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Doc 9640

Manual of Aircraft Ground De-icing/Anti-icing Operations

Third Edition, 2018



Approved by and published under the authority of the Secretary General

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AMENDMENTS

Amendments are announced in the supplements to the *Products and Services Catalogue*; the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

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FOREWORD

Safe aeroplane operations during all types of weather conditions are of the utmost concern to all air carriers, airport authorities, air traffic control and users of air transport services. A review of the history of aeroplane accidents in the air transportation industry revealed that a substantial number are related to winter operations. An examination of these accidents showed a need for formally developed regulations and procedures governing aeroplane de-icing/anti-icing operations directed towards all segments of aviation including aeroplane manufacturers, airline operators and engineering, maintenance and service organizations. This material was intended, in particular, for use by flight crews of all aeroplane types and categories, as well as aeroplane maintenance and service personnel.

The International Air Transport Association (IATA) convened a Global De-icing/Anti-icing Task Force that met for the first time in Helsinki, Finland in September 1992. In October 1993, this task force became the IATA Global De-icing/Anti-icing Industry Forum. In a cooperative effort between IATA and ICAO, a drafting group was formed to develop a stand-alone ground de-icing/anti-icing document that would be published by ICAO. The meetings, convened throughout the year for the purpose of developing this document, were attended by representatives of civil aviation authorities, airline operators, aeroplane manufacturers, ground equipment and fluid manufacturers, pilot associations and airport authorities. The result was the publication of the first edition of the *Manual of Aircraft Ground De/Anti-icing Operations* (Doc 9640) in 1995. While a second edition was published in 2000, the information contained therein became increasingly out-of-date with modern methods and the document was discontinued in 2011.

This third edition of Doc 9640 is based largely on the latest information as described in SAE document AS6285, "Aircraft Ground Deicing/Anti-icing Processes". Established by the aircraft de-icing industry as directed by the "SAE ICAO IATA Council for Globalized Aircraft Deicing Standards", SAE document AS6285 comprises a summary of information essential to the planning and execution of de-icing/anti-icing operations during conditions that are conducive to aeroplane icing on the ground. Subsequently, the third edition of Doc 9640 contains general information intended to increase the basic understanding of aeroplane ground de-icing/anti-icing operations and to facilitate the development of standardized procedures and guidance material for the various segments of the aviation industry. It includes information on the full range of de-icing/anti-icing fluids and on data updating. The document provides a general description of the various factors relating to aeroplane icing on the ground and the minimum procedural requirements necessary for safe and efficient operations. It is the individual operator's responsibility, however, to comply with the requirements imposed by aeroplane, equipment and fluid manufacturers, regulatory and environmental authorities and individual operator programmes.

Additional reference material used to prepare this publication includes documentation from regulatory authorities, airlines, aeroplane manufacturers, equipment and fluid manufacturers, industry and academic, standardization and professional associations (see Publications for a complete listing). Although no reference is made in this document to any specific instructions or recommendations given by aeroplane, equipment or fluid manufacturers, nevertheless these must also be taken into consideration.

The images in Figures II-1-1, III-6-1, III-9-1 and III-10-1 were reproduced by kind permission of the National Aeronautics and Space Administration (NASA) and are found in the online training course entitled, “A Pilot’s Guide to Ground Icing” (<https://aircrafticing.grc.nasa.gov/>).

Suggestions for improving the format, content or presentation of this manual are welcome. Any such recommendation or suggestion will be examined and, if found suitable, will be included in regular updates to the manual. Regular revision will ensure that the manual remains both pertinent and accurate. Comments on this manual should be addressed to:

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TABLE OF CONTENTS

	<i>Page</i>
Foreword	(v)
Glossary of terms and abbreviations	(ix)
Publications	(xiii)
PART I — GENERAL.....	I-(i)
Chapter 1. Introduction	I-1-1
Chapter 2. The clean aircraft concept (CAC).....	I-2-1
Chapter 3. Ground de-icing/anti-icing programme elements	I-3-1
PART II — WEATHER AND ICING CONDITIONS	II-(i)
Chapter 1. Aeroplane icing on the ground	II-1-1
Chapter 2. Ice detection and warning systems	II-2-1
Chapter 3. Determination of precipitation type	II-3-1
PART III — DE-ICING/ANTI-ICING PROCESSES	III-(i)
Chapter 1. Roles and responsibilities	III-1-1
Chapter 2. Aeroplane ground de-icing/anti-icing alternatives	III-2-1
Chapter 3. Aeroplane ground de-icing/anti-icing fluids	III-3-1
Chapter 4. Holdover time (HOT).....	III-4-1
Chapter 5. Aerodrome de-icing/anti-icing facilities.....	III-5-1
Chapter 6. De-icing/anti-icing check procedures	III-6-1
Chapter 7. De-icing/anti-icing communications.....	III-7-1
Chapter 8. De-icing/anti-icing methods.....	III-8-1
Chapter 9. De-icing/anti-icing fluid residue	III-9-1
Chapter 10. Equipment.....	III-10-1
PART IV — TRAINING AND QUALITY ASSURANCE (QA).....	IV-(i)
Chapter 1. Training and qualifying of personnel	IV-1-1
Chapter 2. Quality assurance (QA) programme	IV-2-1

GLOSSARY OF TERMS AND ABBREVIATIONS

When the following terms are used in this manual, they have the meanings indicated below.

Active frost. A condition when frost is forming. Active frost occurs when the surface temperature is at or below 0°C and at or below the dew point.

Anti-icing. Anti-icing is a precautionary procedure by which clean aircraft surfaces are protected against the formation of ice and frost and the accumulation of snow and slush for a limited period of time.

Cold-soak effect. The wings of aeroplanes are said to be “cold-soaked” when they contain very cold fuel as a result of having just landed after a flight at high altitude or from having been refuelled with very cold fuel. The following factors contribute to cold-soaking: temperature and quantity of fuel in fuel cells, type and location of fuel cells, length of time at high altitude, temperature of refuelled fuel and time since refuelling.

Clear ice. Whenever precipitation falls on a cold-soaked aeroplane on the ground, clear icing may occur. Even in ambient temperatures between –2°C and +15°C, ice or frost can form in the presence of visible moisture or high humidity if the aeroplane structure remains at 0°C or below. Clear ice is very difficult to detect visually and may break loose during or after take-off.

Critical surfaces. The critical surfaces should be determined by the aircraft manufacturer, but may include the following: wings, control surfaces, propellers, horizontal stabilizers, vertical stabilizers or any other stabilizing surface on an aircraft. These surfaces should be completely free of ice, snow, slush or frost before take-off.

De-icing. The process that removes ice, snow, slush or frost from aircraft surfaces.

De-icing/anti-icing. A procedure combining both the de-icing process and the anti-icing process and that can be performed in one or two steps:

One-step de-icing/anti-icing. Heated anti-icing fluid is used to de-ice the aircraft and remains on the surfaces to provide anti-icing capability.

Two-step de-icing/anti-icing. This procedure contains two distinct steps. The first step, de-icing, is followed by the second step, anti-icing, as a separate fluid application.

Drizzle. Fairly uniform precipitation composed exclusively of fine drops (diameter less than 0.5 mm (0.02 in)) very close together. Drizzle appears to float while following air currents although, unlike fog droplets, drizzle falls to the ground.

Fog and ground fog. A visible aggregate of minute water particles (droplets) in the air reducing the horizontal visibility at the Earth's surface to less than 1 kilometre.

Freezing fog. A fog formed of supercooled water droplets that freeze upon contact with exposed objects and form a coating of rime/clear ice.

Freezing rain and freezing drizzle. Rain or drizzle in the form of supercooled water droplets that freeze upon impact with any surface.

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

High humidity. An atmospheric condition where the relative humidity is close to saturation.

Hoar frost. A greyish-white crystalline deposit of frozen water vapour formed on surfaces in clear, still weather.

Note.— This differs from the World Meteorological Organization definition of hoar frost for the purposes of this document.

Holdover time (HOT). The *estimated* amount of time that the anti-icing fluid will prevent the formation of ice and frost and the accumulation of snow on the protected (treated) surfaces of an aeroplane.

Precipitation intensity. Intensity of precipitation is an indication of the amount of precipitation collected per unit time interval. It is expressed as light, moderate or heavy. Intensity is defined according 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 criterion is based on time and does not accurately describe the intensity at a particular time of observation.

Rain. Precipitation of liquid water particles, either in the form of drops of more than 0.5 mm in diameter or smaller drops that, in contrast to drizzle, are widely separated.

Rime. A deposit of ice, produced by freezing of supercooled fog or cloud droplets on objects at temperatures below or slightly above freezing. It is composed of grains separated by air, sometimes adorned with crystalline branches.

Shear force. Shear force is a force applied laterally on an anti-icing fluid. When applied to a Type II, III 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 fluid viscosity may fall outside the range set by the manufacturer and tested for certification. Fluid degraded in this manner should not be used for operational purposes.

Slush. Water-saturated snow that will be displaced with a splatter by a heel-and-toe slap-down motion against the ground.

Snow. Precipitation of ice crystals, mostly branched in the form of six-pointed stars. The crystals are isolated or agglomerated to form snowflakes.

Dry snow. Snow from which a snowball cannot readily be made and that has a temperature less than 0°C.

Wet snow. Snow that contains a great deal of liquid water.

Visible moisture. Fog, rain, snow, sleet, high humidity (condensation on surfaces) and ice crystals can all produce visible moisture on aircraft, taxiways and runways exposed to and contaminated by these conditions.

ABBREVIATIONS

When the following abbreviations are used in this manual, they have the meanings indicated below.

APU	Auxiliary power unit
ATC	Air traffic control
CAA	Civil aviation authority
CAC	Clean aircraft concept
CSFF	Cold-soaked fuel frost
ERP	Emergency response plan
FAA	Federal Aviation Administration
HOT	Holdover time
IATA	International Air Transport Association
LWE	Liquid water equivalent
LWES	Liquid Water Equivalent System
METAR	Meteorological Terminal Air Report
NASA	National Aeronautics and Space Administration
QA	Quality assurance
SAE	Society of Automotive Engineers
TAF	Terminal Aerodrome Forecast
TC	Transport Canada

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PUBLICATIONS

(referred to in this manual)

ICAO PUBLICATIONS

Annexes to the Convention on International Civil Aviation

Annex 6 — *Operation of Aircraft, Part I — International Commercial Air Transport — Aeroplanes*

Annex 14 — *Aerodromes, Volume I — Aerodrome Design and Operations*

Procedures for Air Navigation Services

Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444)

OTHER PUBLICATIONS

SAE International Standards:

AMS1424N:	Deicing/Anti-Icing Fluid, Aircraft, SAE Type I
AMS1428J:	Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV
ARP4902B:	Design of Aircraft Deicing Facilities
ARP6257:	Aircraft Ground De/Anti-Icing Communication Phraseology for Flight and Ground Crews
AS5681:	Minimum Operational Performance Specification for Remote On-Ground Ice Detection Systems
AS6285:	Aircraft Ground Deicing/Anti-Icing Processes
AS6286:	Training and Qualification Program for Deicing/Anti-Icing of Aircraft on the Ground

Part I

GENERAL

I-(i)

Chapter 1

INTRODUCTION

1.1 As early as 1950, some States had established civil aviation regulations prohibiting take-off for aeroplanes with frost, snow or ice adhering to wings, propellers or control surfaces of the aeroplane. The effects of such icing are wide-ranging, unpredictable and dependent upon individual aeroplane design. The magnitude of these effects is dependent upon many variables, but the effects can be both significant and dangerous.

1.2 All aeroplanes are designed to fly clean. When an aeroplane is affected by snow, slush or ice (e.g., frost, ice pellets, hail) a potential safety hazard exists. Wind tunnel and flight tests indicate that ice, frost or snow formations with a thickness and surface roughness similar to medium or coarse sandpaper on the leading edge and upper surface of a wing can reduce wing lift by as much as 30 per cent and increase drag by up to 40 per cent. In addition, aeroplane efficiency decreases as a result of increased weight, increased stall speed, reduced lift, reduced stability and control, degraded thrust and increased drag; even seemingly insubstantial contamination such as frost may have a considerable adverse effect (see Figure I-1-1). Such contamination will significantly alter aeroplane flight characteristics. The primary influence is surface roughness relative to critical portions of an aerodynamic surface. However, contamination can also occur on the fuselage, landing gear, engine nacelles and so forth, and while frost on these surfaces does not directly affect lift, it still increases overall drag. Additionally, interference with control surfaces, brakes and landing gear and loss of radio communications may occur. Ice forming on pitot tubes and static ports or on angle of attack vanes may give false airspeed, angle of attack and engine power information for air data systems. Ice on critical surfaces and on the airframe may also break away during take-off and be ingested into engines, possibly damaging fan and compressor blades. It is therefore imperative that take-off not be attempted unless it has been ascertained that all critical surfaces of the aeroplane and all instrument probes are free of adhering snow, frost or other ice formations. This vital requirement is known as the “clean aircraft concept (CAC)” (see Part I, Chapter 2).

1.3 A wing has a critical angle of attack when the lift starts to decrease and the aeroplane is said to stall. Before the critical angle of attack, as angle of attack increases, more lift is produced. This is needed during take-off. When the wing is contaminated by small amounts of frost, the critical angle of attack is decreased and the airfoil may stall even before a stall warning.

1.4 Most aeroplanes used in commercial air transport operations, as well as some other aeroplane types, are certificated for flight in icing conditions. Certified aeroplanes were designed to have the capability to penetrate supercooled cloud icing conditions and have demonstrated this in flight. This capability is provided either by ice protection equipment installed on critical surfaces, such as the leading edge, or by demonstrating that the ice formed under supercooled cloud icing conditions on certain unprotected components will not significantly affect aeroplane performance, stability and control. Ice, frost and snow formed on these surfaces on the ground can have a totally different effect on aeroplane flight characteristics than ice formed in flight. Exposure on the ground to weather conditions that are conducive to ice formation can cause accumulation of frost, snow or ice on areas of the aeroplane where the ice protection provided is designed for in-flight use only. In addition, aeroplanes are certified and considered airworthy only after extensive flight tests have been performed. These test programmes are predominantly conducted with a clean aircraft flying in a clean environment with the exception of dedicated testing to assess the impact of icing in both natural icing conditions and using artificial ice shapes. If ice formations, other than those assessed in this dedicated testing are present, the airworthiness of the aeroplane may be invalid and no attempt should be made to fly the aeroplane until it has been restored to the clean configuration.

1.5 The common practice developed by the aviation industry, over many years of operational experience, is to de-ice/anti-ice an aeroplane prior to take-off. Various techniques for ground de-icing/anti-icing aeroplanes have been developed. The most common of these techniques is the use of freezing point depressant fluids to aid the ground de-icing/anti-icing process and to provide a protective anti-icing film to delay the formation of frost, snow or ice on aeroplane surfaces.

1.6 In scheduled airline operations where large numbers of aeroplanes are dispatched, the process of ensuring airworthiness must be a team effort, where each member of the team has specific duties and responsibilities (see Annex 6, Part I). In private aeroplane operations, all functions may be performed by only one person—the pilot. In all cases, the pilot-in-command has the ultimate responsibility of ascertaining that the aeroplane is safe for flight.

1.7 The only known method for positively ascertaining that an aeroplane is clean prior to take-off is by close inspection. Under conditions of precipitation or fog, or where moisture can be splashed, blown or sublimated onto critical surfaces in subfreezing weather, many factors influence whether and how much ice, frost or snow may accumulate and result in surface roughness. Even in above-freezing weather conditions, for aeroplanes that have just landed after descending from high altitude or have refuelled with very cold fuel, the wings may be colder than 0°C due to fuel in the wing tanks being well below zero. This cold-soak effect may cause ice or frost to form on the wing surfaces. Most of the factors that influence the accumulation of freezing precipitation and affect cold-soak are listed below:

- a) ambient temperature;
- b) relative humidity;
- c) precipitation type and rate;
- d) fog type and density;
- e) radiation cooling;
- f) wind speed and direction;
- g) aeroplane surface temperature (including the temperature of fuel in the wing tanks, i.e. 'cold soaked fuel frost' effect);
- h) presence of de-icing fluid;
- i) de-icing/anti-icing fluid type and temperature;
- j) de-icing/anti-icing fluid aqueous solution (strength);
- k) de-icing/anti-icing fluid application procedure;
- l) time elapsed since anti-icing treatment;
- m) operation in close proximity to other aeroplane jet blast, equipment and structures;
- n) operations on snow, slush or wet surfaces;
- o) aeroplane component inclination angle, contour and surface roughness; and
- p) conditions under which the aeroplane is parked (outside or fully or partially in the hangar).

1.8 It is essential for all personnel to recognize that final assurance for a safe take-off rests in a thorough pre-take-off check. Personnel must understand and have a thorough knowledge of the following:

- a) the adverse effects that ice, frost or snow on the critical surfaces and airframe can have on aeroplane performance and handling qualities;
- b) the various procedures that are available for aeroplane ground de-icing/anti-icing;
- c) the capabilities and limitations of these procedures;
- d) the variables that will influence the effectiveness of these procedures; and
- e) the critical areas of the particular aeroplane.

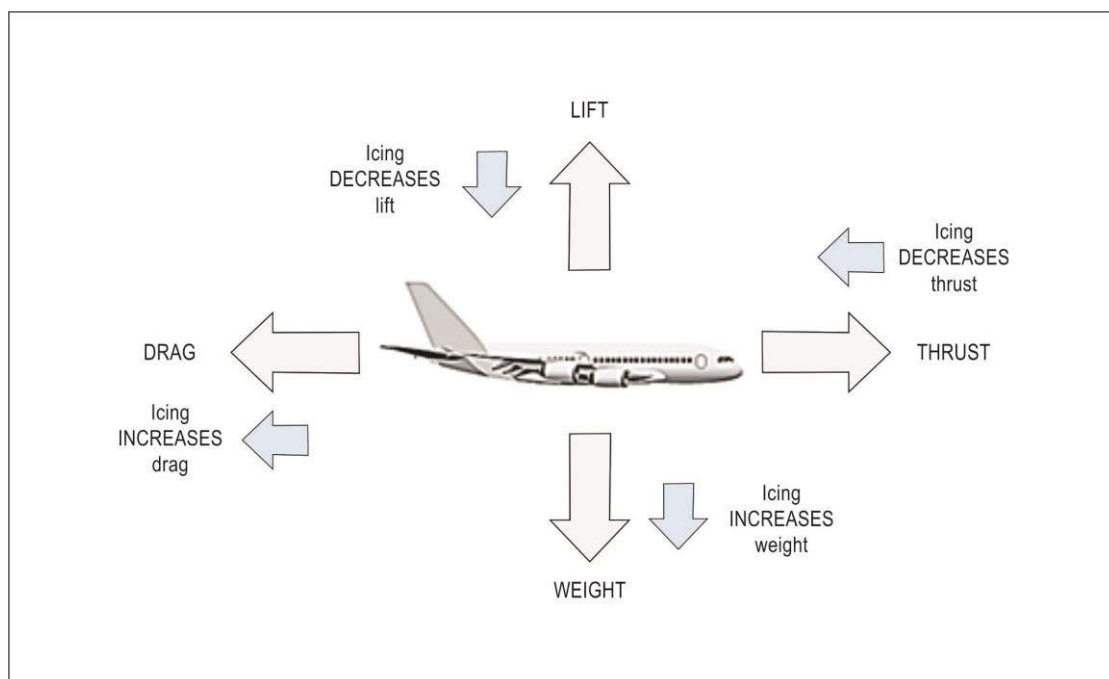


Figure I-1-1. The effects of icing on the forces of flight