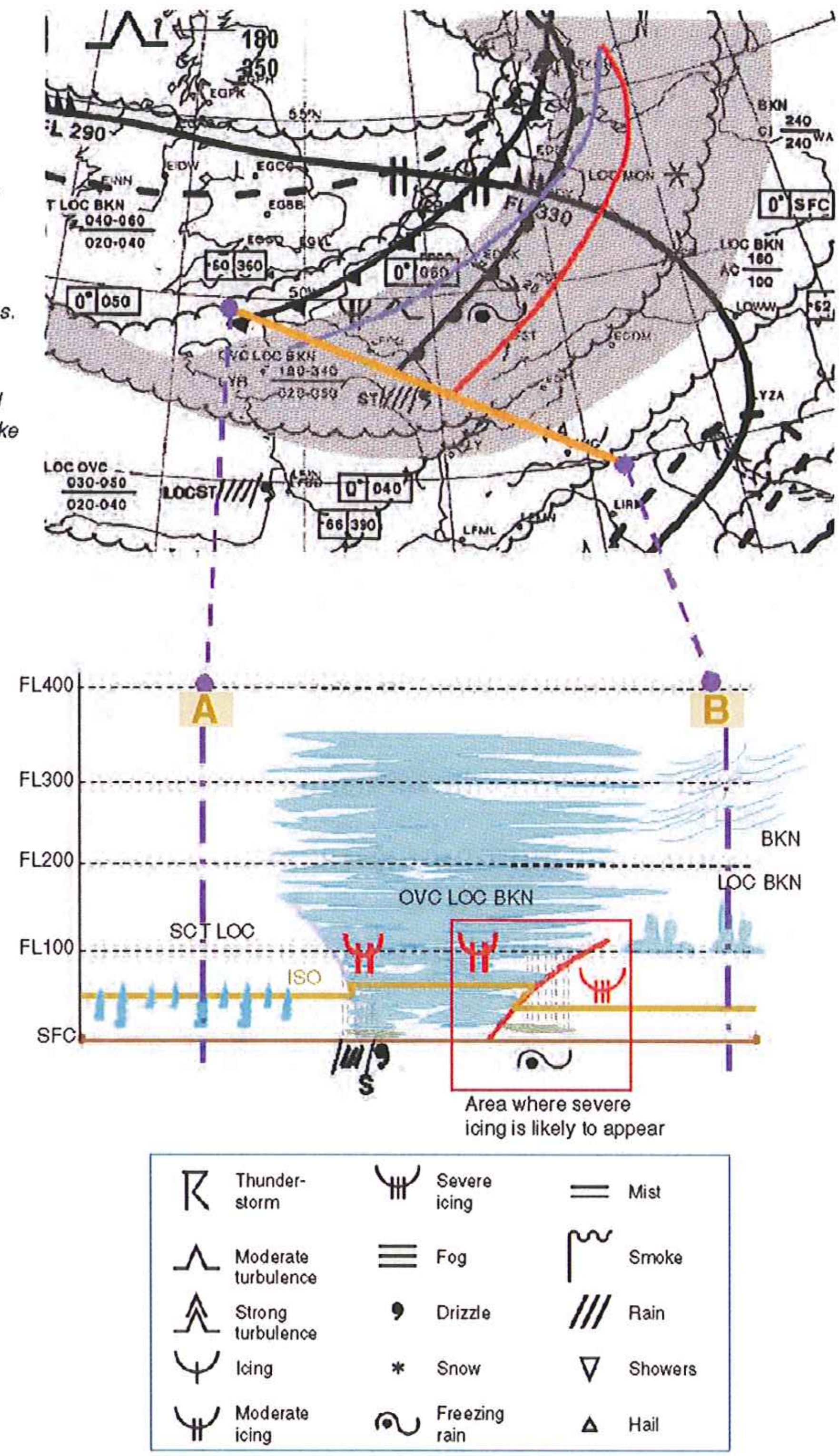
AIRMET/SIGMET	
At subsonic cruising levels	At transonic level and supersonic cruising levels
Thunderstorm (OBCS. EMBD, SQL, FRQ) - TS **Tropical cyclone** - TC (+cyclone name) **Thunderstorm with heavy hail** - TS HVYGR **Severe turbulence** - SEV TURB **Severe icing and severe icing due to freezing rain** -SEV ICE, SEV ICE (FZRA) **Severe mountain waves** - SEV MTW **Heavy sandstorm/duststorm** - HVY SS/DS **Volcanic ash** - VA (+volcano name)	**Moderate or severe turbulence** - MOD SEV TURB **Cumulonimbus clouds** - (ISOL, OCNL, FRQ) CB **Hail** - GR **Volcanic ash** - VA (+volcano name)

4. Weather charts

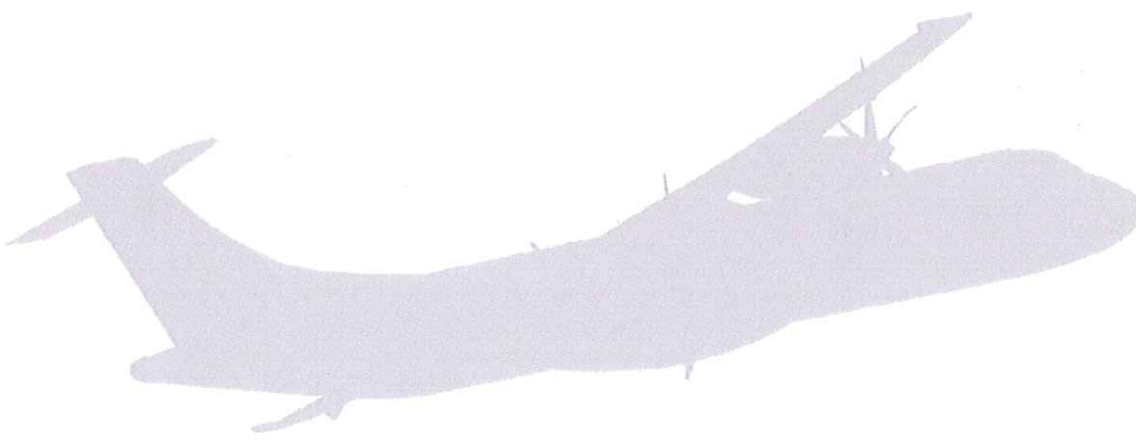
Analyzed synoptic charts show the surface weather over a specified area. Prognostic synoptic charts aim to show the expected synoptic situation some hours later, usually 12 or 24 hours ahead. Similarly, current and prognostic charts are available for various pressure levels. In the briefing room the crew should find charts covering low and medium flight over the UK and North West Europe, medium and high level flights to Europe and the Mediterranean, low, medium and high level flights to North America, high level flights to the Middle and Far East and high level flights to Africa.

Although these charts are less precise than TAF messages, they are very relevant in flight preparation. Because of the wide area covered in comparison to all other means, they allow the crew to anticipate a weather degradation and so to prepare a contingency flight plan. However information shown on such charts must be always cross-checked with last Metar and TAF available for more accuracy.

This weather chart shows typical icing conditions. The associated vertical representation gives a picture of what crew should expect during the flight. Doing such analysis is essential in the briefing room to anticipate a potential degradation of meteorological conditions. Actually having a good overview of the location of the 0 °C level and cloud layer allows the crew to take the appropriate decision to escape ice accretion area, particularly severe icing ones.



C. Aircraft de-/anti-icing



Safe aircraft operation in cold weather conditions raises specific problems: Aircraft downtime and delays in flight schedules. These can be minimized by a program of preventive cold weather servicing.

The operator must develop procedures for cold weather servicing which meet their specific requirements, based on:

- Their cold weather experience;
- The available equipment and material;
- The climatic conditions existing at their destinations.

Technical ATR documentation contains the appropriate information to assist the operator in defining, developing and implementing cold weather preventive maintenance procedures that will minimize aircraft downtime and improve the safe operating level of their aircraft in adverse climatic conditions.

1. Some questions to answer before de-icing

Who is responsible?

The person technically releasing the aircraft is responsible for the performance and verification of the results of the de-/anti-icing treatment. The responsibility of accepting the performed treatment lies, however, with the Captain. The transfer of responsibility takes place at the moment the aircraft starts moving under its own power.

When?

Icing conditions on ground can be expected when air temperatures approach or fall below freezing and when moisture or ice occurs in the form of either precipitation or condensation.
Aircraft-related circumstances could also result in ice accretion, when humid air at temperatures above freezing comes in contact with cold structure.

Clean aircraft concept

Any contamination of aircraft surfaces can lead to handling and control difficulties, performance losses and/or mechanical damage.

De-icing?

Are the conditions of frost, ice, snow or slush such that de-icing is required to provide clean surfaces at engine start?

Anti-icing?

Is the risk of precipitation such that anti-icing is required to ensure clean surfaces at lift off?

Checks?

Do you have enough information and adequate knowledge to dispatch the aircraft?

2. Basics

2.1. Definitions

De-icing

De-icing is a procedure by which snow, frost, ice and slush are removed from aircraft in order to provide clean surfaces. De-icing can be accomplished by use of fluids, by mechanical means or by heating the aircraft.

Anti-icing

Anti-icing is a precautionary procedure which provides protection against formation of frost or ice and accumulation of snow on treated surfaces of the aircraft, for a limited period of time (holdover time).

De-icing/anti-icing process

De-icing and anti-icing may be performed as a one-step or two-step process, depending on predetermined practices, prevailing weather conditions, concentration of FPD (freezing point depressant) used, and available de-icing equipment and facilities. Note that when a large holdover time is expected or needed, a two-step procedure is recommended, using undiluted fluid for the second step.

The one-step process

It is accomplished using a heated or in certain case an unheated FPD mixture. In this process, the residual FPD fluid film provides a very limited anti-icing protection. This protection can be enhanced by the use of cold fluids or by the use of techniques to cool heated fluid during the de-icing process.

The two-step process

This process involves both de-icing and anti-icing procedure. First step (de-icing) is accomplished with hot water or a hot mixture of FPD fluid and water. The ambient weather conditions and the type of accumulation to be removed from the aircraft must be considered when determining which de-icing fluid to use. The second step (anti-icing) involves application of type II or type IV fluid and water to the critical surfaces of the aircraft.

2.2. Equipment and material

De-icing or anti-icing procedures use the following products:

- Hot air
- Heated water
- Type I de-icing fluids (in accordance with ISO, SAE or AEA standards).
- Type II or type IV anti-icing fluid (in accordance with ISO, SAE or AEA standards).

Note: The staff performing this operation must observe the safety precautions in force (gloves, and safety goggles). If de-icing or anti-icing fluid is accidentally sprayed on skin, rinse thoroughly with water to avoid irritation.

2.3. Fluid selection

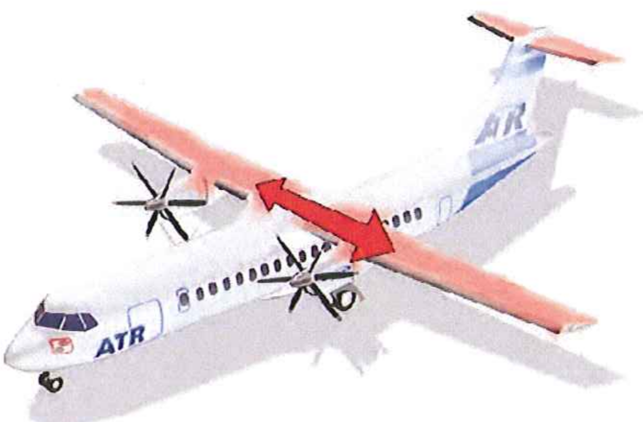
The selection of de-icing process depends on numerous parameters. Therefore, only the experience of the operator will direct the choice of the appropriate method according to the prevailing weather. The following table provides basic information to determine the appropriate procedure to be used:

OAT (Outside Air Temperature)	One-step procedure	Two-step procedure	
		First step: de-icing	**Second step: anti-icing**
Type I fluid (orange)			
–3 °C (27 °F) and above	Freezing point of heated fluid mixture shall be at least 10 °C (18 °F) below actual OAT.	Water heated to 60 °C (140 °F) minimum at the nozzle or a heated mixture of fluid and water	Freezing point of heated fluid mixture shall be at least 10 °C (18 °F) below actual OAT.
Below –3 °C (27 °F)		Freezing point of heated fluid mixture shall not be more than 3 °C (5 °F) above actual OAT	
Type II (translucent) or type IV (green) fluid			
–3 °C (27 °F) and above	50/50 heated fluid/water type II or type IV mixture	Water heated to 60 °C (140 °F) minimum at the nozzle or a heated mixture of type I, II or IV fluid and water	50/50 fluid/water type II or type IV mixture
Below –3 °C (27 °F) to –14 °C (7 °F)	75/25 heated fluid/water type II or type IV mixture	Heated 50/50 fluid/water type II or type IV mixture or suitable mixture of type I with freezing point not more than 3 °C (5 °F) above actual OAT	75/25 fluid/water type II or type IV mixture
Below –14 °C (7 °F) to –25 °C (–13 °F)	100/0 heated fluid/water type II or type IV mixture	Heated 75/25 fluid/water type II or type IV mixture or suitable mixture of type I with freezing point not more than 3 °C (5 °F) above actual OAT	100/0 fluid/water type II or type IV mixture
Below –25 °C (–13 °F)	Type II or IV fluid may be used below –25 °C (–13 °F) provided that the freezing point of the fluid is at least 7 °C (14 °F) below OAT and that aerodynamic acceptance criteria are met. Consider the use of type I when type II or IV fluid cannot be used.		

Note:

– The second step anti-icing has to be applied before the first step freezes, typically within 3 minutes.

– For heated fluid temperature not less than 60 °C (140 °F) at the nozzle is desired.



Warning

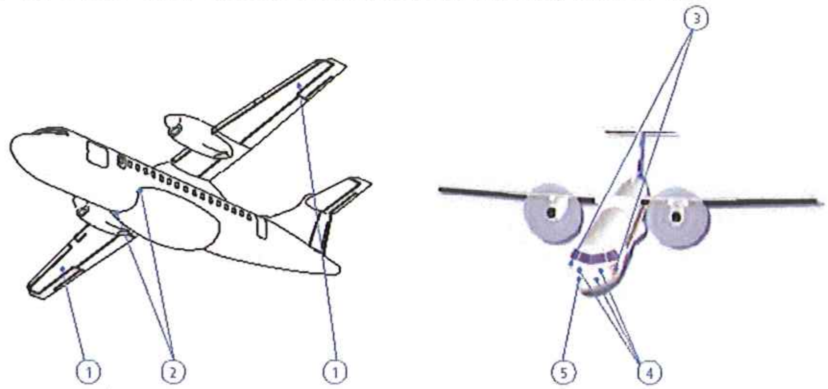
- Aircraft must be de-iced/anti-iced symmetrically, so that left-hand and right-hand side receive the same treatment, whatever the status of the aircraft prior to the de-icing/anti-icing procedure. Aerodynamics problems could result if this requirement is not met.
- Anti-icing procedure can only be performed on an aircraft previously cleared of all icing, ice or snow. If an additional treatment is required after previous anti-icing, it is prohibited to perform new anti-icing without having washed or de-iced the aircraft. If not, a dry film can appear and may not be blown away by wind during taxing/take-off.

3. De-icing and anti-icing procedures

3.1. Aircraft preparation

ATR aircraft can be de-iced and anti-iced both at the parking area and at the holding point, engine running in hotel mode, bleeds OFF. If a procedure is initiated at the parking area it is recommended to observe the following points:

- Check that all doors and emergency exits are closed.
- The aircraft shall be placed facing into the wind, engines not running.
- Apply parking brakes and install wheel chocks.
- Install blanking devices and protective equipment on the following components.



1 - Naca ports
2 - Air conditioning inlets of the main landing gear fairing
3 - Static ports
4 - Pitot probes
5 - Temperature sensors

Caution: Maintain the control column at full forward position during whole operation and engage gust lock.

3.2. Procedures

3.2.1. Snow removal

Before de-icing, ground staff has to sweep or blow off the snow layer.

Check that ground staff:

- Pays attention to antennas, probes and vortex generators and avoids walking on "no step" areas.
- Starts from the various hinge points to avoid snow accumulation.
- Removes snow from engine air intakes, propeller blades, landing gears and brakes.

3.2.2. De-icing/anti-icing

Set platform to suitable height so that the ground staff is above the surface to be treated. The spray must be applied at low angle (less than 45 degrees).

Warning

- Spraying thickened fluids onto the horizontal stabilizer must be successively performed from the underneath and the above of the surfaces. When spraying from the underneath, the elevator shall be maintained in full up position, and when spraying from the above in down position, to better clean the leading edge.
- On the various fairing and fillets, the de-icing or anti-icing fluid should not be sprayed at pressure higher than 1.5 psi (0.103 bar). On the other parts, the pressure of the sprayed fluid should not exceed the pressure recommended by the fluid manufacturer.

De-icing or anti-icing of the fuselage

Avoid as much as possible direct spraying on the windshields and windows.

Special precaution shall be taken to prevent fluid spraying onto the ADC probe and sensors (pitot probes, statics sensors, TAT probes). Any contaminants entering these probe/sensors may lead to erroneous flight parameters while in flight.

De-icing or anti-icing of airfoil and control surfaces

Start de-icing/anti-icing by filling the gap between fixed and movable surfaces in order to avoid accumulation of contaminant, then proceed from the leading edge backward. caution: special care must be paid to the gaps between:

- Wings/ailerons/tabs
- Horizontal stabilizer/elevators/ tabs
- Rudder/vertical stabilizer/tab

These gaps must be clear of any contamination and must be checked after any de-icing or anti-icing procedure.

De-icing of landing gear

Prevent fluid contact with shock absorbers.

Avoid de-icing or anti-icing fluid entering brake unit.

Pay particular attention to proximity switches.

De-icing of propellers

Propeller covers should be used when possible. In order to avoid any de-icing fluid ingress in the engine air intakes, no propeller blade should be in front of the air intake or the air intake cover should be installed. In case of air intake de-icing fluid ingestion, the area must be wiped up.

3.3. Hotel mode

Hotel mode is specific to ATR. It allows the aircraft to be de-iced while the right engine is running with the propeller stopped and bleed air valve off. Thus the ATR could be de-iced and anti-iced like jet aircraft at the holding point.

Air intake and wing snow removal, and propeller de-icing must be performed prior to hotel mode activation. "hotel mode" de-icing/anti-icing procedure can be conducted provided:

- De-icing/anti-icing gantry is not used,
- Manual procedures are applied (with a de-icing nozzle from a movable platform) to avoid any inadvertent entry of fluid into engines, naca ports, air conditioning inlets, static ports, pitot probes, temperature sensors, and engine 2 bleed air valve off.

NB: The ground procedures to apply are entirely described in JIC 12-31-12 "De-icing and/or anti-icing of the aircraft".

4. Fluid residues

Thickened de/anti-icing fluids (Type II or Type IV) can leave residue in aerodynamically quite areas. These residues accumulate over time, can rehydrate, and form into a gellike substance and freeze during flight. If located on critical surfaces or in areas of flight control components and linkages, handling characteristics may be affected and control surface movement may be restricted.

Aircraft exposed to de/anti-icing fluids shall be subjected to periodic inspections for fluids residues, and any residue found shall be removed.

Experience has shown that spraying water onto the concerned surface may help after few minutes in detecting those residues while transforming into gel.

The following conditions are prone to residue formation:

- Preventive application of type II or IV anti-icing fluids for overnight protection.
- Successive application of type II or IV anti-icing fluids in one-step de/anti-icing procedures.
- High temperature gradient on ground along a day (i.e. spring season)

It is recommended to prefer a two-step de-/anti-icing procedure where the first step using neat or diluted type I fluid will clean the aircraft from any contaminants including thickened fluid residues.

Detailed periodic inspections of the critical surfaces are also recommended all along the winter season to detect any residue formation. Inspection interval may be adapted according to the operator experience and the frequency of exposure to type II or IV anti-icing fluids.

5. Captain's decision

As the final decision rests with the Captain, his request will supersede the ground crew member's judgement to not de-ice.

As the Captain is responsible for the anti-icing condition of the aircraft during ground manoeuvering prior to takeoff, he can request another anti-icing application with a different mixture ratio to have the aircraft protected for a longer period against accumulation of precipitation. Equally, he can simply request a repeat application.

Therefore, the Captain should take into account forecasted or expected weather conditions, taxi conditions, taxi times, holdover time and other relevant factors. The Captain must, when in doubt about the aerodynamic cleanliness of the aircraft, perform an inspection or simply request a further de-/anti-icing.

Even when responsibilities are clearly defined and understood, sufficient communication between flight and ground crews is necessary. Any observation considered valuable should be mentioned to the other party to have redundancy in the process of decisionmaking.

6. Anti-icing codes

It is essential that the flight crew receives clear information from ground staff concerning the treatment applied to the aircraft.

The AEA (Association of European Airlines) recommendations and the SAE and ISO specifications promote the standardized use of a four-element code. This gives flight crew the minimum details to assess holdover times. The use of local time is preferred but, in any case, statement of the reference is essential. These information must be recorded and communicated to the flight crew by referring to the last step of the procedure.

Examples of anti-icing codes

AEA Type II/75/16.43 local TLS / 19 Dec 99

AEA Type II	:	Type of fluid used
75	:	Percentage of fluid/water mixtures by volume, i.e. 75% fluid/25% water
16.43	:	Local time of start of last application
19 Dec 99	:	Date

ISO Type I/50:50/06.30 UTC/ 19 Dec 99

ISO Type I	:	Type of fluid used
50:50	:	Percentage of fluid/water mixtures by volume, i.e. 50% fluid / 50% water
06.30	:	Time (UTC) of start of last application
19 Dec 99	:	Date

7. Holdover time

Holdover protection is achieved by anti-icing fluids remaining on and **protecting aircraft surfaces for a period of time.** With a one-step de/anti-icing operation, holdover begins at the start of the operation. With a two-step operation, holdover begins at the start of the second (anti-icing) step. Holdover time will have effectively run out, when frozen deposits start to form/ accumulate on aircraft surfaces.

Due to its properties type I fluid forms a thin liquid-wetting film, which gives a rather limited holdover time, depending on weather conditions. With this type of fluid, increasing the concentration of fluid in the fluid/water mix would provide no additional holdover time.
Type II and type IV fluids contain a thickener which enables the fluid to form a thicker liquid-wetting film on external surfaces. This film provides a longer holdover time, especially in conditions of freezing precipitation. With this type of fluid, additional holdover time will be provided by increasing the concentration of fluid in the fluid/water mix, with maximum holdover time available from undiluted fluid.

Tables given below provide an indication of the protection timeframe that could reasonably be expected under precipitation conditions.
However, due to the many variables that can influence holdover times, these times **should not be considered as minimum or maximum, since the actual time of protection may be extended or reduced,** depending upon the particular conditions existing at the time.
The lower limit of the published time span is used to indicate the estimated time of protection during heavy precipitation and the upper limit, the estimated time of protection during light precipitation.

Caution: The protection times represented in these tables are for general information purposes only. They are taken from the ISO/SAE specifications, effective October 1st, 1999. However, local authority requirements may differ. The protection time will be shortened in severe weather conditions. Heavy precipitation rates or high moisture content, high wind velocity and jet blast may cause a degradation of the protective film. If these conditions occur, the protection time may be shortened considerably. This is also the case when the aircraft skin temperature is significantly lower than the outside air temperature.
The indicated times should, therefore, only be used in conjunction with a pretakeoff check.
All de/anti-icing fluids following the specifications mentioned below are approved for all ATR aircraft:

- Type I: SAE AMS 1424 standard last effective issue
- Type II: SAE AMS 1428 standard last effective issue
- Type IV: SAE AMS 1428 standard last effective issue

7.1. Estimated holdover times for Type I fluid mixtures

The table below is an example of the holdover times anticipated for SAE Type I fluid mixtures, as a function of weather conditions and OAT.

Caution: This table is for use in departure planning only, and it should be used in conjunction with pre-takeoff check procedures.

Example for training only

OAT		Approximate holdover times under various weather conditions (hours: minutes)						
°C	°F	Frost(1)	Freezing fog	Light snow	Moderate snow	Freezing drizzle(2)	Light freezing rain	Rain on cold soaked wing
-3 and above	27 and above	0:45	0:11-0:17	0:11-0:16	0:06-0:11	0:09-0:13	0:02-0:05	0:02-0:05
Below -3 to -6	Below 27 to 21	0:45	0:08-0:14	0:08-0:13	0:05-0:08	0:07-0:10	0:02-0:05	CAUTION: Clear ice may require touch for confirmation
-7 to -10	20 to 14	0:45	0:06-0:10	0:06-0:10	0:04-0:06	0:05-0:08	0:02-0:05	
Below -10	Below 14	0:45	0:05-0:09	0:04-0:06	0:02-0:04			

°C: Degrees Celsius - °F: Degrees Fahrenheit - OAT: Outside Air Temperature
(1) During conditions that apply to aircraft protection for ACTIVE FROST
(2) Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

SAE Type I fluid/water mixture is selected so that the freezing point of the mixture is at least 10 °C (18 °F) below OAT.

Caution: The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity or jet blast will reduce holdover time below the lowest time stated in the range. Holdover time may be reduced when aircraft skin temperature is lower than OAT.

Caution: SAE Type I fluid used during ground de-icing/anti-icing is not intended for and does not provide protection during flight.

Guidelines for the application of SAE Type I fluid mixtures.

The table below is an example of the minimum concentrations of the SAE Type I fluid mixtures as a function of the Outside Air Temperature (OAT).

Example for training only

	One-step Procedure De-icing/anti-icing	Two-step procedure	
		First step: de-icing	Second step anti-icing (1)
−3 °C (27 °F) and above	Freezing point of heated fluid (2) mixture shall be at least 10 °C (18 °F) below OAT	Water heated to 60 °C (140 °F) minimum at the nozzle or a heated mix of fluid and water	Freezing point of fluid mixture shall be at least 10 °C (18 °F) below actual OAT
Below −3 °C (27 °F)		Freezing point of heated fluid mixture shall not be more than 3 °C (5 °F) above OAT	

(1) To be applied before first step fluid freezes, typically within 3 minutes.

(2) Clean aircraft may be anti-iced with unheated fluid.

Note: For heated fluids, a fluid temperature not less than 60 °C (140 °F) at the nozzle is desirable. Upper temperature limit shall not exceed 90 °C or fluid manufacturers recommendations.

Caution: Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix (more Glycol) can be used under the latter conditions.

7.2. Estimated holdover times for Type II fluid mixtures

The table below is an example of the holdover times anticipated for SAE Type II fluid mixtures, as a function of weather conditions and OAT.

Caution: This table is for use in departure planning only, and it should be used in conjunction with pre-takeoff check procedures.

Example for training only

OAT		SAE Type II fluid concentration	Approximate holdover times under various weather conditions (hours: minutes)						
°C	**°F**	**Neat-fluid / water (Vol. % / Vol. %)**	**Frost (1)**	**Freezing fog**	**Snow**	**Freezing drizzle (3)**	**Light freezing rain**	**Rain on cold soaked wing**	**Others (4)**
Above 0	**Above 32**	100/0	12:00	0:30-1:30	0:25-0:55	0:30-0:55	0:15-0:30	0:05-0:40	**Caution:** No holdover time guidelines exist
		75/25	6:00	0:25-1:00	0:15-0:40	0:20-0:45	0:10-0:25	0:05-0:25	
		50/50	4:00	0:15-0:35	0:05-0:15	0:05-0:15	0:05-0:10	**Caution:** Clear ice may require touch for confirmation	
0 to −3	**32 to 27**	100/0	8:00	0:35-1:30	0:20-0:45	0:30-0:55	0:15-0:30		
		75/25	5:00	0:25-1:00	0:15-0:30	0:20-0:45	0:10-0:25		
		50/50	3:00	0:15-0:30	0:05-0:15	0:05-0:15	0:05-0:10		
Below −3 to −14	**Below 27 to 7**	100/0	8:00	0:20-1:05	0:15-0:35	0:15-0:45 (2)	0:10-0:30 (2)		
		75/25	5:00	0:20-0:55	0:15-0:25	0:15-0:30 (2)	0:10-0:20 (2)		
Below −14 to −25	**Below 7 to −13**	100/0	8:00	0:15-0:20	0:15-0:30				
Below −25	**Below −13**	100/0	SAE Type II fluid may be used below −25 °C (−13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type II fluid cannot be used.						

°C: Degrees Celsius - °F: Degrees Fahrenheit - OAT: Outside Air Temperature - Vol: Volume

(1) During conditions that apply to aircraft protection for ACTIVE FROST

(2) No holdover time guidelines exist for this condition below −10 °C (14 °F)

(3) Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

(4) Snow pellets, snow grains, ice pellets, moderate and heavy freezing rain, hail

Caution: The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may be reduced when aircraft skin temperature is lower than OAT.

Caution: SAE Type II fluid used during ground de-icing/anti-icing is not intended for and does not provide protection during flight.

7.3. Estimated holdover times for Type IV fluid mixtures

The table below is an example of the holdover times anticipated for SAE Type IV fluid mixtures, as a function of weather conditions and OAT.

Caution: This table is for use in departure planning only, and it should be used in conjunction with pre-takeoff check procedures.

Example for training only

OAT		SAE Type IV fluid concentration	Approximate holdover times under various weather conditions (hours: minutes)						
°C	°F	Neat-fluid / water (Vol. % / Vol. %)	Frost [1]	Freezing fog	Snow	Freezing drizzle [3]	Light freezing rain	Rain on cold soaked wing	
Above 0	Above 32	100/0	18:00	1:05-2:15	0:35-1:05	0:40-1:10	0:25-0:40	0:10-0:50	Others [4] CAUTION: No holdover time guidelines exist
		75/25	6:00	1:05-1:45	0:30-1:15	0:35-0:50	0:15-0:30	0:05-0:35	
		50/50	4:00	0:15-0:35	0:05-0:20	0:10-0:20	0:05-0:10	CAUTION: Clear ice may require touch for confirmation	
0 to -3	32 to 27	100/0	12:00	1:05-2:15	0:30-0:55	0:40-1:10	0:25-0:40		
		75/25	5:00	1:05-1:45	0:25-0:55	0:35-0:50	0:15-0:30		
		50/50	3:00	0:15-0:35	0:05-0:15	0:10-0:20	0:05-0:10		
Below -3 to -14	Below 27 to 7	100/0	12:00	0:20-1:20	0:20-0:40	0:20-0:45 [2]	0:10-0:25 [2]		
		75/25	5:00	0:25-0:50	0:15-0:25	0:15-0:30 [2]	0:10-0:20 [2]		
Below -14 to -25	Below 7 to -13	100/0	12:00	0:15-0:40	0:15-0:30				
Below -25	Below -13	100/0	SAE Type IV fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

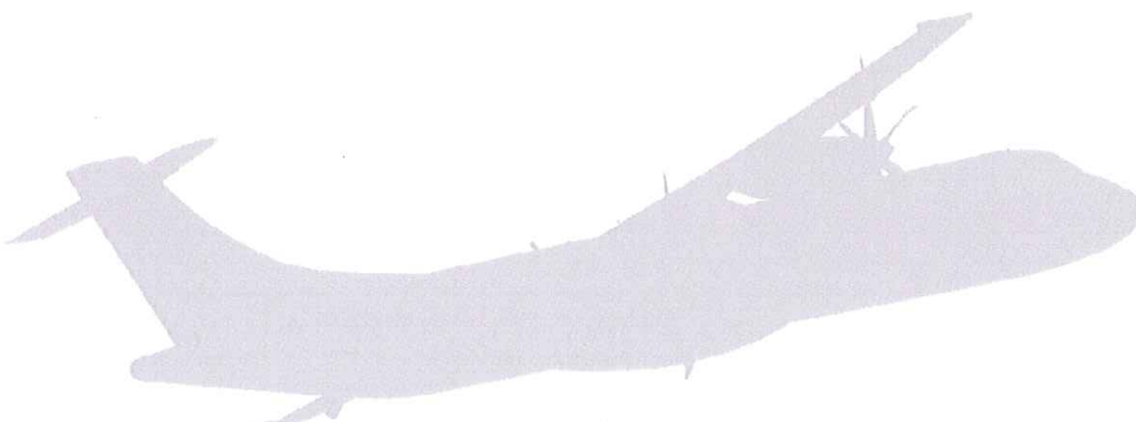
°C: Degrees Celsius - °F: Degrees Fahrenheit - OAT: Outside Air Temperature - Vol: Volume

(1) During conditions that apply to aircraft protection for ACTIVE FROST
(2) No holdover time guidelines exist for this condition below −10 °C (14 °F)
(3) Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
(4) Snow pellets, snow grains, ice pellets, moderate and heavy freezing rain, hail

Caution: The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may be reduced when aircraft skin temperature is lower than OAT.

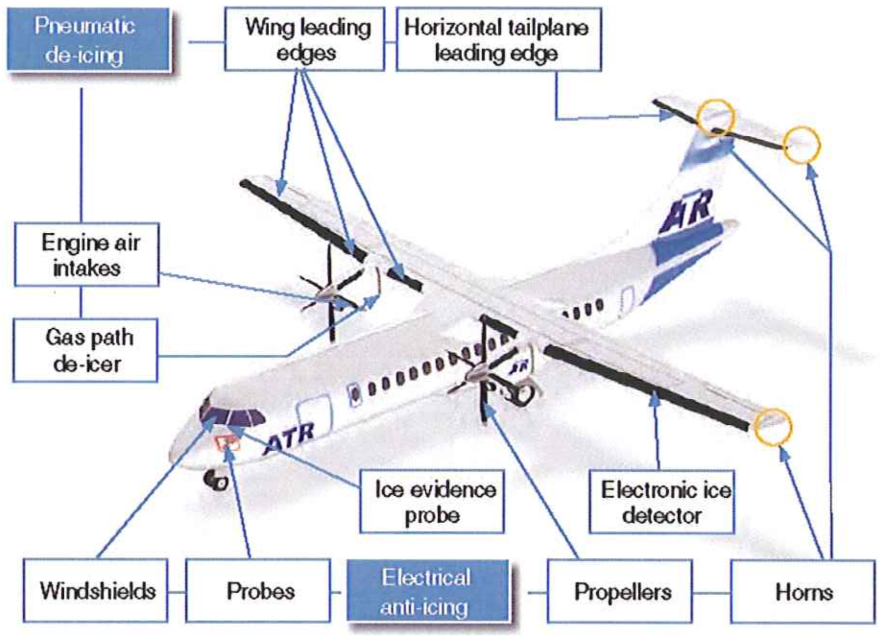
Caution: SAE Type IV fluid used during ground de-icing/anti-icing is not intended for and does not provide protection during flight.

D. Aircraft ice protection systems



1. Systems description

On a turboprop aircraft the ancillary power available (bleed air and electrical power) is less than on a jet. Consequently a permanent thermal protection is impracticable, in particular for the airframe. A solution consists in installing a pneumatic de-icing system on the exposed critical parts (i.e airframe) complemented by an electrical anti-icing protection for the parts on which a pneumatic de-icing device is not applicable, i.e rotating components (such as propellers), windshields, probes. This philosophy is applied on all new generation turboprop airplanes. On ATR aircraft, ice protection is generally provided by the system, as illustrated on the figure below.
Note: To review the specific system installed on your aircraft, refer to your FCOM.



Example of ATR 72-500 basic ice protection system

1.1. Electrical System

The electrical heating power is supplied by AC wild frequency power.

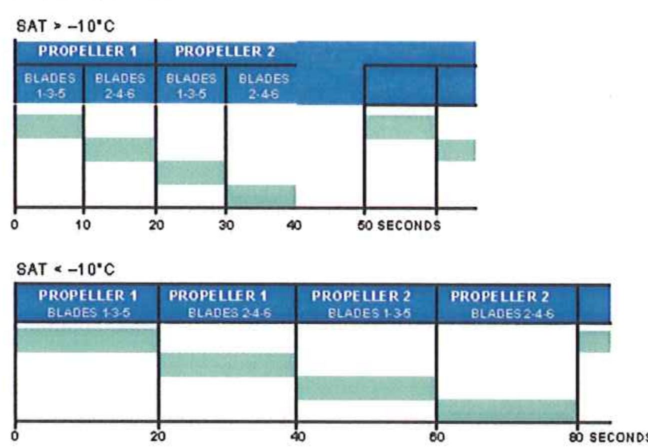
Permanent level

- Probes and windshield (always selected ON),

Anti-icing

- Side windows (heating for defogging only, not for ice protection),
- Flight control horns (ailerons, elevators, rudder),
- Inner leading edge of propeller blades (outer part is de-iced by centrifugal force only).

Propeller ice protection system combines electrical heating of blades leading edge and centrifugal force. Heating cycle duration have been optimized according to OAT to decrease the adhesion strength of the accreted ice. Ice is then shed by the centrifugal effect.



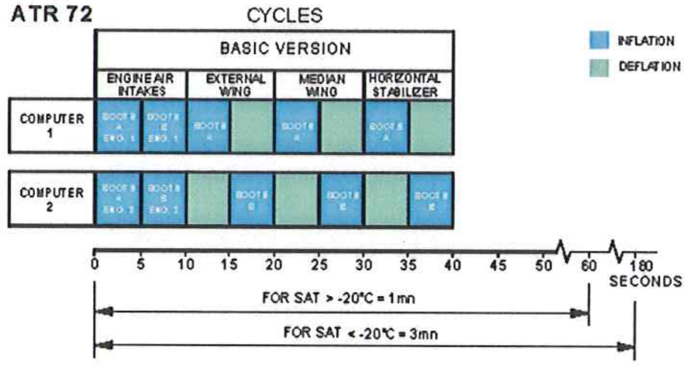
Electrical ice protection sequence – Example of sequencing applicable to ATR 72-500.

1.2. Pneumatic System

Pneumatic System (de-icing) supplying the de-icing for the critical areas of the airframe:

- Wing and horizontal tailplane leading edges,
- Engine air intakes and engine gas paths[1].

The pneumatic boot de-icers are constituted by dual chambers (chordwise chambers on the airframe) which alternatively inflate. The de-icing cycle duration has been determined by tests to provide optimized de-icing performance according to the outside air temperature. Two cycles are available: 1 mn for cool temperature and 3 mn for cold temperature. On ATR-500 aircraft the cycles are automatically set.



Pneumatic de-icing system – Example of sequencing applicable to ATR 72-500.

1.3. Aircraft Performance Monitoring

Some Aviation Investigation Authorities have recommended to all aircraft manufacturers developing an onboard detector to warn the crew when the aircraft is in severe icing conditions. Recent recommendations also ask for the installation of low speed warning devices.

In response to the Authority recommendations, ATR has developed the Aircraft Performance Monitoring (APM) to contribute to the safety of flights and to deal with severe icing conditions. This function is included into the MPC (Multi Purpose Computer) and does not need additional sensors or any calculation of atmospheric ice content. The APM calculates, during the flight, the airplane actual performance and compares them with the expected ones. It also computes the actual minimum icing and severe icing speeds for the given flight condition.

2. Systems operation

2.1. Ice accretion monitoring

Ice accretion may be detected primarily by observing the Ice Evidence Probe (IEP). At night, the IEP is automatically illuminated when NAV lights are turned ON. Ice accretion may also be detected on windshield, airframe (leading edges), wipers, side windows and propeller spinners (visible from cockpit on ATR 42).

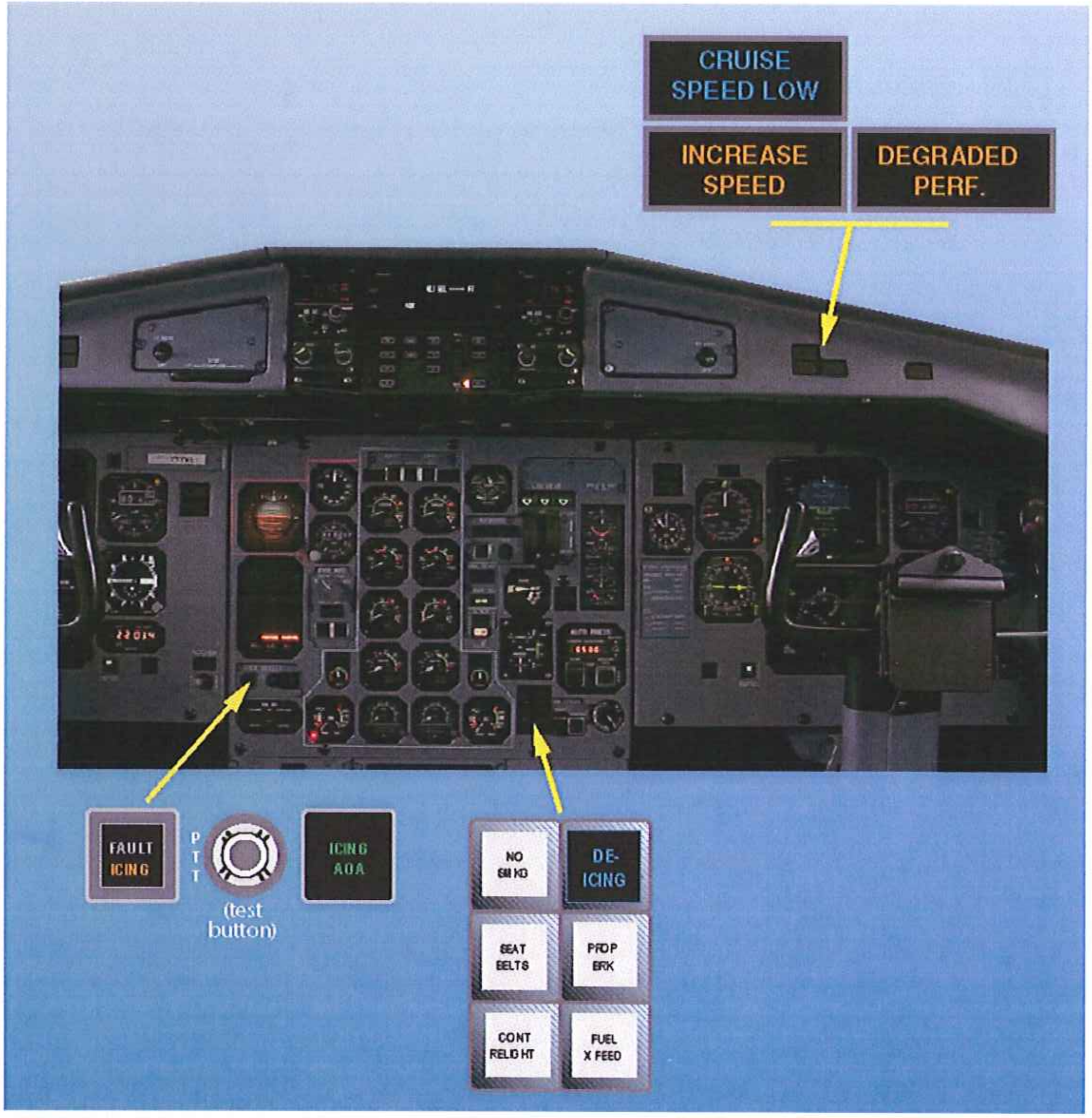
The IEP allows monitoring ice accretion and is designed to retain ice on its surface until the whole aircraft is free of ice. On the ATR 42 without IEP, this role is ensured by the propeller spinner. In addition to the primary means of recognising ice accretion mentioned above, an anti icing advisory system (AAS) is installed on ATR aircraft.

It includes:

- An electronic ice detector
- Three lights in the cockpit on the central panel between the two pilots: ICING (amber), ICING AOA (green), DE ICING (blue).

This system is not a primary system but has been designed to alert the crew to implement the correct procedures when flying in icing conditions (see Procedures). The electronic ice detector is located under the left wing and alerts the crew as soon as and as long as ice accretion develops on the probe. Aural and visual alerts are generated (Amber ICING light on the central panel and single chime).

1: Certain local regulations require that the engine de-icing system be activated whenever the anti-icing system is engaged.



ATR 72-500 cockpit view

ICING (amber - ice detector light)

ICING flashes amber when ice accretion is detected and horns anti-icing and/or airframe de-icing are not selected *ON* (associated with a single chime if horns anti-icing and airframe de-icing are not selected ON). The crew has forgotten to select both ice protection systems. Icing light is flashing until the airframe push-button is selected *ON*. ICING illuminates steady amber when ice accretion is detected provided both horns anti-icing and airframe de-icing are selected *ON*.

Note: To verify that the electronic ice detection is functionning properly, press the ice detector test push button.

ICING AOA (green - push button)

Illuminates green as soon as one of the horn anti-icing push buttons is selected *ON*, reminding the crew that the stall warning AOA threshold is lower in icing conditions. The lower stall warning AOA threshold defined for icing is active.

The ICING AOA green light can only be extinguished manually by depressing it, provided both horns anti-icing buttons are selected *OFF*. This should be done after the pilots have confirmed that aircraft is clear of ice. In this case the stall warning AOA threshold recovers the values defined for flight in normal conditions.

DE-ICING (blue)

Illuminates blue when the airframe deicing system is selected *ON*.
Flashes blue when the airframe de-icing system is still selected *ON* five minutes after the last ice accretion detection.

2.2. Enhanced Ice accretion monitoring with the APM

Icing drastically decreases the aircraft performance: an abnormal increase in drag can be due to ice accretion on the aerodynamical surfaces of the aircraft. Monitoring the aircraft performance is thus an efficient means of ice detection, in addition to the common means detailed above.

The APM enables to compare the aircraft theoretical drag with the in-flight drag computed with the measured parameters, and therefore to detect if an abnormal loss of aircraft performance occurs. The APM is activated in icing conditions, i.e. when ICING AOA is illuminated, or if the airframe de-icing is activated, or if ice accretion has been detected, and aims at alerting the crew of a risk of severe icing conditions, through three different levels of signal:

- Cruise speed low
- Degraded Performance
- Increase speed

CRUISE SPEED LOW (blue)

The speed in cruise is monitored and if an abnormal increase in drag induces an abnormal speed decrease of more than 10kts compared to the expected one, this message lights on.

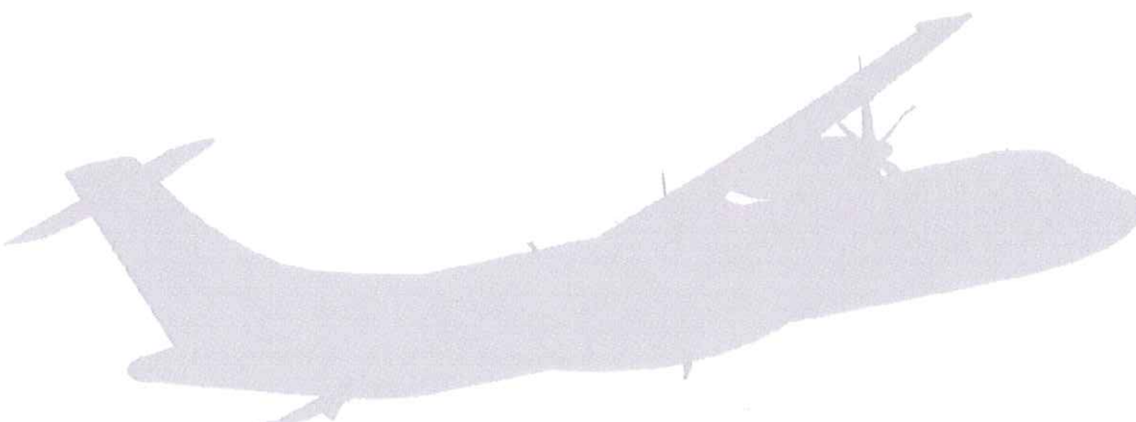
DEGRADED PERF. (amber)

In cruise or in climb, if an abnormal drag increase induces a speed decrease or a loss of rate of climb, this alert is triggered in association with a single chime and a master CAUTION on the attention getter. In cruise, this occurs right after the CRUISE LOW SPEED.

INCREASE SPEED (amber)

In cruise, climb or descent, if the drag is abnormally high and that IAS is lower than the MSIS (Minimum Severe Icing Speed equivalent to red bug + 10 kts), this message flashes in association with a single chime and a master CAUTION on the attention getter. This occurs right after the DEGRADED PERF.

E. Performance



1. Impact of contamination by ice or snow

As the aircraft's external shapes are carefully optimized from an aerodynamic point of view, it is no wonder that any deviation from the original lines due to ice accretion leads to an overall degradation of performance and handling, whatever the type. The real surprise comes from the amount of degradation actually involved and the lack of a "logical" relationship with the type of accretion.

Comprehensive wind tunnel tests have been carried out by various institutes and manufacturers over the past several decades, providing a wealth of results that have been largely confirmed by flight tests on different types of jets and turboprops.

The main effects of ice accretion can be summarised as follows.

NB: These conditions are certification cases, and not severe ice cases. Severe icing may thus lead to more detrimental effects.

1.1. Lift

The lift curves are substantially modified compared to clean aircraft;

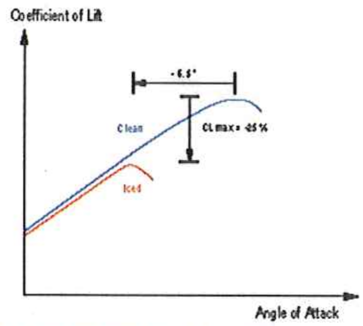
- Reduction of lift at a given angle of attack,
- Reduction of maximum lift,
- Reduction of maximum lift angle of attack.

When the maximum lift capability of the wing decreases by 25%, the actual stall speed is 12% higher than the basic stall speed (clean aircraft).

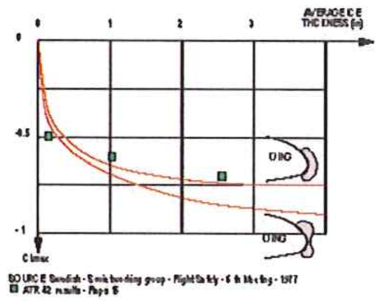
Consequently an iced aircraft flying at a given speed (and thus at a given CL) will have a reduced stall margin either looking at angle of attack (6.5° less margin) or looking at stall speed (12% less margin).

More surprising is the fact evidenced by fig. 4: the bulk of maximum lift degradation is already present with accretions as small as a few millimeters.

A CLmax decrease of 0.5 typically means a stall speed increase of 10kt for an ATR 42 with flaps 15. The ATR 42 wind tunnel test results with single or double horn shapes are consistent with the curves derived from extensive tests carried out on conventional airfoils by the Swedish - Soviet working group on flight safety.



Effect of certified ice shapes on lift curve – Flaps 30, gear down standard de-icers

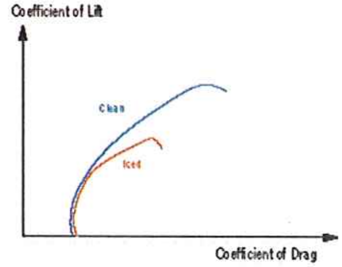


Effect of ice shape on CLmax – Wind tunnel tests – Flaps 15

1.2. Drag

The drag polar is also heavily affected (fig. 5)

- Greater drag at a given angle of attack,
- Greater drag at a given lift,
- Best lift/drag ratio at a lower lift coefficient.



ATR 72 – Effect of certified ice shapes on drag polar – Flaps 0 – Standard de-icers

1.3. Performance

The drag and lift penalties described in the chapter "Weather Revision" give a good idea of the performance impacts that could be expected from ice accretion. Beyond the main phenomenon, other effects should not be underestimated: for example, ice accretion on propeller blades will reduce the efficiency and the available thrust of propeller driven aircraft, ice accretion in the engine air intakes may cause engine flame out. Evidence has shown that unusual accretion patterns located further aft the leading edge, can have an even more adverse effect on performance. On the other hand, ice weight effect will remain marginal when compared to other penalties.

1.4. Handling

In order to ensure a satisfactory behaviour, aircraft are carefully designed so that stall will occur initially at the inner portion of the wing and spread toward the tip as angle of attack increases. Roll moments and abruptness of lift drop are then minimised.

This stall behaviour can be completely jeopardized by ice accretions that have no particular reason to be symmetrical or regular along the entire span of the wing.

Other potentially hazardous effects are also linked to tail surface icing: reduced maximum lift and stall angle of attack may result in tail surface stall under conditions where, if clean, it would properly do its job.

These conditions are those of high negative angle of attack and downloads on the tail surfaces, encountered for extreme manoeuvers at high flap settings.

Separated airflow on the tail surface can also seriously affect elevator behaviour when manually actuated, as aerodynamic compensation of control surfaces is a fine tuned and delicate technique.

Similar anomalies can affect other unpowered controls (such as ailerons) when ice accretion exists.

ATR in particular has documented the effects on aileron behaviour of unusual ice shapes associated to freezing drizzle.

2. Documentation provided by ATR

ATR provides data to compute flight plans in icing conditions. This data can be found under the label "Icing Conditions" for the following sections:

- Climb: FCOM section 3.04
- Cruise: FCOM section 3.05
- Holding: FCOM section 3.06
- Descent: FCOM section 3.07
- One engine inoperative 3.09

All performance data given for icing conditions derive from flight tests measurements performed with ice shapes representative of the worst icing cases considered by certification and applicable losses of propeller efficiency.

Because of the variability of real icing, climb performance published for icing conditions must be regarded with the utmost care. Always compare actual performances to predicted ones.

Note that FOS, the ATR flight operations software, is able to compute a complete flight in icing conditions.

```
LFBO/LFBD    19/09/2003     PREPARED BY : ......
FLT NBR ......              CPT .........        F/O .........      INST .........
UNITS: KG/NM/FT/KT          CAB ATTN .........   CAB ATTN .........
--------------------------------------------------------------------------------
LFBO TOC WPT1 WPT2 WPT3 TOD LFBD
--------------------------------------------------------------------------------
AIRCRAFT               FL      SPEED       PAX:...  BAGGAGE   CARGO    =  PAYLOAD
42-300 42-300          50   CLIMB/DESC.    .......  .......   .......  =  .......
              MAX CRUISE   160KT/220KT
FUEL FACTOR = 1.00   AIR COND. = NORMAL     ISA        ATMOSPHERIC COND. = ICING
--------------------------------------------------------------------------------
                    E.FUEL   A.FUEL   E.TIME     NM     FL       WIND
  DESTI    LFBD      262     ......   00:24      79     50     0 KT TAIL
+ ALTERNAT             0     ......   00:00
+ RESERVE    5% F    200     ......   00:17
+ FINAL RESERVE      316     ......   00:45
+ ADDITIONAL FUEL    500     ......   00:43
                    -----------------------
= MIN T/O FUEL      1278     ......    2:09
+ HOTEL                0     ......   00:00
+ TAXI                14     ......   00:03
+ EXTRA FUEL        ......   ......   ..:..
                    -----------------------
= MIN BLOCK FUEL    1292     ......   ..:..     CAPT.SIGN . . . . . . . .
--------------------------------------------------------------------------------
                  E.WT    A.WT    WT LIMIT:    | FUEL MANAGEMENT
  OEW            10000   ......                |                  E.FUEL  A.FUEL
+ PAYLOAD         5384   ......                |  ALTERN              0  ......
= ZFW            15384   ......  MZFW = 15540  |+ FINAL RESERV       316  ......
+ MIN T/O FUEL    1278   ......                |= MIN ALTERNAT      316  ......
= TOW            16662   ......  RTOW = .....  |  FOB AT DESTI  ......  ......
- TRIP FUEL        262   ......                |- MIN ALTERNAT      316  ......
= LW             16400   ......  RLW  = .....  |= DEST HOLDING  ......  ......
                                               |  E.TIME                ..:..
--------------------------------------------------------------------------------
      SCHED. BLOCK    FLIGHT    DELAY  CONTRACTOR  . . . .    BLOCK FUEL . . . .
DEP   ..:..  ..:..    ..:..     ..:..  LITERS      . . . .    RFOB       . . . .
ARR   ..:..  ..:..    ..:..     CODE   FUEL Q      . . . .    FUEL BURNT . . . .
TIME  ..:..  ..:..    ..:..     ....   REMAINING Q . . . .
--------------------------------------------------------------------------------
```

Example of a FOS flight planning log computed in icing conditions

3. Performance on contaminated runways

Operations on fluid contaminated runways raise numerous questions from operators. Airlines which often operate under cold or inclement conditions are generally concerned in obtaining a better understanding of the numerous factors influencing aircraft braking performance: on one hand, how to minimize the payload loss, and on the other, how to maintain a high level of safety.

It is evident that the braking performance is strongly affected by a slippery runway, however, one should also consider the loss in acceleration performance and in aircraft lateral controllability.

Once the performance impact of a contaminated runway is explained, it is quite necessary to review the operational information provided to the pilots. This information mainly contains some penalties (e.g. weight penalty or maximum crosswind reduction) but as well some indications on the runway condition provided as a "friction coefficient".

All this information should be readily understood so as to jeopardize neither airline safety nor airline economics.

3.1. What is a contaminated runway?

A runway is considered contaminated when more than 25% of the surface is covered with a contaminant. Contaminants are water, slush, snow and ice.

Definitions (extract from FCOM 3.03.01)	
Damp	A runway is damp when the surface is not dry, but when the water on it does not give it a shiny appearance.
Wet	A runway is considered as wet when the surface has a shiny appearance due to a thin layer of water. When this layer does not exceed 3 mm depth, there is no substantial risk of hydroplaning.
Standing water	Is caused by heavy rainfall and/or insufficient runway drainage with a depth of more than 3 mm.
Slush	Is water saturated with snow, which spatters when stepping firmly on it. It is encountered at temperature around 5°C and its density is approximately 0.85 kg/liter (7.1 lb/US GAL).
Wet snow	Is a condition where, if compacted by hand, snow will stick together and tend to form a snowball. Its density is approximately 0.4 kg/liter (3.35 lb/US GAL).
Dry snow	Is a condition where snow can be blown if loose, or if compacted by hand, will fall apart again upon release. Its density is approximately 0.2 kg/liter (1.7 lb/US GAL).
Compacted snow	Is a condition where snow has been compressed (a typical friction coefficient is 0.2).
Icy	Is a condition where the friction coefficient is 0.05 or below.

3.2. Braking means

There are two ways of decelerating an aircraft:

- **The primary way is with the wheel brakes.** Wheel brakes stopping performance depends on the load applied on the wheels and on the slip ratio. The efficiency of the brakes can be improved by increasing the load on the wheels and by maintaining the slip ratio at its optimum (anti-skid system).
- **Secondly, reverse thrust** decelerates the aircraft by creating a force opposite to the aircraft motion regardless of the runway condition. The use of reverse thrust is indispensable on contaminated runways.

3.3. Braking performance

- The presence of contaminants on the runway affects the performance by:
  1. A reduction of the friction forces (μ) between the tire and the runway surface,
  2. An additional drag due to contaminant spray impingement and contaminant displacement drag,
  3. Aquaplaning (hydroplaning) phenomenon.
- There is a clear distinction between the effect of fluid contaminants and hard contaminants:
  - Hard contaminants (compacted snow and ice) reduce the friction forces.
  - Fluid contaminants (water, slush, and loose snow) reduce the friction forces, create an additional drag and may lead to aquaplaning.

- To develop a model of the reduced μ according to the type of contaminant is a difficult issue. Until recently, regulations stated that μwet and μcont can be derived from the μ observed on a dry runway (μdry/2 for wet runway, μdry/4 for water and slush).
- Nevertheless, recent studies and test shave improved the model of μ for wet and contaminated runways, which are no longer derived from μdry. The certification of the most recent aircraft already incorporates these improvements.

3.4. Correlation between reported μ and braking performance

- Airports release a friction coefficient derived from a measuring vehicle. This friction coefficient is termed as "reported μ".

  The actual friction coefficient, termed as "effective μ" is the result of the interaction tire/runway and depends on the tire pressure, tire wear, aircraft speed, aircraft weight and anti-skid system efficiency.

  To date, **there is no way to establish a clear correlation between the "reported μ" and the "effective μ".** There is even a poor correlation between the "reported μ" of the different measuring vehicles.

  It is then very difficult to link the published performance on a contaminated runway to a "reported μ" only.
- The presence of **fluid contaminants** (water, slush and loose snow) on the runway surface **reduces the friction coefficient**, may lead to aquaplaning (also called hydroplaning) and creates an **additional drag**.

  This additional drag is due to the precipitation of the contaminant onto the landing gear and the airframe, and to the displacement of the fluid from the path of the tire. Consequently, braking and accelerating performance are affected. The impact on the accelerating performance leads to a limitation in the depth of the contaminant for takeoff.

  Hard contaminants (compacted snow and ice) only affect the braking performance of the aircraft by a reduction of the **friction coefficient**.

  ATR publishes takeoff and landing performance according to the **type of contaminant**, and to the **depth** of fluid contaminants.

3.5. Aircraft directional control

- When the wheel is yawed, a side-friction force appears. The total friction force is then divided into the braking force (component opposite to the aircraft motion) and the cornering force (side-friction).

  The maximum cornering force (i.e. directional control) is obtained when the braking force is nil, while a maximum braking force means no cornering.
- The sharing between cornering and braking is dependent on the slip ratio, that is, on the efficiency of the anti-skid system.
- Cornering capability is usually not a problem on a dry runway, nevertheless when the total friction force is significantly reduced by the presence of a contaminant on the runway, in crosswind conditions, the pilot may have to choose between braking or controlling the aircraft.

4. Aircraft braking means

Aircraft braking performance, in other words, aircraft "stopping capability", depends on many parameters. Three means allow aircraft to decelerate: wheel brakes, aerodynamic drag, and reverse thrust.

4.1. Wheel brakes

Brakes are the primary means to stop an aircraft, particularly on a dry runway.

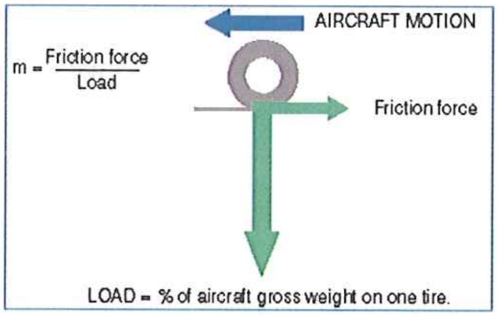
Deceleration is obtained by friction forces between runway and tires. Forces appear at the contact zone tire/runway. By applying brakes, wheels are slowed down. This creates a force opposed to aircraft motion, which depends on wheel speed and load applied on the wheel.

4.1.1. Wheel load

A load must be placed on the wheel to increase contact surface between tire and runway, and to create a braking/friction force.

There is no optimum on the load to be placed on wheels. The greater the load, the higher the friction, the better the braking action.

The friction coefficient is defined as the ratio between maximum available tire friction force and vertical load acting on a tire. This coefficient is named MU or µ.



4.1.2. Wheel speed

The area of tire/runway contact has its own speed, which can vary between two extremes:

- Free rolling speed, which is equal to aircraft speed.
- Lock-up speed, which is zero.

Any intermediate speed causes the tire to slip over runway surface with a speed equal to: Aircraft speed – Speed of tire at the contact point. The slipping is often expressed in terms of percentage to aircraft speed.

Friction force depends on the slipping percentage. It is easily understood that a free-rolling wheel (in other words, 0% slip) does not resist to aircraft motion, therefore does not create a friction force. So, in theory, there is no braking action.

It is a well-known fact that a locked-up wheel simply "skidding" over the runway has a bad braking performance. Hence, the advent of so-called "anti-skid" systems on modern aircraft.

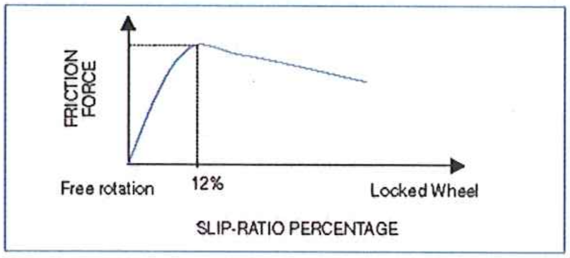
Somewhere in between these two extremes lies the best braking performance.
The following figure shows that the maximum friction force, leading to the maximum braking performance, is obtained for a slip ratio around 12%.

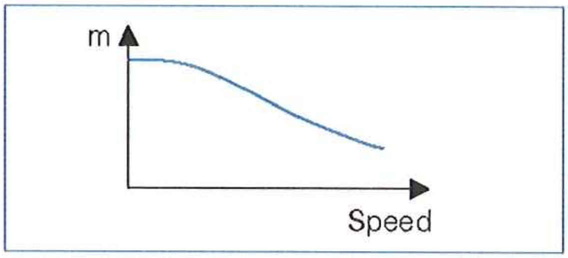
Tests have demonstrated that the friction force on a dry runway varies with the aircraft speed as shown on the following graph:

PRINCIPLE OF ANTI-SKID SYSTEM

Extracted from FCOM, 1.14

The system compares the speed of each main gear wheel (given by a tachometer) to a velocity reference signal. The anti skid system applies a deceleration law continuously adapting the actual wheel speed to the reference speed.





4.2. Reverse thrust

Reverse thrust creates a force opposite to aircraft motion, inducing a significant decelerating force, which is independent of runway contaminant.

According to JAR 25.109, regulations do not allow a credit for the effect of reverse performance on a dry runway.

However, regulations presently allow crediting reverses effect on takeoff performance for wet and contaminated runways.

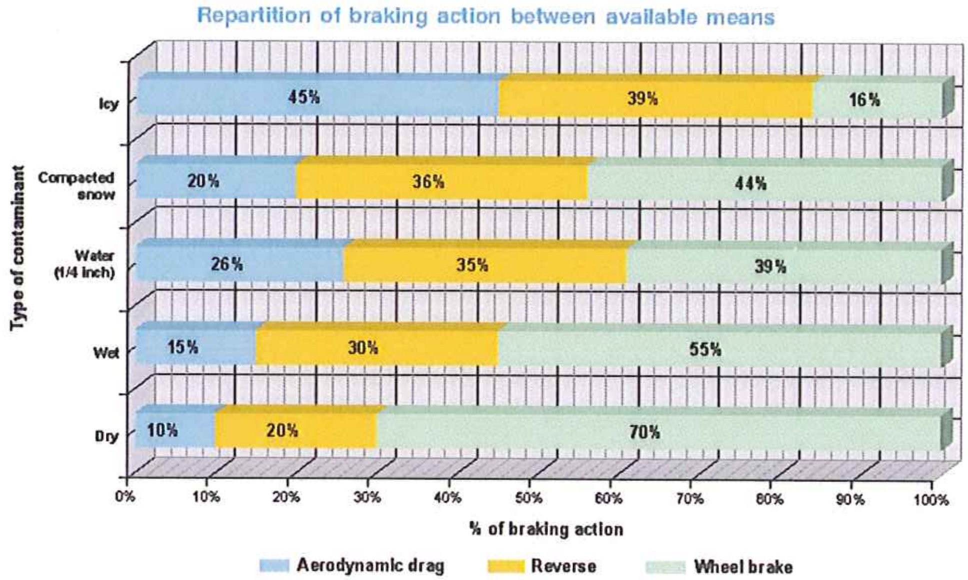
The situation is a bit different for landing performance where regulations allow crediting effect of reverse only for contaminated runways, and not for dry and wet runways.

Remark: This may lead to a performance-limited weight on a wet or contaminated runway being greater than the performance-limited weight on a dry runway. It is compulsory to restrict the performance-limited weight on a wet/contaminated runway to that of the corresponding dry runway.

As illustrated by the following graphs, reverse proportionally have a more significant effect on contaminated runways than on dry runways, since only low deceleration rates can be achieved on contaminated or slippery runways.

The results are computed with the following data:

- ATR 42-300
- MLW: 16.4 Tons
- Flaps 30



5. Braking performance

5.1. Influence of the contaminants

Presence of contaminants on the runway surface affects braking performance in various ways.

The first obvious consequence of the presence of contaminants between tire and runway surface is a loss of friction force, hence a reduced μ. If this phenomenon is quite natural to understand, it is difficult to convert to useable figures. That is why the mathematical model is still evolving and is monitored by regulations.

Presence of a fluid contaminant like water or slush can also lead to a phenomenon known as aquaplaning or hydroplaning. In such a configuration, there is a loss of contact, therefore a loss of friction, between tire and runway surface.

Fluid contaminants produce a lot of precipitation on airframe and landing gears, causing additional drag.

Hard contaminants: Compacted snow and ice
Decrease of friction forces

Fluid contaminants: Water, slush and loose snow
Decrease of friction forces + precipitation drag + aquaplaning

5.2. Reduction of the friction coefficient μ

Friction force reduction is due to interaction of the contaminant between tire and runway surface. One can easily understand that this reduction depends directly on the contaminant. Let us review the μ reduction by contaminant.

5.2.1. Wet runway

The following text is extracted from the ICAO Airport Services Manual, Part 2.

"Normal wet friction is the condition where, due to the presence of water on a runway, the available friction coefficient is reduced below that available on the runway when it is dry. This is because water cannot be completely squeezed out from between the tire and the runway and, as a result, there is only partial contact with the runway by the tire. There is consequently a marked reduction in the force opposing the relative motion of the tire and runway because the remainder of the contacts is between tire and water.
To obtain a high coefficient of friction on a wet or water-covered runway, it is, therefore, necessary for the intervening water film to be displaced or broken through during the time each element of tire and runway are in contact. As the speed rises, the time of contact is reduced and there is less time for the process to be completed; thus, friction coefficient on wet surfaces tend to fall as the speed is raised, i.e. the conditions in effect become more slippery."

In other words, we expect μ_{wet} to be less than μ_{dry}, and to decrease as speed increases.

Until recently, regulations stated that a good representation of the surface of a wet runway condition is obtained when considering μ_{dry} divided by two.

As of today, a new method has been developed taking into account:

- Level of tire wear
- Type of runway
- Tire inflation pressure
- Anti-skid effect demonstrated through flight tests on wet runways.

In any cases, the braking friction coefficient decreases (non-linearly) with aircraft ground speed.

5.2.2. Fluid contaminated runway: water, slush and loose snow

The reason for friction force reduction on a runway contaminated by water or slush is similar to the one on a wet runway. Loss in friction is due to the presence of a contaminant film between runway and tire resulting in a reduced area of tire/runway dry contact.

As for the μ_{wet}, μcont is often derived from μ_{dry}. Again, until recently, regulations stated that $\mu_{cont}=\mu_{fry}/4$.

As for wet condition, a new model has been developed to take into account state of tire wear, type of runway, tire inflation pressure and anti-skid effect.

5.2.3. Hard contaminated runway: compacted snow and ice

These two types of contaminants differ from water and slush, as they are hard. Wheels just roll over them, as they do on a dry runway surface but with reduced friction forces.

As no rolling resistance or precipitant drag is involved, the amount of contaminant on the runway surface is of no consequence. Assuming an extreme and non-operational situation, it would be possible to takeoff from a runway covered with a high layer of hard compacted snow, while it would not be possible to takeoff from a runway covered with 10 inch of slush. One can easily imagine that rolling resistance and precipitation drag would be too important.

The model of friction forces on a runway covered by compacted snow and icy runway as defined in the FCOM section 2.02, leads to the following μ:

Compacted snow: μ = 0.35 to 0.30
Icy runway: μ = 0.25 and below

5.3. Precipitation drag

Regulation requires, in AMJ 25.1591:

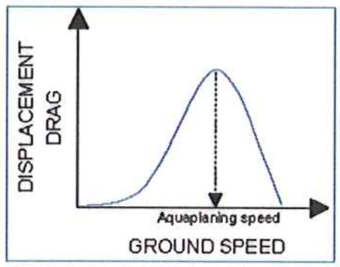
"During take-off acceleration, account should be taken of precipitation drag. During accelerate-stop deceleration and at landing, credit may be taken for precipitation drag."

■ Displacement drag

Drag produced by the displacement of contaminant fluid from tire path, and increases with speed up to a value close to aquaplaning speed.

It is proportional to the density of contaminant, to the frontal area of the tire in the contaminant and to the geometry of the landing gear.

Drag displacement = $0.5 \rho S_{tire} GS^2 C_D K$
ρ is the density of the contaminant
S_{tire} is the frontal area of tire in the contaminant
GS is the ground speed
C_D is the coefficient equal to 0.75 for water or slush
K is the coefficient for wheels



■ Spray impingement drag

Additional drag produced by the spray thrown up by wheels (mainly those of nose gear) onto fuselage.

5.4. Aquaplaning

As previously explained, presence of water on the runway creates an intervening water film between tire and runway leading to a reduction of the dry area. This phenomenon gets more critical at higher speeds, where water cannot be squeezed out from the interface between tire and runway. Aquaplaning is a situation where "the tires of the aircraft are, to a large extent, separated from the runway surface by a thin fluid film. Under these conditions, tire traction drops to almost negligible values and aircraft wheels braking as well as wheel steering for directional control is, therefore, virtually ineffective." ICAO Airport Services Manual, Part 2.

Aquaplaning speed depends on tire pressure and on the specific gravity of the contaminant (i.e. How dense is the contaminant).

In other words, **aquaplaning speed is a threshold from which friction forces decrease dramatically.**

6. Correlation between reported μ and braking performance

6.1. Information provided by airport authorities

Airport authorities give measurements of a runway friction coefficient. Results are published via a standard form defined by the 1981 ICAO AGA meeting called SNOWTAM

SNOWTAM	Priority Indicator	ADDRESSES	
Date and Time of filing	Originator's Indicator	SNOW NOTAM ("S" SERIES) SERIAL NUMBER	NOTAM S

AERODROME	A					
DATE/TIME OF OBSERVATION *(Time of completion of measurement in GMT)*	B		B		B	
RUNWAY DESIGNATORS	C		C		C	
CLEARED RUNWAY LENGTH, IF LESS THAN PUBLISHED LENGTH *(m)*	D		D		D	
CLEARED RUNWAY WIDTH, IF LESS THAN PUBLISHED WIDTH *(m; if offset left or right of centre line add "L" or "R")*	E		E		E	
DEPOSITS OVER TOTAL RUNWAY LENGTH *(Observed on each third of the runway, starting from threshold having the lower runway designation number)* NIL – CLEAR AND DRY 1 – DAMP 2 – WET or water patches 3 – RIME OR FROST COVERED *(depth normally less than 1 mm)* 4 – DRY SNOW 5 – WET SNOW 6 – SLUSH 7 – ICE 8 – COMPACTED OR ROLLED SNOW 9 – FROZEN RUTS OR RIDGES	F		F		F	
MEAN DEPTH *(mm)* FOR EACH THIRD OF TOTAL RUNWAY LENGTH	G		G		G	
BRAKING ACTION ON EACH THIRD OF RUNWAY AND MEASURING EQUIPMENT MEASURED OR CALCULATED COEFFICIENT *or* ESTIMATED BRAKING ACTION 0.40 and above — GOOD – 5 0.39 to 0.36 — MEDIUM/GOOD – 4 0.35 to 0.30 — MEDIUM – 3 0.29 to 0.26 — MEDIUM/POOR – 2 0.25 and below — POOR – 1 9 – unreliable — UNRELIABLE – 9 *(When quoting a measured coefficient use the observed two figures, followed by the abbreviation of the measuring equipment used. When quoting an estimate use single digits)*	H		H		H	
CRITICAL SNOWBANKS *(If present, insert height (cm)/distance from the edge of runway (m) followed by "L", "R" or "LR" if applicable)*	J		J		J	
RUNWAY LIGHTS *(If obscured, insert "YES" followed by "L", "R" or both "LR" if applicable)*	K		K		K	
FURTHER CLEARANCE *(If planned insert length (m)/width (m) to be cleared or if to full dimensions, insert "TOTAL")*	L		L		L	
FURTHER CLEARANCE EXPECTED TO BE COMPLETED BY . . . *(GMT)*	M		M		M	
TAXIWAY *(If no appropriate taxiway is available, insert "NO")*	N		N		N	
TAXIWAY SNOWBANKS *(If more than 60 cm, insert "YES" followed by distance apart, m)*	P		P		P	
APRON *(If unusable insert "NO")*	R					
NEXT PLANNED OBSERVATION/MEASUREMENT IS FOR . . . *(day/month/hour in GMT)*	S					
PLAIN LANGUAGE REMARKS *(Including contaminant coverage and other operationally significant information, e.g. sanding, deicing)*	T					

SIGNATURE OF ORIGINATOR *(not for transmission)*

A SNOWTAM contains:

- The type of contaminant,
- Mean depth for each third of total runway length,
- Estimated braking action,
- Reported μ.

The following table relates reported μ to estimated braking action and equivalent runway status.

		Equivalent runway status	
Braking action	Friction coefficient	Take-off	Landing
Good	0,40 and above	1	1
Good/medium	0,39 to 0,36	2	2
Medium	0,35 to 0,30	3/6	5/6
Medium/Poor	0,29 to 0,26	4	5
Poor	0,25 and below	7	7
Unreliable	Unreliable	8	8

Equivalent runway status:
1: Dry runway
2: Wet up to 3 mm depth
3: Slush or water for depths between 3 and 6 mm
4: Slush or water for depths between 6 and 13 mm
5: Slush or water for depths between 3 and 13 mm
6: Compact snow
7: Ion
8: Runway with high risk of hydroplaning

6.2. Difficulties in assessing the effective μ

The two major problems introduced by airport authorities evaluation of runway characteristics are:

- Correlation between test devices, even though some correlation charts have been established.
- Correlation between measurements made with test devices or friction measuring vehicles and aircraft performance.

These measurements are made with a great variety of measuring vehicles, such as: Skidometer, Saab Friction Tester (SFT), MU-Meter, James Brake Decelerometer (JDB), Tapley meter, Diagonal Braked Vehicle (DBV). Refer to ICAO, Airport Services Manual, Part 2 for further information on these measuring vehicles.

The main difficulty in assessing braking action on a contaminated runway is that it does not depend solely on runway surface adherence characteristics.

What must be found is the resulting loss of friction due to interaction between tire and runway. Moreover, the resulting friction forces depend on the load, i.e. aircraft weight, tire wear, tire pressure and anti-skid system efficiency.

In other words, to get a good assessment of the braking action of an ATR 72 landing at 15,000 kg, 95 kt with tire pressure 144 PSI, the airport should use a similar spare ATR 72... Quite difficult and pretty costly!

The only way out is to use some smaller vehicles. These vehicles operate at much lower speeds and weights than an aircraft. Then comes the problem of correlating figures obtained from these measuring vehicles and actual braking performance of an aircraft. The adopted method was to conduct some tests with real aircraft and to compare results with those obtained from measuring vehicles.

Results demonstrated poor correlation. For instance, when a Tapley meter reads 0.36, a MU-meter reads 0.4, a SFT reads 0.43, a JBD 12... To date, scientists have been unsuccessful in providing the industry with reliable and universal values. Tests and studies are still in progress.

As it is quite difficult to correlate the measured μ with the actual one, termed as effective μ, measured μ is termed as "reported μ".

In other words, one should not get confused between:

1. Effective μ: The actual friction coefficient induced by tire/runway surface interaction between a given aircraft and a given runway, for the conditions of the day.

2. Reported μ: Friction coefficient measured by measuring vehicle.

Particularities of fluid contaminants

Moreover, aircraft braking performance on a runway covered by a fluid contaminant (water, slush and loose snow) does not depend only on the friction coefficient μ.

The model of aircraft braking performance (takeoff and landing) on a contaminated runway takes into account not only the reduction of a friction coefficient but also:
- The displacement drag
- The impingement drag

These two additional drags (required to be taken into account by regulations) require knowing type and depth of the contaminant.

In other words, even assuming the advent of a new measuring friction device providing a reported μ equal to effective μ, it would be impossible to provide takeoff and landing performance only as a function of reported μ. ATR would still require information regarding the depth of fluid contaminants.

6.3. Data provided by ATR

Please refer to FCOM section Performances for further details on contaminated runway performance.

Hard contaminants

For hard contaminants, namely compacted snow and ice, ATR provides corrections to apply independently of the amount of contaminants on the runway. Behind these terms are some effective μ. These two sets of data are certified.

Fluid contaminants

ATR provides takeoff and landing corrections on a runway contaminated by a fluid contaminant (water, slush and loose snow) as a function of the depth of contaminants on the runway.

In other words, pilots cannot get the performance from reported *μ* or Braking Action.

Pilots need the **type and depth of contaminant** on the runway.

7. Aircraft directional control

The previous section analyzes impact of the reduction of friction forces on aircraft braking performance. The reduction of friction forces also significantly reduces aircraft directional control.

One should also consider the effect of the crosswind component on a slippery runway.

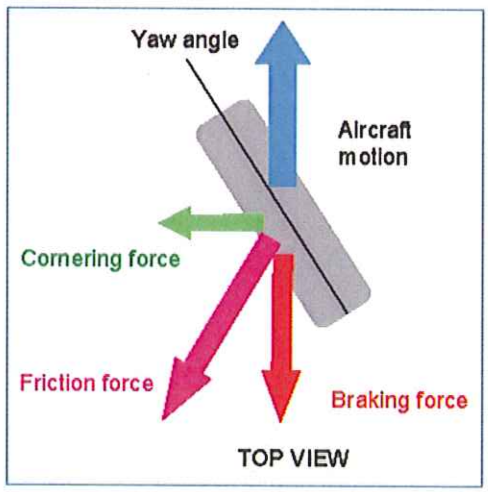
7.1. Influence of slip ratio

When a rolling wheel is yawed, the force on the wheel can be resolved 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".

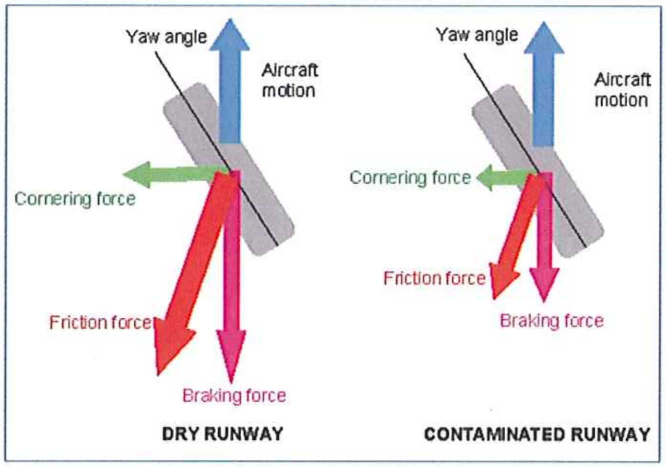
Steering capability is obtained via the cornering force.

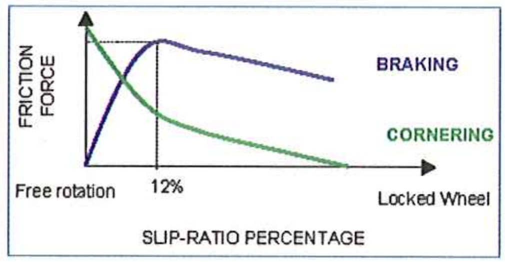
Maximum cornering effect is obtained from a free-rolling wheel, whereas a locked wheel produces zero cornering effect. With respect to braking performance, we can recall that a free-rolling wheel produces no braking. In other words, maximum steering control is obtained when brakes are not applied. One realizes that there must be some compromise between cornering and braking.

The following figure illustrates this principle. The figure above shows that when maximum braking efficiency is reached (i.e. 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 choose between braking or controlling the aircraft. He may not have both at the same time.





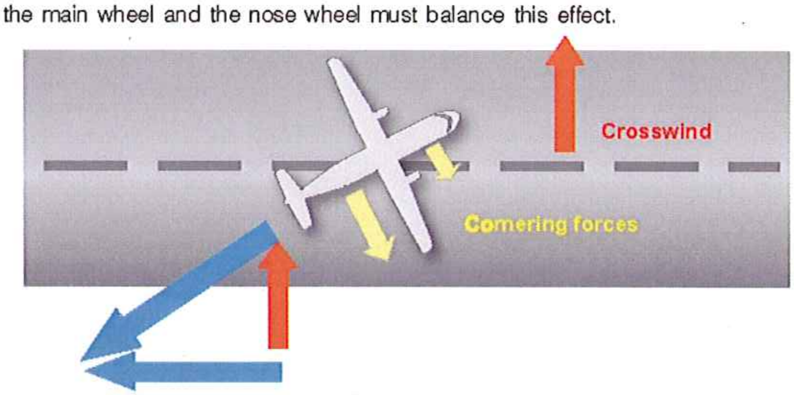
7.2. Influence of wheel yaw angle

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 providing the maximum cornering force depends on the runway condition and diminishes 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.

7.3. Ground controllability

During a crosswind landing, or aborted takeoff, cornering force is the primary way of maintaining the aircraft within the runway width. In a crosswind situation, the aircraft crabs. That is, the aircraft's nose is not aligned with the runway centerline. Refer to Figure below. The wind component can be resolved into two directions: crosswind and head/ tail wind. Similarly, thrust reverse component is resolved both in a component parallel to the runway centerline, actually stopping the aircraft, and in a component perpendicular to the runway. For the purpose of this example, let's refer to it as "cross-reverse".

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



In such a situation, releasing the brakes would actually allow a greater cornering force to be developed, thus, regaining aircraft directional control.

8. Performance determination

ATR provides data to compute take-off and landing on contaminated runways. They look like distance penalties to apply to normal computation. See FCOM section 3.03.08 for takeoff correction and FCOM section 3.08.03 for landing distances.

Note that FOS, the ATR flight planning software is able to compute more accurate performance charts.

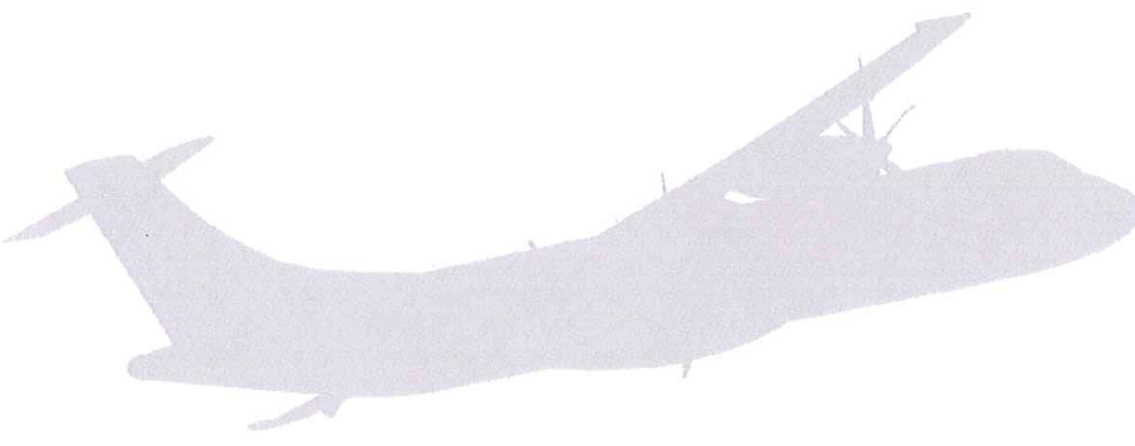
The following example illustrates FOS method and is based on these assumptions:

- Blagnac airport runway 32L
- TORA: 3500 m
- TODA: 3800 m
- ASDA: 3800 m
- Slope: -0,1%
- QNH: 1019
- Contaminant: water or slush $^1/_4$ inch

```
:-------------------------------------------------------------------------------:
:  F15  :  19/09/2003                 BLAGNAC                   :     LFBO  32L  :
:-------------------------------------------------------------------------------:
: ELEVATION=  499.0(FT)            LIMITATION CODES         : ATR42-300         JAR-DGAC:
: T.O.R.A. = 3500.0(M )     0-DRY CHECK    5-TYRE SPEED     :                         :
: A.S.D.A. = 3800.0(M )     1-STRUCTURE    6-BRAKE ENERGY   : V2/VS OPTIMIZED   V1/VR OPTIMIZED:
: T.O.D.A. = 3800.0(M )     2-2ND-SEGMENT 7-RWY 2 ENGINES   : AIR COND. OFF           :
: SLOPE    =  -0.10( %)     3-RUNWAY       8-FINAL T.O.     : NORMAL CONDITIONS       :
:                           4-OBSTACLE     9-VMC            : WITHOUT REVERSE         :
:-----------------------------------------------------------:                         :
:                                                           :                         :
:                                                           :                         :
:                                                           :                         :
:                                                           :                         :
:-----------------------------------------------------------:-------------------------:
: - WIND:    TOW(KG) DTOW1/DTOW2        QNH=1019.00(HPA)    : WATER OR SLUSH 1/4 INCH (6.3 MM) :
:O - KT :  V1 VR V2(IAS KT)  CODES      DQNH=  +10/  -10    : SCREEN HEIGHT 15 FT     :
:A  -   :  DV1 DVR DV2/DV1 DVR DV2                          : DRY CHECK               :
:T    - :---------------------------------------------------:-------------------------:
:(DC) - :      -10       :      -5        :       0         :     10     :     20     :
:-------:----------------:----------------:-----------------:------------:------------:
: -10.0 :15736  +50/  -51:16135  +51/  -51:16516  +51/  -52:16773  +52/  -52:16900   +0/   +0:
:       : 103 103 110 4-4 : 105 105 111 4-4 : 104 104 110 4-4 : 105 105 111 4-4 : 100 101 108 1-1 :
:       :+0 +0 +0/+0 +0 +0:+0 +0 +0/+0 +0 +0:+0 +0 +1/+0 +0 +0:+0 +0 +1/+0 +0 +0:-1 +0 +0/+0 +0 +0:
:-------:----------------:----------------:-----------------:------------:------------:
:   0.0 :15526  +52/  -53:15923  +53/  -53:16303  +53/  -54:16559  +54/  -54:16802  +54/  -55:
:       : 102 102 109 4-4 : 104 104 110 4-4 : 103 103 110 4-4 : 104 104 111 4-4 : 105 105 111 4-4 :
:       :+1 +1 +0/+0 +0 +0:+0 +0 +1/+0 +0 +0:+1 +1 +0/+0 +0 +0:+1 +1 +0/+0 +0 -1:+0 +0 +1/+0 +0 +0:
:-------:----------------:----------------:-----------------:------------:------------:
:   5.0 :15425  +53/  -54:15822  +54/  -54:16201  +54/  -55:16457  +55/  -55:16699  +55/  -56:
:       : 102 102 108 4-4 : 101 101 108 4-4 : 103 103 109 4-4 : 104 104 110 4-4 : 105 105 111 4-4 :
:       :+0 +0 +1/+0 +0 +0:+3 +3 +2/+0 +0 +0:+0 +0 +1/+0 +0 +0:+0 +0 +0/+0 +0 +0:+0 +0 +0/+0 +0 +0:
:-------:----------------:----------------:-----------------:------------:------------:
:  10.0 :15323  +55/  -56:15720  +56/  -57:16098  +57/  -57:16354  +57/  -58:16595  +57/  -58:
:       : 102 102 108 4-4 : 101 101 108 4-4 : 103 103 109 4-4 : 104 104 110 4-4 : 105 105 111 4-4 :
:       :+0 +0 +0/+0 +0 +0:+0 +0 +0/+0 +0 -1:+0 +0 +0/-1 -1 +0:+0 +0 +0/-1 -1 +0:+0 +0 +0/-1 -1 +0:
:-------:----------------:----------------:-----------------:------------:------------:
:  15.0 :15222  +58/  -59:15619  +58/  -59:15995  +59/  -60:16251  +59/  -60:16491  +59/  -61:
:       : 101 101 108 4-4 : 101 101 107 4-4 : 102 102 109 4-4 : 103 103 110 4-4 : 104 104 110 4-4 :
:       :+1 +1 +0/+0 +0 -1:+0 +0 +0/+0 +0 +0:+1 +1 +0/+0 +0 -1:+1 +1 +0/+0 +0 -1:+0 +0 +1/+0 +0 +0:
:-------:----------------:----------------:-----------------:------------:------------:
:  20.0 :15124  +61/  -62:15520  +61/  -62:15896  +62/  -63:16151  +62/  -63:16391  +63/  -64:
:       : 101 101 107 4-4 : 101 101 107 4-4 : 102 102 108 4-4 : 103 103 109 4-4 : 104 104 110 4-4 :
:       :+0 +0 +1/+0 +0 +0:+0 +0 +0/-1 -1 +0:+0 +0 +0/+0 +0 +0:+0 +0 +0/+0 +0 +0:+0 +0 +0/+0 +0 +0:
:-------:----------------:----------------:-----------------:------------:------------:
/OBSTACLE FROM BEGINNING OF TORA : DISTANCE(M )/HEIGHT(FT)
/   4145/ 309    4155/ 307    4160/ 310    4180/ 311    4545/ 316
/MINI. ACCELERATION HEIGHT :    502.(FT)  QNH ALT. :  1001.(FT)
/MAXI. ACCELERATION HEIGHT :   3551.(FT)  QNH ALT. :  4050.(FT)
FOS WINDOWS 4.0.3   /TLC:M1 APR.2003 AT00G76U.PDF ATR42*00/AA/PW-120   T00/15-AR-BY8.-JA
```

Example of a FOS take-off performance chart for a contaminated runway

F. Procedures



1. Parking

When leaving the aircraft parked in cold weather conditions, some precautions need to be taken for the safety of the following flight. Refer to the Service Letter SL 30-5011 for ATR 42 aircraft and SL 30-6004 for ATR 72 aircraft for the detailed procedures.

The main points to remember are to protect the exposed airframe parts, and especially the engine, the wheels, the blades and the gears against the snow or ice accumulation. And to remove the standing water that could freeze from the critical parts, notably the flaps hinges.

2. Exterior inspection

2.1. Walk-around

An exterior inspection of the aircraft is performed before each flight. For cold weather operation, the crew must be particularly vigilant and shall not forget to check the following parts of aircraft. If the crew detects ice or pollution on ANY surface, de-icing and anti-icing procedures are required.

- engine inlets
- engines cowling and draining
- propellers
- pack inlets
- landing gear assemblies
- landing gear doors
- pitot, and static vents
- angle of attack sensors
- fuel tank vents

It is essential that the following aerodynamical surfaces are checked clear of ice or snow too:

- fuselage
- wings
- vertical and horizontal stabilizer
- control surfaces

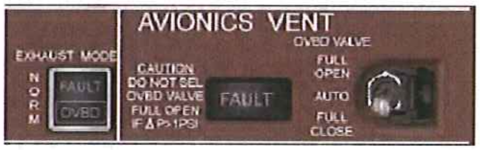
2.2. Frost due to condensation

Light hoar frost can appear under fuel tanks with winter anti-cylonic conditions and light wind. This phenomenon is induced by a difference of temperature between wing skin and fuel inside tanks.

Note: takeoff is only possible with no more than 2 millimeters of frost under wings. The rest of the aircraft must be totally clear of frost. Takeoff must be performed with atmospheric icing speeds and performance penalties must be applied. It is the Captain's responsibility to assess the under-surface of the wings before initiating a takeoff with the under-surface polluted.

3. Cockpit preparation

3.1. Cold weather operation

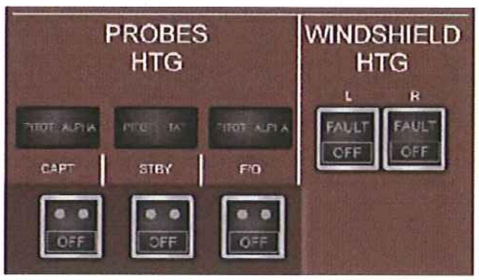


Avionic vent panel with overboard valve on full close

Apply normal procedures plus the following items:

- Provided air intake and both pack inlets are free of snow, frost, ice, start engine 2 in Hotel Mode
- In order to quickly improve cabin warm up, select the overboard valve to "full close" position.

With this position selected, the overboard valve drives hot avionics cooling flow to the cabin, thus increasing quickly cabin temperature.



Permanent anti-icing panel selected ON for every flight

3.2. Permanent anti-icing

Before each flight, the crew must select permanent anti-icing ON (level 1): probes and front windshield are heated to prevent ice building up.

4. Taxi

4.1. Taxi procedure

ATR recommends both engines taxi procedures, particularly in case of contaminated runways:

- To avoid skidding by using differential power when friction coefficient is low (especially when OAT is very low).
- To allow a good warm-up of engine n°1 before takeoff.

4.2. Caution

Nose wheel deflection must be used with little variations. Observe special care with thick contaminant layer. In this case, apply the following procedure to avoid landing gear damage:

- Set 18% of torque on both engine
- Use brakes to maintain a speed down to a walking pace for 30 seconds with 18% of torque. In this way, brakes temperature increases and eliminates any contamination on landing gear assemblies.
- Use no sewheel steering with little variations to ensure symmetrical brake warming.

5. Take-off

Icing conditions and contaminated runways introduce operational constraints. Thus to ensure both safety and payload maximization at takeoff, crew have to focus on some important points, developed in the current chapter. A synoptic table summarizes take-off situations.

5.1. Take-off in atmospheric icing conditions

According to FCOM 2.02.08 the crew must select "anti-icing" ON to prevent ice accretion on airframe. As soon as "anti-icing" is ON, what is confirmed by the "ICING AOA" light ON, the crew must monitor speed to stay in the flight envelope.

Furthermore takeoff speeds are increased while "ICING AOA" light is ON, leading to performance reduction.

Note: The take-off sequence is assumed to last until the aircraft has reached 1500ft AGL or when 10 minutes elapsed from brakes release, whichever occurs first.

When the icing conditions are met after this point, the take-off is performed in normal conditions. The take-off performance, and the payload are thus maximized. Once the take-off sequence is completed and when the icing conditions are met, the anti-icing and de-icing systems are switched ON and the icing speeds are set.

5.2. Take-off on contaminated runways

In this case the crew has to select propellers anti-icing only. This is to prevent ice formation on blades induced by projection of contaminants such as slush or snow. Thus, takeoff performances are optimum.

Furthermore landing gears must be cycled after takeoff to avoid ice accretion on rods and paddles.

5.3. Fluid type II and fluid type IV particularities

These fluids present a high viscosity –to increase the holdover time protection– and can thus increase stick forces at the aircraft rotation: these control forces may be more than twice the normal takeoff force. This should not be interpreted as a "pitch jam" leading to an unnecessary abort decision above V1. Although not systematic, this phenomenon should be anticipated and discussed during pre-takeoff briefing each time de-icing/anti-icing procedures are performed. These increased pitch forces are strictly limited to the rotation phase and disappear after takeoff. Refer to FCOM 2.02.08 for further information on the "pitch jam" matter.

In very exceptional circumstances, because of increased rotation forces, the pilot can consider that takeoff is impossible and consequently initiate an aborted takeoff.

To handle this problem, ATR provides two methods described in AFM appendices.

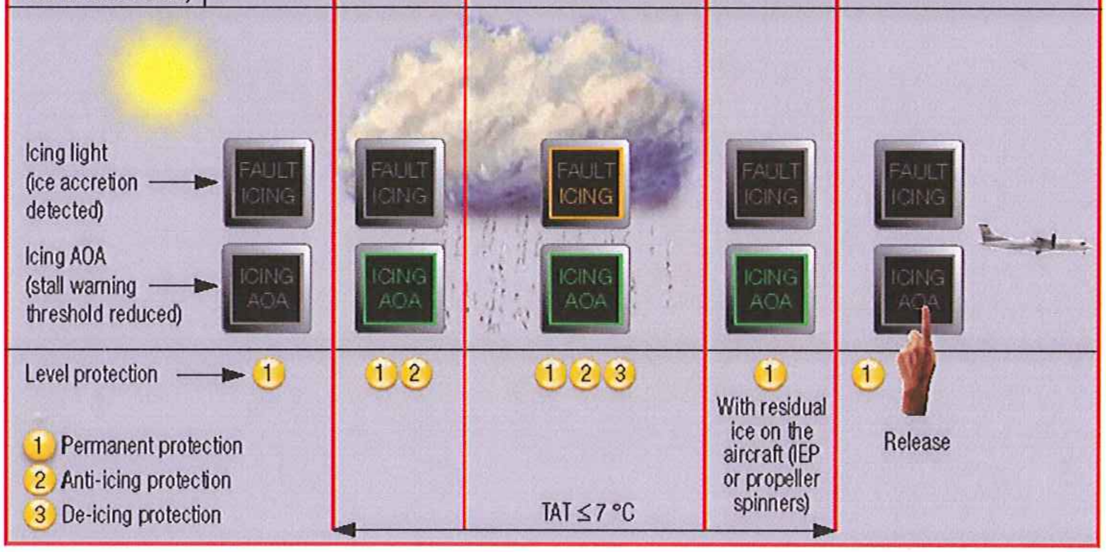
- **Method 1:** This method applies to a crew who has not received a specific training. In this case the crew applies the standard takeoff procedure, but TOD, TOR and ASD are increased by 20% on ATR 42 and 25% on ATR 72.
- **Method 2:** This method applies to a crew who has received a specific training. In this case, the crew has to perform a specific briefing to review possible increase stick force at rotation. If this happens the captain request the first officer's assistance. He orders "pull" and the first officer pull the control wheel until pitch reaches 5°. Proceeding in such a way minimizes takeoff penalties. 70m only are added to the takeoff distance.

TAKE-OFF IN COLD WEATHER

	ICING CONDITIONS IN FLIGHT	GROUND ICING CONDITIONS WITHOUT ATMOSPHERIC ICING CONDITIONS	WHEN USING ANTI & DE-ICING FLUID TYPES II & IV
FLIGHT OPERATIONS	Apply normal procedure + these following items: Cockpit preparation ■ Icing speeds bugs set  Before take-off ■ Anti-icing ON Take-off & after take-off ■ Respect icing speeds(red bug for the flaps retraction)	Apply normal procedure + these following items: Taxi Contaminant may adhere to wheel brakes when taxiing on contaminated ramp, taxiways and runway in this case apply this special following procedure:  Set 18% torque on each engine and keep taxi speed down to a "walking pace" for 30 seconds using normal brake action with minimum use of nose wheel steering to ensure a symmetrical warming up of the brakes. Before take-off ■ Prop anti-icing ON After take-off ■ Landing gear recycle Note: Special procedure for the landing	After ground anti-icing procedure, using type II & IV fluids, higher than normal stick forces may be encountered. ATR AFM provides two flight procedures depending on crew training. METHOD 1 Pilots without specific training ■ Apply normal procedure METHOD 2 Pilots with specific training ■ A specific briefing before take-off must be completed ■ The Captain is the pilot flying.  In case of difficulties to rotate, the Captain should require the First Officer's assistance. CPT orders "PULL": First Officer helps the Captain to pull the control wheel until pitch reaches 5°.
PERFORMANCE	■ Determine take-off data with icing conditions.	■ Determine take-off data with contaminated runway computation charts	METHOD 1 ■ Determine Vr for lowest available V2 & assume V1=Vr ■ Increase TOR, TOD, ASD by 20% for ATR 42, and 25% for ATR 72 METHOD 2 ■ Increase TOD by 80m for ATR 42-500 and 70m for other ATR.

6. Flight profile in icing conditions

Conditions	Non icing conditions	Entering icing conditions	At 1st visual indication of ice accretion and as long as icing conditions exist	Leaving icing conditions	When the aircraft is visually verified clear of ice
Speeds	Normal	Icing	Icing	Icing	Normal
Cont. relight (only for ATR 42-300 & 72-200)	As required	As required	ON	As required	As required



This diagram is a sum-up of the different procedures for flight in atmospheric icing conditions that can be found in FCOM 2.02.08:

- Entering icing conditions
- At first visual indication of ice accretion and as long as icing conditions exist
- Leaving icing conditions
- When the aircraft is visually verified clear of ice

6.1. Entering icing conditions

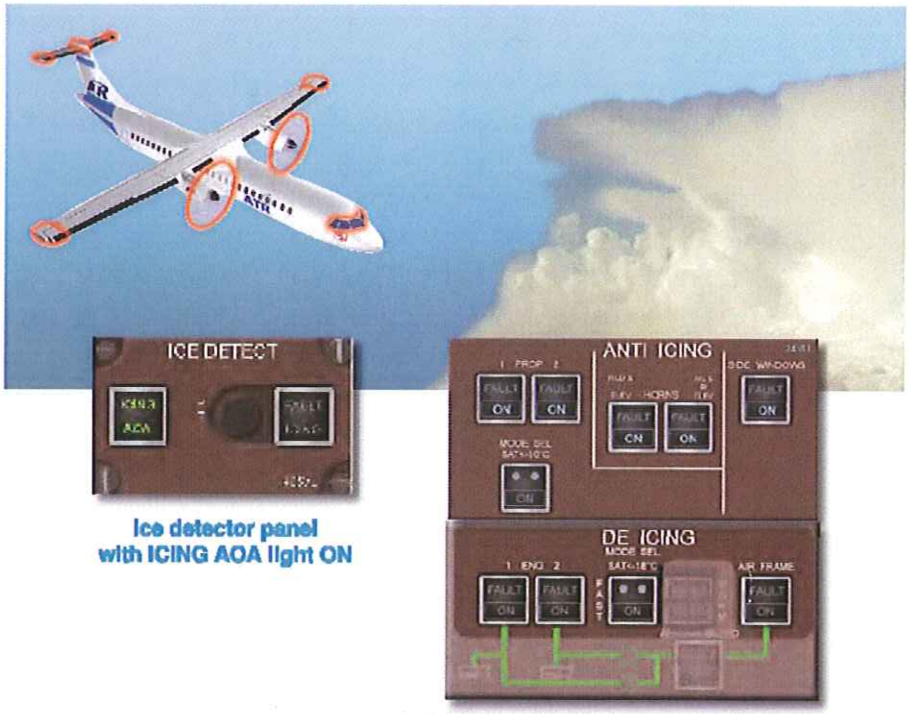
Operations in atmospheric icing conditions require special care since ice accretion on airframe and propellers significantly modify their aerodynamic characteristics. To avoid such problems, the crew must select "anti-icing" level ON (level 2) as soon as aircraft reaches icing conditions.

Icing conditions definition:

- Visible moisture
- Temperature SAT ≤ 5 °C on ground or at take-off
  TAT ≤ 7 °C in flight
- Visibility less than 1 Nm

By depressing one of both horns push buttons to the ON position, "ICING AOA" green light appears automatically, alerting the crew that the stall threshold alarm has been decreased

- In normal operations the stick shaker threshold is set at ~12° of angle of attack to prevent stall with flaps 0.
- When ICING AOA light is ON, stick shaker threshold is reduced at ~7°.



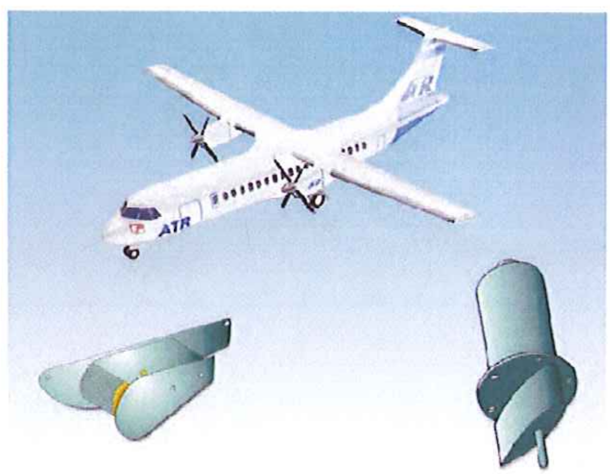
Ice detector panel with ICING AOA light ON

Anti-icing and de-icing panels with level 2 ON

⚠ Under FAA regulation Eng 1 and 2 de-icing must be engaged while in icing conditions

6.2. At 1st visual indication of ice accretion and as long as icing conditions exist

6.2.1. Ice accretion



Aircraft enters in ice accretion area, at first sign of ice building up on any part of the airframe. The Ice Evidence Probe and the Ice detector are two supplementary devices to help the crew detecting such situation:

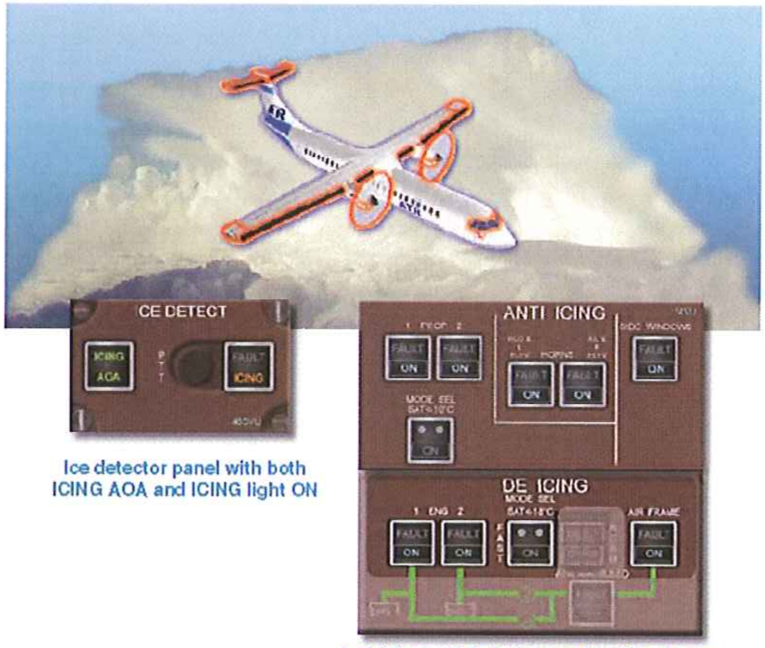
■ Ice evidence probe (primary mean)

This component is located near the cockpit left side window. When encountering ice accretion, ice builds up on the leading edge of this probe allowing visual detection. An integrated lighting controlled by the NAV LIGHT switch has been included for night operations.

Some ATR 42 may not be equipped with an IEP. In this case, the propeller spinners are the primary mean of detection.

■ Ice detector

The ice detector electronic sensor is located under left wing, and alerts the crew with a single chime, a master caution and an icing amber light as soon as ice accretion is sensed. If ice accretion is detected with horns anti-icing and/or airframe de-icing still OFF the icing light will flash until the crew select both anti-icing and de-icing systems ON. The icing light remains steady ON as long as ice builds upon the aircraft.



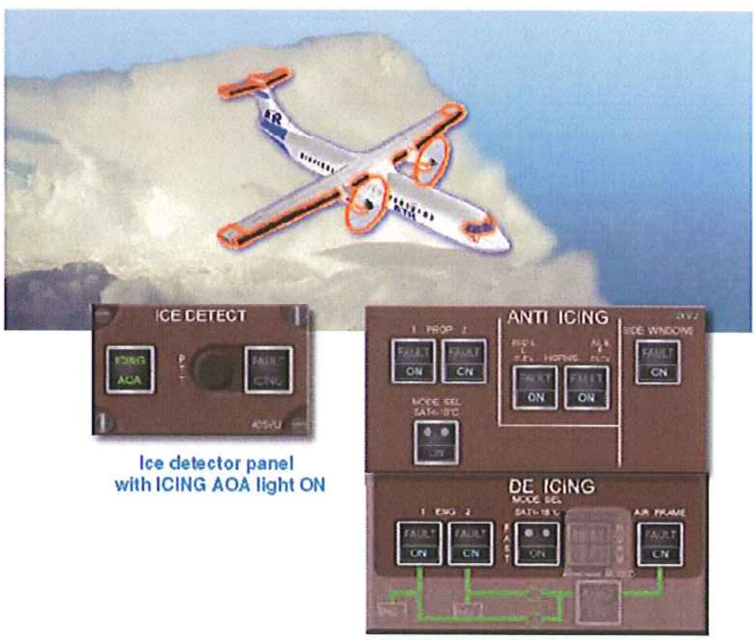
Ice detector panel with both ICING AOA and ICING light ON

Anti-icing and de-icing panels with systems ON (level 2 and 3)

6.2.2. End of ice accretion

In icing conditions, even if ice accretion stops, crew must maintain "anti-icing" and "deicing" ON (level 2 and 3) for many reasons:

- To anticipate further ice accretion areas
- To keep aircraft in the flight envelope (due to ice on airframe, aerodynamic characteristics could change).



Ice detector panel with ICING AOA light ON

Anti-icing and de-icing panels with systems ON (level 2 and 3)

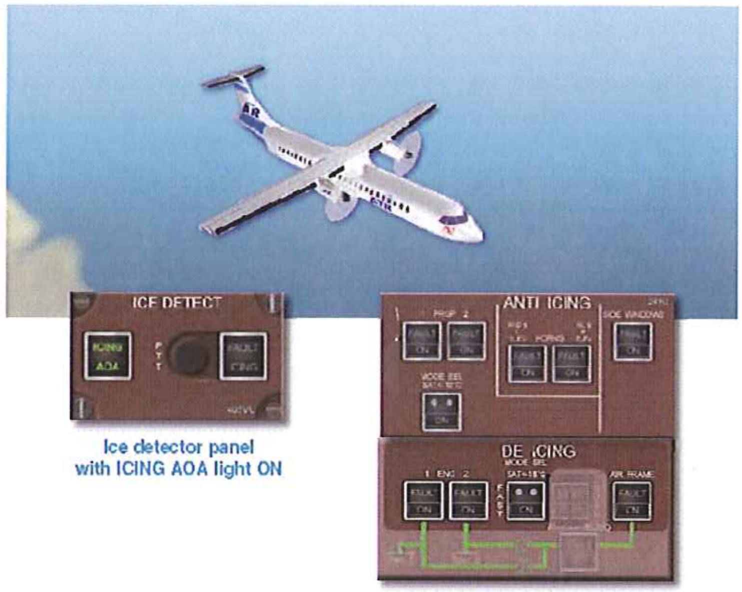
Blue memo de-icing light will flash 5 minutes after the last detection of ice accretion by the ice detector. This must be disregarded and de-icing systems must remain ON until icing conditions are left.

6.3. Leaving icing conditions

One can consider leaving icing conditions when:

- Total Air Temperature (TAT) is above 7 °C
  And/Or
- Aircraft is flying without visible moisture

When leaving icing conditions, crew selects anti-icing and de-icing systems OFF and continues flying with "ICING AOA" light ON until aircraft is checked clear of ice.



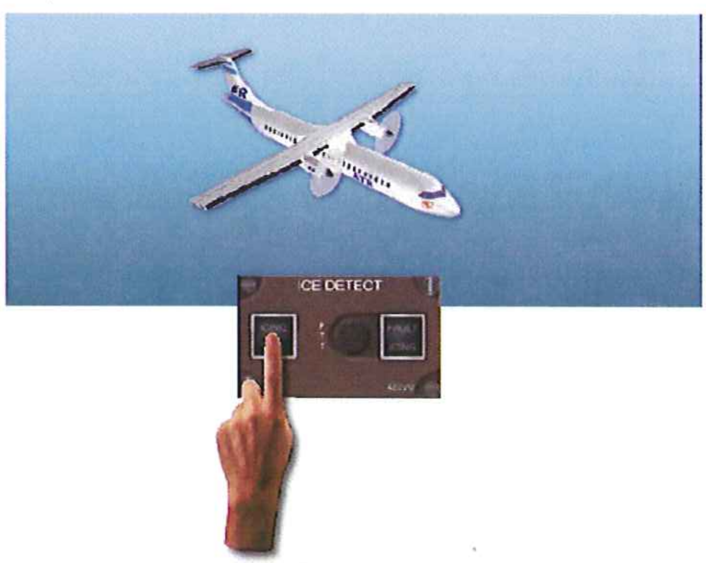
Ice detector panel
with ICING AOA light ON

Anti-icing and de-icing panels
with systems OFF

6.4. When the aircraft is visually verified clear of ice

As soon as normal conditions are recovered (temperature, visibility), airframe condition must be monitored. If the Ice Evidence Probe (IEP) is checked clear of ice, this means that there is no more ice on the critical airframe surfaces. (If the IEP is not installed, the propeller spinner shall be used as a visual mean.)

Thus depress ICING AOA light. When ICING AOA light is OFF, normal flight conditions are recovered and normal operating speeds must be applied.



Reset of ICING AOA

7. Procedures following APM alerts

The APM aims at drawing the attention of the flight crew to a potential risk of ice accretion. It does not replace the previous procedures, which details how to manage the flight profile in icing conditions, but it helps to detect when the aircraft is facing severe icing conditions.

APM and its associated alerts are additional means to detect the ice accretion, but do not replace the general methodology for flight in icing conditions.

CRUISE SPEED LOW

This alert is an advisory alert to warn the flight crew to monitor potential ice accretion. The associated procedure is detailed in the QRH normal procedures.

DEGRADED PERF.

This alert is a caution alert triggered in cruise or in climb to warn the flight crew of an abnormal decrease in the aircraft speed, that can be caused by ice accretion on the aerodynamic parts of the aircraft. The flight crew has to switch on the de-icing systems and to determine if the atmospheric icing conditions are confirmed.

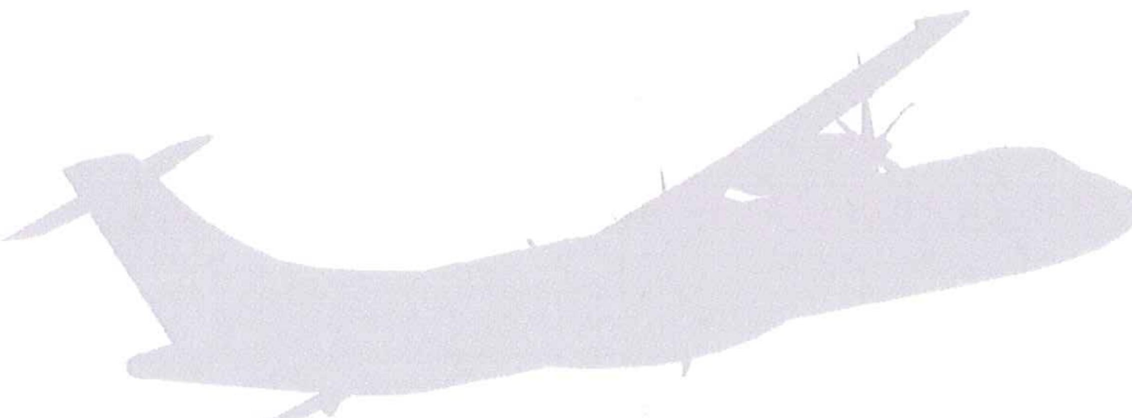
The associated procedure is detailed in the QRH following failures procedures.

INCREASE SPEED

This alert is a caution alert triggered in flight to warn the flight crew of an abnormal decrease in the aircraft speed, that can be caused by ice accretion. The flight crew has to check if the abnormal conditions are observed, and once confirmed, they have to recover the aircraft speed immediately.

The associated procedure is detailed in the QRH following failures procedures.

G. Severe icing



1. Overview

Current certification standards for icing call for protection against ice accretions generated within a certain icing envelope defined in the Appendix C of JAR/FAR25. Icing conditions in clouds were established as being satisfactory standards for the design and the certification of airplane ice protection provisions. However atmospheric icing conditions are highly variable and can exceed these standards. An aircraft certified for flight into known icing conditions may transit into more severe icing conditions. Under these conditions, the ice protection systems may not be able to adequately protect the aircraft.

The AIM 7-20 provides the following definition for the icing severity index: "Severe". The rate of accumulation is such that de-icing/anti-icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary."

The icing conditions are characterized by their median volumetric diameters of droplets, the liquid water content, the outside air temperature and the time of exposure. Exceedance of one of these parameters may lead to accumulation of ice either beyond the capacity of the ice protection systems or in locations not normally prone to icing and not protected. In this case the ice protection provisions may no longer be effective to provide safe operations and the flight crew may be required to promptly exit these conditions.

The current certification standards for icing refer to supercooled clouds having droplets of a median diameter (MVD) between 15 and 50 microns. In this view icing conditions involving larger droplet diameter such as Supercooled Large Droplets (SLD) may be considered as severe icing conditions.

1.1. Supercooled large droplet

Freezing rain and freezing drizzle are forms of SLD. These conditions are observed and forecast as surface conditions. They are typically found below 10,000 feet AGL. However, SLD may exist at altitude and not be detected on the surface. Pilots have reported SLD encounters up to 18,000 feet. Ice pellets on the surface also frequently indicate the presence of SLD aloft, but SLD conditions at altitude may be completely undetectable from the ground.

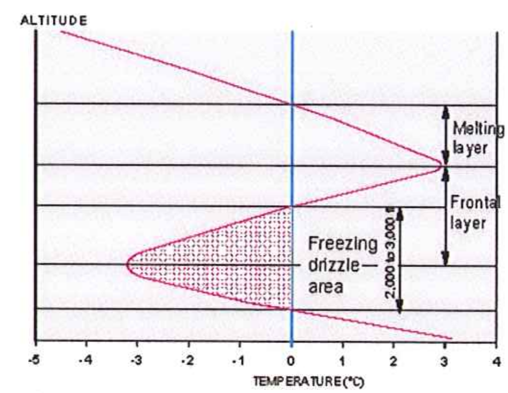
Two different atmospheric conditions result in the formation of freezing rain and freezing drizzle:

- Temperature inversion
- Collision-coalescence Process

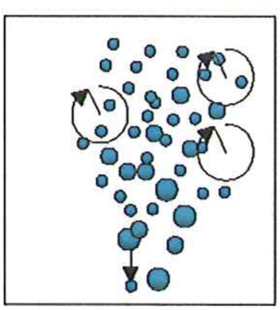
1.2. Temperature inversion

Ordinarily, temperatures decrease with altitude. However, when there is a temperature inversion, this is not the case. A layer of cold air lies under a layer of warmer air. Temperature inversions are most often associated with warm fronts and stationary fronts.

Freezing rain and occasionally freezing drizzle can form when liquid water dropsfall from an area of warm air through a layer of air that is at or below freezing.

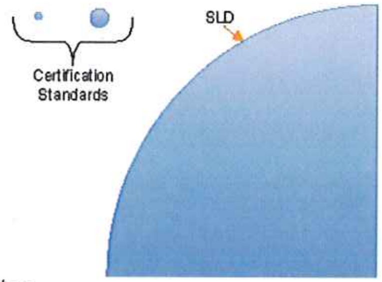


1.3. Collision-coalescence process



Freezing drizzle is more often formed via the collision-coalescence process, than temperature inversion. Through condensation, some droplets within the clouds may grow in diameter, begin to settle, and fall fast enough to collide with smaller, slower moving droplets to coalesce and form bigger droplets. These droplets can be found throughout the entire depth of the cloud. This process is more likely to occur when the cloud temperatures are warmer than –15 °C.

Supercooled Large Droplets (SLD) can be 100 times larger than the droplets to be considered in the current certification standards



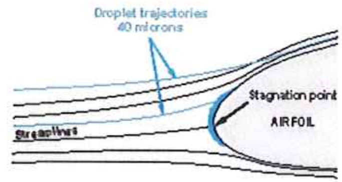
Certification Standards

- Droplets diameter from 5 to 135 microns
- MVD from 15 to 50 microns

Supercooled Large Droplets

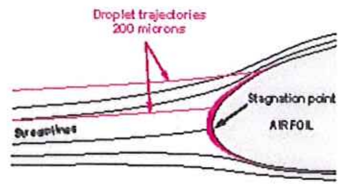
- Droplets diameter from 5 to 2000 microns
- MVD from 15 to 2000 microns

Droplet trajectory relative to the aircraft is governed by aerodynamic forces acting on the droplet and its inertia. The opposite chart evidences how small droplets, essentially following the streamlines will escape the airfoil except close to the stagnation point, when the much heavier larger droplets will tend to go straight, with a significantly extended accretion coverage.



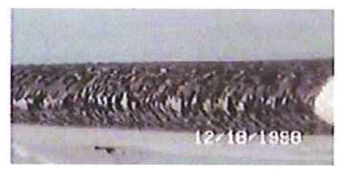
200 microns versus 40 microns:

- Droplet aerodynamic drag x 25
- Droplet inertia x 125



Large droplets will also tend to stream back before freezing, further extending the coverage of the resulting ice accretion.

The extent of the ATR wing de-icing boots is such as it is unlikely to accrete ice beyond the protection on the upper surface. Nevertheless under these SLD conditions ice may accrete aft of the protected area on the lower surface and the whole boots extent may be covered with residual ice.



Case of severe icing conditions: the whole chordwise extent of the boot is covered with ice.

2. Detection of SLD

2.1. Conditions conducive to SLD

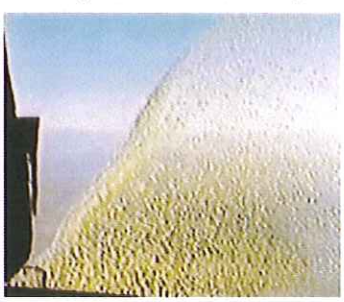
The following weather conditions may be a sign of SLD encounters:

- Visible water precipitation at temperatures close to 0 °C ambient air temperature (SAT)
- Droplets that splash or splatter on impact on cockpit windows at temperatures close to 0 °C ambient air temperature

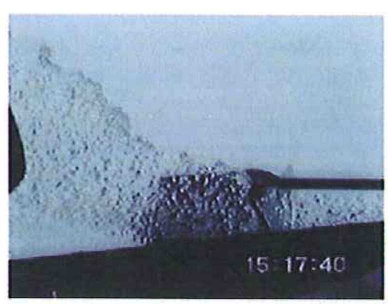
2.2. Visual Cues

SLD encounters have been experienced several times on ATR during either flight test campaigns or commercial flights and the following visual cues were established:

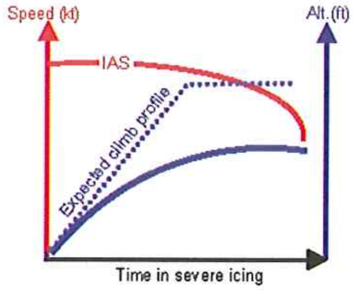
- Ice spots covering all or a substantial part of the unheated portion of either forward side windows, possibly associated with water splashing and streaming on the windshields
- Unexpected decrease in speed or rate of climb



SLD- Total coverage of the unheated part of the side window. The yellow color is due to the water used during tanker tests.



SLD - Partial coverage of the unheated part of the side window"

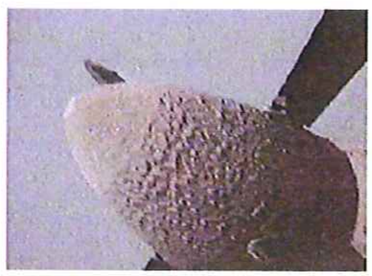


Speed and ROC decreases

The following may be used as secondary indications of SLD encounters:

- Unusually extensive ice accretion on the airframe in areas not normally observed to collect ice,
- Accumulation of ice on the propeller spinner farther aft than normally observed,
- Accumulation of ice on the lower surface of the wing aft of the protected areas.

SLD - Underwing ice accretion



SLD - Ice accretion on the propeller spinner

3. Procedure

In case of severe icing, the crew must apply the SEVERE ICING emergency procedure. Each step of this procedure is explained below.

INCREASE RED BUG BY 10KTS

During a severe Ice exposure, the icing atmosphere can create conditions beyond the ability of the aircraft system to withstand. Ice will be accreting faster than the deicing system can get rid of it. The airfoil shape will be changed and the stall warning system may not activate before the wing stall. It is to avoid this circumstance that an additional safety margin of 10kts is added. Remember to apply conservative maneuvering speed any time needed (refer to FCOM 2.02.01 Operating speeds).

PWR MGT SET TO MCT

Severe Ice on the aircraft increases the drag enormously, max available power will be required. Set CL/PL at 100%/MCT. As power equal NP multiplied by TQ, it is mandatory to set both CL/PL at their maximum continuous values.

FIRMLY HOLD CONTROL WHEEL AND DISENGAGE AP

The AP may mask tactile cues that indicate adverse changes in handling characteristics. Full aileron trim may be required so if the AP does not disengage automatically because of the unusual trim requirement, when disengaged manually expect strong control column forces to avoid an aircraft upset.

ESCAPE SEVERE ICING CONDITIONS

Always plan the escape route when first encountering any ice accretion, anticipate conditions deteriorating. Severe Ice atmosphere is usually very localised, climb (if possible) or descend (if terrain clearance allows). An increase of 1 °C may be sufficient for escape.

Change heading based on information provided by ATC.

NOTIFY ATC

■ If an unusual roll response or uncommanded roll control movement is observed.

This is standard ATR stall symptoms which require stall recovery by:

Pushing firmly on the control wheel

Setting flaps 15°

Both actions reduce the angle of attack.

■ If the flaps are extended, do not retract them until the airframe is clear of ice.

Accretions collected with flaps 15° were found to be further aft and more severe than flaps 0°. Indeed, in flaps 15° configuration, the low angle of attack – especially close to VFE – increases the exposure of the upper side to large droplet impingement.

After this exposure, retracting flaps from 15° to 0° would increase the angle of attack, and the airflow could easily disrupt from the contaminated wing, resulting in a stall.

■ If the aircraft is not clear of ice, use flaps 15° for landing.

Ice contaminated tail stalls are almost always associated with flaps extension. Lowering the flaps increases the wing downwash, and thereby greatly increases the horizontal stabilizer's angle of attack.

Increasing tailplane angle of attack with ice on the tail can disrupt the airflow under the stabilizer and make the elevator less effective. The elevator may oscillate without pilot input and cause an uncommanded pitch change.

SEVERE ICING

MINIMUM ICING SPEED .... INCREASE RED BUG by 10 kt
PWR MGT .... MCT
CL/PL...... .... 100%/MCT
AP (if engaged) .... FIRMLY HOLD CONTROL WHEEL and DISENGAGE
SEVERE ICING CONDITIONS .... ESCAPE
ATC .... NOTIFY

■ **If an unusual roll response or uncommanded roll control movement is observed:**

Push firmly on the control wheel
FLAPS 15

■ **If the flaps are extended, do not retract them until the airframe is clear of ice.**

■ **If the aircraft is not clear of ice:**

GPWS .... FLAP OVRD
STEEP SLOPE APPROACH (≥ 4.5°) .... PROHIBITED
APP/LDG CONF .... MAINTAIN FLAPS 15
.... with "REDUCED FLAPS APP/LDG icing speeds" + 5 kt
Multiply landing distance FLAPS xx by yy, depending on aircraft.

DETECTION

Visual cue identifying severe icing is characterized by ice covering all or a substantial part of the unheated portion of either side window

and/or

Unexpected decrease in speed or rate of climb

and/or

The following secondary indications:

- Water splashing and streaming on the windshield
- Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice
- Accumulation of ice on the lower surface of the wing aft of the protected areas
- Accumulation of ice on propeller spinner farther aft than normally observed

The following weather conditions may be conducive to severe in-flight icing:

- Visible rain at temperatures close to 0°C ambient air temperature (SAT)
- Droplets that splash or splatter on impact at temperatures close to 0°C ambient air temperature (SAT).

Appendices

Glossary / Definitions

Anti-icing is a precautionary procedure, which provides protection against the formation of frost or ice and the accumulation of snow on treated surfaces of the aircraft, for a limited period of time (holdover time).

Anti-icing code describes the quality of the treatment the aircraft has received and provides information to determine the holdover time.

Aquaplaning or **hydroplaning** is a situation where the tires of the aircraft are, to a large extent, separated from the runway surface by a thin fluid film.

Braking action is a report on the conditions of the airport movement areas, providing pilots the quality or degree of braking that may be expected. Braking action is reported in terms of: good, medium to good, medium, medium to poor, poor, nil or unreliable.

Clear ice is a smooth compact rime, usually transparent, fairly amorphous, with a ragged surface, and morphologically similar to glaze.

Contaminated runway: A runway is considered to be contaminated when more than 25% of the runway surface area (whether in isolated areas or not) within the required length and width being used is covered by the following:

- Surface water more than 3 mm (0.125 in) deep, or slush, or loose snow, equivalent to more than 3 mm (0.125 in) of water; or
- Snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow); or
- Ice, including wet ice

Damp runway: A runway is considered damp when the surface is not dry, but when the moisture on its surface does not give it a shiny appearance.

De-icing is a procedure by which frost, ice, slush or snow is removed from the aircraft in order to provide clean surfaces. This procedure can be accomplished by mechanical methods or pneumatic methods or the use of heated fluids.
De/Anti-icing is a combination of the two procedures, de-icing and anti-icing, performed in one or two steps. A de-/anti-icing fluid, applied prior to the onset of freezing conditions, protects against the build up of frozen deposits for a certain period of time, depending on the fluid used and the intensity of precipitation. With continuing precipitation, holdover time will eventually run out and deposits will start to build up on exposed surfaces. However, the fluid film present will minimize the likelihood of these frozen deposits bonding to the structure, making subsequent de-icing much easier.

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

Dry runway: A dry runway is one which is neither wet nor contaminated, and includes those paved runways which have been specially prepared with grooves or porous pavement and maintained to retain "effectively dry" braking action, even when moisture is present.

Fluids (de-icing and anti-icing)

- De-icing fluids are:
  a) Heated water
  b) Newtonian fluid (ISO or SAE or AEA Type I in accordance with ISO 11075 specification)
  c) Mixtures of water and Type I fluid
  d) Non-Newtonian fluid (ISO or SAE or AEA Type II or IV in accordance with ISO 11078 specification)
  e) Mixtures of water and Type II or IV fluid

  De-icing fluid is normally applied heated to ensure maximum efficiency.

- Anti-icing fluids are:
  - a) Newtonian fluid (ISO or SAE or AEA Type I in accordance with ISO 11075 specification)
  - b) Mixtures of water and Type I fluid

The first two anti-icing fluids are normally applied heated at 60°C on clean aircraft surfaces.

  - c) Non-Newtonian fluid (ISO or SAE or AEA Type II or IV in accordance with ISO 11078 specification)
  - d) Mixtures of water and Type II or IV fluid

The last two anti-icing fluids are normally applied unheated on clean aircraft surfaces.

Freezing conditions are conditions in which the outside air temperature is below +3°C (37.4F) and visible moisture in any form (such as fog with visibility below 1.5 km, rain, snow, sleet or ice crystals) or standing water, slush, ice or snow is present on the runway.

Freezing fog (Metar code: FZFG) is a suspension of numerous tiny supercooled water droplets which freeze upon impact with ground or other exposed objects, generally reducing the horizontal visibility at the earth's surface to less than 1 km (5/8 mile).

Freezing drizzle (Metar code: FZDZ) is a fairly uniform precipitation composed exclusively of fine drops – diameter less than 0.5 mm (0.02 inch) – very close together which freeze upon impact with the ground or other objects.

Freezing rain (Metar code: FZRA) is a precipitation of liquid water particles which freeze upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5 mm (0.02 inch) diameter or smaller drops which, in contrast to drizzle, are widely separated.

Friction coefficient is the relationship between the friction force acting on the wheel and the normal force on the wheel. The normal force depends on the weight of the aircraft and the lift of the wings.

Frost is a deposit of ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects. Hoar frost (a rough white deposit of crystalline appearance formed at temperatures below freezing point) 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, brushing alone cannot clear hoar frost. Thin hoar frost is a uniform white deposit of fine crystalline texture, which is thin enough to distinguish surface features underneath, such as paint lines, markings, or lettering.

Glaze ice or rain ice is a smooth coating of clear ice formed when the temperature is below freezing and freezing rain contacts a solid surface. It can only be removed by de-icing fluid; hard or sharp tools should not be used to scrape or chip the ice off as this can result in damage to the aircraft.

Grooved runway: see dry runway.

Ground visibility: The visibility at an aerodrome, as reported by an accredited observer.

Hail (Metar code: GR) is a precipitation of small balls or pieces of ice, with a diameter ranging from 5 to 50 mm (0.2 to 2.0 inches), falling either separately or agglomerated.

Holdover time is the estimated time anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the protected surfaces of an aircraft, under (average) weather conditions mentioned in the guidelines for holdover time. The ISO/SAE specification states that the start of the holdover time is from the beginning of the anti-icing treatment.

Ice Pellets (Metar code PE) is a precipitation of transparent (sleet or grains of ice) or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 inch) or less. The pellets of ice usually bounce when hitting hard ground.

Icing conditions may be expected when the OAT (on the ground and for takeoff) is at or below 5°C or when TAT (in flight) is at or below 7°C, and there is visible moisture in the air (such as clouds, fog with low visibility of one mile or less, rain, snow, sleet, ice crystals) or standing water, slush, ice or snow is present on the taxiways or runways.

Icy runway: A runway is considered icy when its friction coefficient is 0.05 or below.

Light freezing rain is a precipitation of liquid water particles which freezes upon impact with exposed objects, in the form of drops of more than 0.5 mm (0.02 inch) which, in contrast to drizzle, are widely separated. Measured intensity of liquid water particles are up to 2.5 mm/hour (0.10 inch/hour) or 25 grams/dm²/hour with a maximum of 2.5 mm (0.10 inch) in 6 minutes.

Non-Newtonian fluids have characteristics that are dependent upon an applied force. The viscosity of Newtonian fluids depends on temperature only.

NOTAM is a notice containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

One-step de-/anti-icing is carried out with an anti-icing fluid, typically heated. The fluid used to de-ice the aircraft remains on aircraft surfaces to provide limited anti-ice capability.

Precipitation: Liquid or frozen water that falls from clouds as rain, drizzle, snow, hail, or sleet.
Continuous: Intensity changes gradually.
Intermittent: Intensity changes gradually, but precipitation stops and starts at least once within the hour preceding the observation.

Precipitation intensity is an indication of the amount of precipitation falling at the time of observation. It is expressed as light, moderate or heavy. Each intensity is defined with respect to the type of precipitation occurring, 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 the 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) diameter or of smaller widely scattered drops.

Rime (a rough white covering of ice deposited from fog at temperature below freezing). As the fog usually consists of super-cooled water drops, which only solidify on contact with a solid object, rime may form only on the windward side or edges and not on the surfaces. It can generally be removed by brushing, but when surfaces, as well as edges, are covered it will be necessary to use an approved de-icing fluid.

Saturation is the maximum amount of water vapor allowable in the air. It is about 0.5 g/m³ at −30 °C and 5 g/m³ at 0 °C for moderate altitudes.

Shear force is a force applied laterally on an anti-icing fluid. When applied to a Type II or IV fluid, the shear force will reduce the viscosity of the fluid; when the shear force is no longer applied, the anti-icing fluid should recover its viscosity. For instance, shear forces are applied whenever the fluid is pumped, forced through an orifice or when subjected to airflow. If excessive shear force is applied, the thickener system could be permanently degraded and the anti-icing fluid viscosity may not recover and may be at an unacceptable level.

SIGMET is an information issued by a meteorological watch office concerning the occurrence, or expected occurrence, of specified en-route weather phenomena, which may affect the safety of aircraft operations.

Sleet is a precipitation in the form of a mixture of rain and snow. For operation in light sleet treat as light freezing rain.

Slush is water saturated with snow, which spatters when stepping firmly on it. It is encountered at temperature around 5°C.

Snow (Metar code SN): Precipitation of ice crystals, most of which are branched, starshaped, or mixed without branched crystals. At temperatures higher than about –5 °C (23 °F), the crystals are generally agglomerated into snowflakes.

- Dry snow: Snow which can be blown if loose or, if compacted by hand, will fall apart upon release; specific gravity: up to but not including 0.35.

Dry snow is normally experienced when temperature is below freezing and can be brushed off easily from the aircraft.

- Wet snow: Snow which, if compacted by hand, will stick together and tend to or form a snowball. Specific gravity: 0.35 up to but not including 0.5. Wet snow is normally experienced when temperature is above freezing and is more difficult to remove from the aircraft structure than dry snow being sufficiently wet to adhere.
- Compacted snow: Snow which has been compressed into a solid mass that resists further compression and will hold together or break up into chunks if picked up. Specific gravity: 0.5 and over.

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

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

Supercooled water droplets is a condition where water remains liquid at negative Celsius temperature. Supercooled drops and droplets are thermodynamically unstable and freeze upon impact.

Two-step de-icing/anti-icing consists of two distinct steps. The first step (de-icing) is followed by the second step (anti-icing) as a separate fluid application. After de-icing a separate overspray of anti-icing fluid is applied to protect the relevant surfaces, thus providing maximum possible anti-ice capability.

Visibility: The ability, as determined by atmospheric conditions and expressed in units of distance, to see and identify prominent unlit objects by day and prominent lit objects by night.

Visible moisture: Fog, rain, snow, sleet, high humidity (condensation on surfaces), ice crystals or when taxiways and/or runways are contaminated by water, slush or snow.

Visual meteorological conditions: Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, equal to or better than specified minimums.

Wet runway: A runway is considered wet when the runway surface is covered with water, or equivalent, less than or equal to 3 mm or when there is sufficient moisture on the runway surface to cause it to appear reflective, but without significant areas of standing water.

Abbreviations

AAL	Above Aerodrome Level
AC	Advisory Circular
A/C	Aircraft
AEA	Association of European Airlines
AFM	Airplane Flight Manual
AGL	Above Ground Level
AIP	Aeronautical Information Publication
ALT	Altitude
ALTN	Alternate
AMSL	Above Mean Sea Level
AOA	Angle of Attack
AOC	Air Operator Certificate
AOT	All Operators Telex
APM	Aircraft Performance Monitoring
ASD	Accelerate-Stop Distance
ASTM	American Society for Testing and Materials
ATA	Aeronautical Transport Association
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATS	Air Traffic Service
AWO	All Weather Operations
°C	Degrees Celsius, Centigrade
CAPT	Captain
CAS	Calibrated Airspeed
CAT	Clear Air Turbulence
CAT I	Landing Category I (II or III)
CAVOK	Ceiling and Visibility OK
CG	Center of Gravity
C/L	Check List
Clouds	As: Altostratus, Ns: Nimbostratus, Sc: Stratocumulus, St: Stratus, Ac: Altocumulus, Cu: Cumulus, Cb: Cumulonimbus
cm	Centimeter
CM1/2	Crew Member 1 (LH) / 2 (RH)
CRT	Cathode Ray Tube
DA	Decision altitude
DBV	Diagonal Braked Vehicle
DFDR	Digital Flight Data Recorder
DET	Detection/Detector
DH	Decision Height
ENG	Engine

Abbreviations

ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
°F	Degrees Fahrenheit
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAR	Federal Aviation Regulations
FCOM	Flight Crew Operating Manual
FL	Flight Level
FLT	Flight
F/O	First Officer
FOD	Foreign Object Damage
F-PLN	Flight Plan
ft	Foot (Feet)
GA	Go Around
GMT	Greenwich Mean Time
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
GS	Ground Speed
G/S	Glide Slope
H	Hour
hPa	hecto Pascal
Hz	Hertz (cycles per second)
IAS	Indicated Air Speed
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrumental Meteorological Conditions
in	inch(es)
INOP	Inoperative
ISA	International Standard Atmosphere
ISO	International Standard Organization
JAA	Joint Aviation Authorities
JAR	Joint Aviation Regulations
K	Kelvin
kg	kilogram
kHz	kilohertz
km	kilometer
kt	knot
lb	pounds (weight)
LDA	Landing Distance Available
LDG	Landing

M	Mach
m	meter
MAPT	Missed Approach Point
MAX	Maximum
mb	Millibar
MDA/H	Minimum Descent Altitude / Height
MIN	Minimum
MLW	Maximum Landing weight
mm	Millimeter
MOCA	Minimum Obstruction Clearance Altitude
MORA	Minimum Off-Route Altitude
MPC	Multi Purpose Computer
ms	Millisecond
MSA	Minimum Safe (or Sector) Altitude
MSL	Mean Sea Level
MTOW	Maximum Take Off Weight
NA	Not Applicable
NAV	Navigation
NIL	No Item Listed (Nothing)
NM	Nautical Miles
NOTAM	Notice To Airmen
OAT	Outside Air Temperature
OCA/H	Obstacle Clearance Altitude / Height
OM	Outer Marker
PANS	Procedures for Air Navigation Services
PAX	Passenger
PERF	Performance
PIREP	Pilot Report
PSI	Pounds per Square Inch
QFE	Actual atmosphere pressure at airport elevation.
QNE	Sea level standard atmosphere (1013 hPa or 29.92" Hg)
QNH	Actual atmosphere pressure at sea level based on local station pressure.
QRH	Quick Reference Handbook
RA	Radio Altitude/Radio Altimeter
REF	Reference
RTOW	Regulatory Take Off Weight
RVR	Runway Visual Range
RWY	Runway
SAE	Society of Automotive Engineers
SAT	Static Air Temperature
SB	Service Bulletin
SFT	Saab Friction Tester

SID	Standard Instrument Departure
SOP	Standard Operating Procedures
STD	Standard
SYS	System
t	ton
T	Temperature
TAF	Terminal Aerodrome Forecast
TAS	True Air Speed
TAT	Total Air Temperature
TBC	To Be Confirmed
TBD	To Be Determined
TEMP	Temperature
T/O	Take-Off
TOD	Take-Off Distance
TOGA	Take-Off/Go-Around
TOR	Take-off Run
TOW	Take-Off Weight
UTC	Coordinated Universal Time
V1	Critical engine failure speed
V2	T/O safety speed
VAPP	Final approach speed
VFR	Visual Flight Rules
VHF	Very High Frequency (30 - 300 MHz)
VMC	Minimum control speed
VMU	Minimum unstick speed
VOR	VHF Omnidirectional Range
VR	Rotation speed
VREF	Landing reference speed
VS	Stalling speed (=VS1g for Airbus FBW aircraft)
WPT	Waypoint
WX	Weather
WXR	Weather Radar
Z	Zulu time (UTC)
ZFW	Zero Fuel Weight

1, allée Pierre Nadot – 31712 Blagnac Cedex – France
Phone: 33 (0)5 62 21 62 07 – Fax: (0)5 62 21 63 67
e-mail: atc@atr.fr

An Alenia Aeronautica and EADS joint venture