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SPECIAL ISSUE

Protection Against Icing: A Comprehensive Overview

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In This Issue

Protection Against Icing: A Comprehensive Overview

An Urgent Safety Report

The laws of aerodynamics, which make flight possible, can be subverted in moments by a build-up of ice that in some situations is barely visible. During icing conditions, ground deicing and anti-icing procedures become an essential element in safe operations. Moreover, in-flight icing issues continue to be made more complex by a growing body of new knowledge, including refinements in our understanding of aerodynamics and weather.

This unprecedented multi-issue Flight Safety Digest *brings together a variety of informational and regulatory documents from U.S. and European sources. Collectively, they offer an overview of the knowledge concerning icing-related accident prevention.*

Documents included in this special report are from such widely divergent sources as the International Civil Aviation Organization (ICAO), the Association of European Airlines (AEA), the U.S. Federal Aviation Administration (FAA), the European Joint Aviation Authorities (JAA) and the Air Line Pilots Association, International (ALPA).

In addition, pertinent articles from FSF publications have been reprinted here.

The contents are organized into discrete sections, including:

- *Deicing/Anti-icing industry update and operational principles;*
- *A table and summaries of icing-related commercial aviation accidents for the years 1946–1996, compiled by the FSF editorial staff from various sources;*
- *Ground deicing and anti-icing;*
- *In-flight icing; and,*
- *Important resources.*

Published at the onset of the icing season in the northern hemisphere, this issue of Flight Safety Digest *deserves close reading by pilots, operations managers, ground crews and dispatchers. It represents another of FSF's contributions to the widest possible distribution of knowledge to enhance aviation safety.*

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Foreword

"Strange as it may seem, a very light coating of snow or ice, light enough to be hardly visible, will have a tremendous effect on reducing the performance of a modern airplane." These words are as true today as they were 58 years ago when Flight Safety Foundation (FSF) founder Jerome "Jerry" F. Lederer said them during a lecture on aviation safety. And despite new technology, training and procedures developed since then to address the problem, accidents related to icing conditions continue to occur.

This multi-issue *Flight Safety Digest* brings together a variety of major informational and regulatory documents issued by U.S. and European aviation authorities on the subject of icing-related accident prevention.

In the past 50 years, as shown by the table beginning on page 6 and accident summaries beginning on page 12, ice has played a role in numerous accidents that have killed crews and passengers and destroyed aircraft. The editorial staff gathered these data from diverse sources to create a single comprehensive record of the losses from icing-related accidents. Without any need for rhetoric, the table and summaries show, through statistics and factual narrative, the grim results of icing-related accidents.

No phase of operations is immune to the threat. Recent U.S. examples of icing encounters with fatal consequences include the following:

- A commuter flight impacted terrain during landing in December 1989, in Pasco, Washington, U.S., killing both crew members and all four passengers. The aircraft had been in icing conditions for about 10 minutes on approach;
- An air transport stalled on takeoff in March 1992, in Flushing, New York, U.S., killing two crew members and 25 passengers; 24 persons survived. The aircraft had been deiced twice before leaving the gate; and,
- A commuter flight went out of control in icing conditions and dived into a soybean field en route to Chicago, Illinois, U.S., in October 1994, killing all 68 aboard.

Icing-related accidents have captured the aviation industry's attention, and it is now widely understood that the problem is international, not just regional. Even the national air carriers of countries with balmy tropical climates are likely to fly to and from latitudes that can be gripped by icy conditions.

This issue of *Flight Safety Digest* — published at the onset of the icing season in the northern hemisphere — displays the international scope of efforts to guard against icing-related accidents. The issue would scarcely have been possible without the labors of the organizations whose work is included here. And they are by no means the only contributors to progress in deicing and anti-icing. Numerous other organizations and individuals — too many to recognize here without unfairly omitting some names — have played their valuable part.

In connection with this *Flight Safety Digest*, the editorial staff wishes to offer several special acknowledgments.

In the areas of standards, specifications and recommended practices, two organizations in particular have been at the leading edge: the Society of Automotive Engineers (SAE) Aerospace G-12 Committee and the International Standards Organization (ISO). Once again, teamwork has been the key to progress. SAE has coordinated its efforts with the FAA and Transport Canada (TC); ISO has combined efforts with the AEA. (For an update on the latest publications of these and other organizations, see "Deicing/Anti-icing Industry Update and Operational Principles," page 1.) It is largely to these organizations that the aviation industry owes thanks for, among other things, up-to-date worldwide standards for deicing and anti-icing fluids.

In 1992, two years before the most widely publicized recent icing-related accident, the International Air Transport Association (IATA) created an international task force led by IATA's Capt. Tore Granaas, Finnair's Capt. Jorma Eloranta and United Airlines' Capt. David Stoddard to draft a ground deicing/anti-icing manual to be published by the International Civil Aviation Organization (ICAO). (See "Manual of Aircraft Ground De/Anti-Icing Operations," page 43.) The meetings in which the document was developed were an outstanding example of industrywide action, encompassing civil aviation authorities, airlines, manufacturers, pilots, airport authorities and Flight Safety Foundation.

In still another example of evolving, internationally based guidance on icing-related accident avoidance procedures, the European Joint Aviation Authorities (JAA) continues to refine its Administrative & Guidance Material Section Four, Operations, Part Two: Procedures Joint Aviation Requirements Operations (JAR OPS). See the Temporary Guidance Leaflet (TGL), reprinted on page 103.

The Association of European Airlines (AEA), a long-time leader in ground deicing and anti-icing of aircraft, has demonstrated how effective measures can result from organizations working as a group to attack the icing problem. AEA, in a continuing campaign, has developed guidelines and methods for reducing the icing risk, especially regarding ground deicing and anti-icing of aircraft. (See "Recommendations for De-Icing/Anti-Icing of Aircraft on the Ground," page 110.)

Finnair invested considerable resources to identify and resolve the effects of wing icing caused by cold-soaked fuel (see "Small Airline Continues to Win Big Battle Against Aircraft Ground Icing," page 134). Under the leadership of Capt. Eloranta, this research resulted in improved ground deicing and anti-icing procedures. Moreover, Finnair developed a wing-ice detection device, which set the example for a still-burgeoning industry of products to detect wing ice. Eloranta's never-ending determination ensured that Finnair's findings and innovations were understood and shared throughout the industry.

As several documents adapted in this special issue attest, the U.S. Federal Aviation Administration (FAA) has undertaken major efforts in icing-related research and regulatory updates. The lengthy list of regulatory and advisory documents beginning on page 201, most of which were published by the FAA, shows the breadth of icing-accident preventive measures.

The contents of this special issue speak compellingly of the need for continuing research and development of technological safeguards for ground operations and flight in icing conditions. But improved equipment, and even improved operating procedures, do not in themselves guarantee safety. They must be applied with understanding. Pilots, air traffic controllers, ground crews and dispatchers must be fully knowledgeable about the effects of icing.

This *Flight Safety Digest* is dedicated to helping educate all personnel associated with flight operations in icing conditions. This is not the last word on the subject; nothing could be, because research and experience create new issues and insights. As a whole, this special issue offers a sobering reminder that in this aspect of aviation, there can be no such thing as too much vigilance.♦

Deicing/Anti-icing Industry Update and Operational Principles

John Posta
Delta Air Lines

Update

The airline industry, in concert with the U.S. Federal Aviation Administration (FAA), the European Joint Aviation Authorities (JAA), Transport Canada (TC), the International Civil Aviation Organization (ICAO) and several other international regulatory agencies, has made tremendous steps to swiftly address safety during winter weather operations. Their efforts have focused on expanding research, enhancing deicing/anti-icing procedures and ensuring proper and thorough training of all personnel involved.

Organizations such as the Society of Automotive Engineers (SAE), Association of European Airlines (AEA), International Standards Organization (ISO) and International Air Transport Association (IATA) have coordinated ongoing technical and operational efforts to provide the airlines and regulatory agencies with the latest guidance. Nevertheless, the transition time to update these documents with the latest technological developments, advancements and standards is slowed by lengthy balloting processes. This causes airlines and agencies throughout the world to fall short of meeting the ultimate goal: to have the most efficient, effective and safe deicing/anti-icing program for the upcoming season. We must expedite the balloting process and strive to incorporate the latest changes and updates into our programs in a timely manner.

The following is an update on several associations in the industry.

AEA. The Association of European Airlines (AEA) Task Force establishes deicing/anti-icing fluid specifications, minimum requirements for deicing/anti-icing procedures and operational requirements for deicing/anti-icing equipment. The AEA has published a deicing awareness booklet and is currently updating its *Recommendations for De-Icing/Anti-Icing of Aircraft on the Ground* (reprinted in this issue, page 110), and addressing standardized deicing contracts, training standards, quality control audit programs, local wing-area frost prevention procedures, Type II and Type IV fluid behavior problems, off-gate procedures and operational issues. The AEA is coordinating its efforts with the JAA. The JAA is publishing Technical Guidance Letter (OPS) 1.345 (A), *Ice and Other Contaminants*. For more information on the AEA Deicing Task Force, contact the chairman, Adriaan Gerritsen at KLM Royal Dutch Airlines, telephone: + 31-20-6490559.

SAE. The Society of Automotive Engineers Aerospace G-12 Committee develops specifications, standards and recommended practices on deicing/anti-icing methods, fluids, deicing facilities, holdover times, ice detection, training requirements, equipment and future deicing technology. The SAE is coordinating its efforts with the FAA and TC. The FAA is publishing a Flight Standards Information Bulletin for Air Transportation (FSAT) on Deicing/Anti-icing. The SAE G-12 subcommittees are responsible for the following documents:

- Aerospace Materials Specification (AMS) 1424A, *Deicing/Anti-icing Fluid* [Newtonian], *Aircraft, SAE Type I*.

- AMS 1428B, *Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian (Pseudoplastic), SAE Types II, III and IV*, is expected to be updated at the October 1997 meeting. This document is being updated to address fluid dry-out problems, primarily with Type IV fluid. Wind tunnel testing certification, to test the fluids for aerodynamic acceptance, is proceeding as scheduled.

- Aerospace Recommended Practice (ARP) 4737B, *Aircraft Deicing/Anti-icing Methods with Fluids*, is being updated and going out for balloting. This is primarily to incorporate the revised Type II and Type IV holdover time tables and the new Type III table.

- ARP 4902, *Design and Operation of Deicing Facilities*, has been balloted and approved by the Aerospace Council and published.

- Aerospace Standard (AS) 116, *Ice Detection*, is published.

- ARP 5149, *Training Requirements for Deicing*, is published.

- AMS 1431A, *Compound, Solid Deicing/Anti-Icing Runways and Taxiways*, and AMS 1435, *Fluid, Generic, Deicing/Anti-Icing Runways and Taxiways,* have been published and are to be revised in October 1997.

For more information on the SAE G-12 Committee, contact Gina Saxton at SAE, telephone: + (412) 776-4841, extension 7319.

IATA. The International Air Transport Association Global Deicing/Anti-icing Working Group produced a deicing/anti-icing operations manual for the ICAO global safety standards and operations manuals linked to mandated procedures for member states. Dedicated international representatives produced the following document:

- Doc. 9640-AN/940, *Manual of Aircraft Ground Deicing/Anti-icing Operations*.

This document is being updated and several additional chapters are expected to be added. For more information on the IATA Global Deicing/Anti-icing Working Group: Capt. Tore Granaas or Capt. Ashok Poduval at IATA, telephone: + (514) 844-6311.

ISO. Teamwork and cooperation are the key factors in accomplishing the goal of safe winter weather operations. The AEA and SAE have shown that this is possible by their diligent and dedicated work together. The AEA and SAE are combining efforts with changes/updates to the ISO documents. This is assigned to the ISO Deicing Working Group, made up of AEA and SAE representatives and chaired by Adriaan Gerritsen of KLM.

The following ISO documents are being revised to recognize SAE specifications:

- ISO 11075, *Aerospace — Aircraft Deicing/Anti-icing Newtonian Fluids, ISO Type I*.

- ISO 11076, *Aerospace — Deicing/Anti-icing Methods with Fluids*.

- ISO 11077, *Aerospace — Self-propelled Deicing/Anti-icing Vehicles — Functional Requirements*.

- ISO 11078, *Aerospace — Aircraft Deicing/Anti-icing Non-Newtonian Fluids, ISO Type II*.

Deicing/Anti-icing Operational Principles

A number of operational principles concerning ground deicing/anti-icing must be understood:

- Our responsibility is ensuring compliance with the clean aircraft concept. The captain has the final authority to determine if the aircraft is airworthy and can operate safely after being deiced/anti-iced. Nevertheless, the ground deicing crew shares in this responsibility by providing an aircraft that complies with the clean aircraft concept.

- Deicing is a procedure for removing frozen contamination from aircraft surfaces to provide a clean surface. Normally this is done using heated (deicing) fluids.

- Anti-icing is a precautionary procedure that protects against the formation of frozen contaminates on treated surfaces of the aircraft for a limited period (the holdover time).

- Deicing/anti-icing is a combination of the deicing and anti-icing procedures. It can be performed in a one-step or two-step operation.

- The one-step procedure is a combination of deicing and anti-icing performed at the same time with the same fluid. The fluid is heated and remains on the aircraft to provide anti-icing protection. This procedure can be repeated so as to minimize the time required to complete the final application.

- The two-step procedure consists of two distinct fluid applications. The first step, deicing with a heated fluid, is followed by the second step, anti-icing as a separate fluid application. Normally, Type II or Type IV fluid is used during the second step, but Type I fluid may be used.

- Type I fluid is an unthickened fluid that is normally applied as a mixture of glycol and water. Mainly, this fluid provides protection against refreezing when there is no delay or a minimal delay between deicing/anti-icing and takeoff and when there is not a high liquid content of freezing precipitation.

- Type II fluid is a thickened fluid that provides protection against refreezing for longer periods and can be used when longer delays are anticipated. Protection time is increased compared with Type I fluid during weather conditions with high liquid content. Type II fluid provides greater protection than Type I fluid against ice, frost or snow.

- Type IV fluid is an enhanced-performance fluid with characteristics similar to Type II. Its anti-icing effectiveness is superior to Type II fluid and holdover time (HOT) is increased significantly under most conditions.

- HOT is the estimated time that the anti-icing fluid will prevent the formation of frozen contaminates on treated surfaces of the aircraft during ground operations. HOTs are used with an operator's approved program and can be developed by the operator, provided they are more conservative than those in the currently approved tables. The HOTs are intended to be used as operational guidelines for departure planning and are used in conjunction with a check of the aircraft surfaces. Because of the many factors that affect HOTs they will never be more than estimates of the fluids' effectiveness. These factors include:
  - Aircraft component angle, contour and surface roughness;
  - Ambient temperature;
  - Aircraft skin temperature;
  - Fluid type;
  - Fluid application procedure;
  - Fluid dilution/strength;
  - Fluid film thickness;
  - Fluid temperature;
  - Operation in close proximity to other aircraft, equipment and structures;
  - Operation on snow or slush or wet ramps, taxiways and runways;
  - Precipitation type and intensity (rate, density and moisture content);
  - Presence of fluid;
  - Radiation cooling;
  - Residual moisture on aircraft surface;
  - Relative humidity;
  - Solar radiation; and,
  - Wind direction and velocity.

Holdover times are only estimates. Only if a scientific number could be derived to cover all these variables could the pilot determine an exact number for the HOT.

- The HOT is determined by the pilot based on the following information:

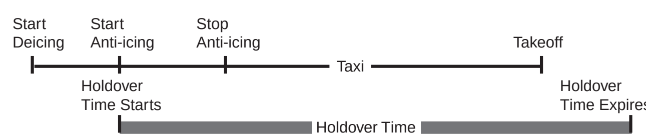
  Precipitation type and intensity — when determining intensity consider the rate, density and moisture content of the precipitation, environmental conditions, aircraft skin temperature and operational experience of the pilot. Because the HOT is only an estimate by the pilot, it will vary based on pilot awareness, experience and degree of conservatism.

- The HOT begins when the final application of deicing/anti-icing fluid begins. During some weather conditions aircraft may have to be deiced/anti-iced several times. Therefore, only the ground deicing/anti-icing crew knows the start time of the final application. The ground crew communicates to the flight crew the start time of the final application of fluid and other necessary information, e.g., type of fluid and percent of glycol mix for Type II and Type IV, and that the aircraft critical surfaces have been checked.

- HOTs do not mean that it is safe to take off in all weather conditions. The deicing/anti-icing fluids provide no protection in flight. Therefore, during the HOT, pilot vigilance and awareness are necessary to avoid takeoff in precipitation conditions in which the aircraft is not certificated to fly.

- The tables are only for six types of weather conditions: frost, freezing fog, snow, freezing drizzle, light freezing rain and rain on cold-soaked wing. The times listed depend on the type of anti-icing fluid, weather and temperature.

- Takeoff should occur before the determined holdover time expires, as shown below.



- When determining the HOT, pilots must consider the numerous factors that affect the fluid's ability to provide protection against frozen contamination. Therefore, the HOT is only approximate and must be adjusted after considering all the variables.

- Precipitation categories specify a time range or a single time. Generally, when a range is given the lower time is for moderate conditions and the upper time is for light conditions. During heavy weather conditions the HOT will be less than the lower time in the range. When a single time is given it may be necessary to adjust the HOT downward after considering all the variables.

- It will be necessary to adjust the HOT based on the numerous factors mentioned earlier.

- The HOT expires when the applied fluid loses its effectiveness or when the time determined by the flight crew expires.♦

About the Author

John Posta, coordinator, flight control programs, Delta Air Lines, is a member of the IATA Global Deicing/Anti-icing Working Group, the SAE G-12 Steering Committee and the ISO Deicing Working Group.

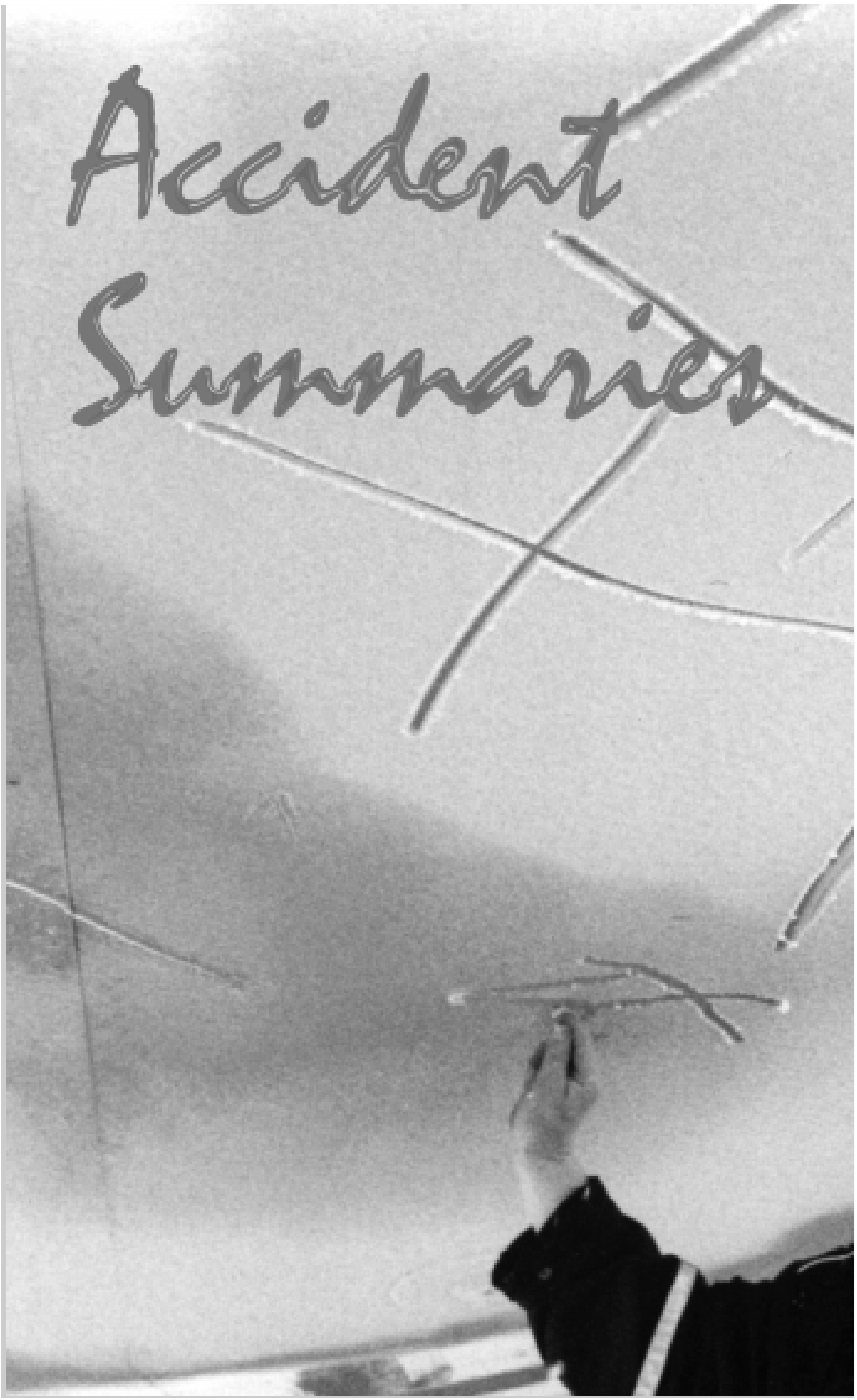

Accident
Summaries

Table 1
Icing-related Commercial Aviation Accidents, 1946–1996

FSF Editorial Staff

The data in this table and the icing-related aircraft accident summaries in the next section were drawn from briefs of accidents by the U.S. National Transportation Safety Board (NTSB); individual NTSB official accident reports; Volumes 1 and 2 of the U.K. Civil Aviation Authority publication, *World Aviation Accident Summary*; Airclaims *Major Loss Record*; *Flight International*; and Flight Safety Foundation's in-house resources. There may be many other icing-related accidents that do not appear in this table, which is not intended as the final word on icing-related accidents. Although the editorial staff made major efforts to ensure the accuracy and clarity of the information, minimal data were available in some reports.

Table 1
Icing-related Commercial Aviation Accidents, 1946–1996

Date	Aircraft	Operator	Location	Number of Injuries
May 26, 1996	British Aerospace BAe 146	Air Wisconsin	Des Moines, Iowa, U.S.	none
March 2, 1995	Cessna 208B	Martinaire	Ardmore, Oklahoma, U.S.	1 minor or none
Oct. 31, 1994	Avions de Transport Regional ATR-72-212	American Eagle	Roselawn, Indiana, U.S.	68 fatal
Feb. 24, 1994	Antonov An-12	North Western Air Transport Directorate	Nalchik, Russia	13 fatal
Feb. 24, 1994	Vickers Viscount 813	British World Airways	Near Uttoxeter, England	1 fatal, 1 serious
March 5, 1993	Fokker F-100	Palair Macedonian Airlines	Skopje, Macedonia	81 fatal, 16 serious
Jan. 2, 1993	Saab 340A	Express I	Hibbing, Minnesota, U.S.	31 minor or none
March 22, 1992	Fokker F-28	USAir	Flushing, New York, U.S.	27 fatal, 9 serious, 15 minor or none
Dec. 27, 1991	McDonnell Douglas MD-81	Scandinavian Airlines System	Stockholm, Sweden	8 serious, 121 minor or none
Feb. 17, 1991	Douglas DC-9	Ryan International Airlines	Cleveland, Ohio, U.S.	2 fatal
Jan. 30, 1991	British Aerospace Jetstream 31	Carolina Commuter Air	Beckley, West Virginia, U.S.	13 serious, 6 minor or none
Jan. 26, 1990	Mitsubishi MU-2B-60	Great Western Aviation	Near Meekatharra, Australia	2 fatal
Dec. 26, 1989	British Aerospace Jetstream 31	NPA United Express	Pasco, Washington, U.S.	6 fatal
Nov. 25, 1989	Fokker F-28	Korean Air	Kimpo, Korea	6 serious, 42 minor or none
March 15, 1989	Nihon Aeroplane Manufacturing Co. NAMC YS-11	Mid Pacific Airlines	Purdue University, Indiana, U.S.	2 fatal
March 3, 1989	Fokker F-28	Air Ontario	Dryden, Ontario, Canada	24 fatal, 45 serious
Dec. 21, 1988	Cessna 207	Baker Aviation	Kotzebue, Alaska, U.S.	6 minor or none
Dec. 16, 1988	Mitsubishi MU-2B-60	Broughton Air Services	Near Leonora Airfield, Australia	10 fatal
Jan. 10, 1988	NAMC YS-11	Tao Domestic	Honshu, Japan	52 minor or none
Dec. 17, 1987	Swearingen SA-226	Avair	Chantilly, Virginia, U.S.	1 serious, 7 minor or none
Nov. 23, 1987	Beechcraft 1900	Ryan Air Service	Near Homer, Alaska, U.S.	18 fatal, 3 serious
Nov. 15, 1987	McDonnell Douglas DC-9-14	Continental Airlines	Denver, Colorado, U.S.	28 fatal, 28 serious, 26 minor or none
Oct. 15, 1987	International (Aeritalia and Aerospatiale) ATR-42	Aero Transporti Italiani	Mount Crezzo, Italy	37 fatal
Feb. 21, 1987	Fokker F-28		Reykjavik, Iceland	6 minor or none
Jan. 18, 1987	Fokker F-27	British Midland Airways	Castle Donington Race Track, England	3 serious
Jan. 6, 1987	Aerospatiale Caravelle 12	Transwede	Stockholm, Sweden	27 minor or none
Dec. 15, 1986	Antonov An-24	CAAC	Near Lanzhou, China	6 fatal, 18 serious, 20 minor or none
May 16, 1986	Beech 99C	Centennial Airlines	Laramie, Wyoming, U.S.	9 minor or none

Table 1
Icing-related Commercial Aviation Accidents, 1946–1996 (continued)

Date	Aircraft	Operator	Location	Number of Injuries
Jan. 31, 1986	Shorts SD3-60	Aer Lingus Commuter	East Midlands Airport, England	2 serious, 34 minor or none
Dec. 15, 1985	Cessna C-207	Ryan Air Service	Napaskiak, Alaska, U.S.	4 serious
Dec. 15, 1985	Douglas DC-3		Dillingham, Alaska, U.S.	3 minor or none
Dec. 12, 1985	Douglas DC-8	Arrow Air	Gander, Newfoundland, Canada	256 fatal
March 12, 1985	de Havilland DHC-6	Sea Airmotive	Barter Island, Alaska, U.S.	2 serious, 2 minor or none
Feb. 5, 1985	Douglas DC-9-15	Airborne Express	Philadelphia, Pennsylvania, U.S.	2 serious
Feb. 5, 1985	Douglas DC-3	BO-S-AIRE Airlines	Charlotte, North Carolina, U.S.	2 minor or none
Feb. 4, 1985	Beech 65-A80	North Pacific Airlines	Soldotna, Alaska, U.S.	9 fatal
Jan. 13, 1984	Fokker F-27	Pilgrim Airlines	New York, New York, U.S.	1 serious, 23 minor or none
Dec. 21, 1983	Beechcraft 200		Detroit, Michigan, U.S.	4 minor or none
Jan. 13, 1982	Boeing 737-222	Air Florida	Washington, D.C., U.S.	78 fatal, 6 serious, 3 minor or none
Dec. 16, 1981	Boeing 727	Sterling Airways	Gander, Newfoundland, Canada	180 minor or none
Jan. 16, 1981	Douglas DC-6A	Northern Air Cargo	Near Gambell, Alaska, U.S.	3 minor or none
Dec. 25, 1980	Dee Howard 500		Toronto, Ontario, Canada	3 minor or none
April 24, 1980	Beech 18S		Cedar Rapids, Iowa, U.S.	1 minor or none
March 2, 1980	On Mark B-26 Invader		California, U.S.	4 fatal
Feb. 16, 1980	Bristol Britannia 253F	Redcoat Air Cargo	Billerica, Massachusetts, U.S.	7 fatal, 1 serious
Nov. 23, 1979	Scottish Aviation Twin Pioneer		Anchorage, Alaska, U.S.	2 minor or none
Nov. 19, 1979	Cessna Citation		Castle Rock, Colorado, U.S.	2 fatal, 1 serious
April 4, 1979	Beech E18		Newburgh, New York, U.S.	1 serious
March 17, 1979	Tupolev Tu-104	Aeroflot	Near Moscow, Russia	90 fatal
Feb. 12, 1979	Frakes Mohawk 298	USAir	Clarksburg, West Virginia, U.S.	2 fatal, 8 serious, 15 minor or none
Jan. 19, 1979	Learjet 25D	Massey Ferguson	Detroit, Michigan, U.S.	6 fatal
Jan. 19, 1979	Piper Aerostar 601		Grand Rapids, Michigan, U.S.	4 fatal, 2 serious
Dec. 7, 1978	Cessna 401A		Rockford, Illinois, U.S.	2 minor or none
Dec. 4, 1978	de Havilland DHC-6		Steamboat Springs, Colorado, U.S.	2 fatal, 14 serious, 6 minor or none
Dec. 4, 1978	Gates Learjet 25B		Anchorage, Alaska, U.S.	5 fatal, 2 serious
Dec. 2, 1978	Douglas DC-3		Des Moines, Iowa, U.S.	2 serious
Nov. 27, 1978	Douglas DC-9	Trans World Airways	Newark, New Jersey, U.S.	none
Nov. 16, 1978	Beech G18S		Hays, Kansas, U.S.	2 fatal
Mar. 18, 1978	Beech A65 Queen Air	Vernair Transport Services	Near Angmagssalik, Greenland	2 fatal
Feb. 19, 1977	Aero Commander 680 FL		Savoonga, Alaska, U.S.	2 serious, 1 minor or none

Table 1
Icing-related Commercial Aviation Accidents, 1946–1996 (continued)

Date	Aircraft	Operator	Location	Number of Injuries
Jan. 31, 1977	Chase YC122		Anchorage, Alaska, U.S.	1 fatal, 2 serious
Jan. 15, 1977	Vickers Viscount	Linjeflyg	Near Bromma Airport, Stockholm, Sweden	22 fatal
Jan. 13, 1977	Douglas DC-8	Japan Airlines	Anchorage, Alaska, U.S.	5 fatal
Nov. 29, 1976	de Havilland DH-104		Albany, New York, U.S.	6 minor or none
March 16, 1976	Beech 99		Wappingers Falls, New York, U.S.	1 serious, 8 minor or none
Nov. 24, 1975	Beech E18S		Fort Wayne, Indiana, U.S.	1 minor or none
March 12, 1975	Beech 95-C55		Gaylord, Michigan, U.S.	1 minor or none
Feb. 21, 1975	Gates Learjet 25		Albuquerque, New Mexico, U.S.	9 minor or none
Jan. 31, 1975	Cessna 402B		Dodge City, Kansas, U.S.	1 serious, 2 minor or none
Jan. 14, 1975	Beech TC-45J		Evansville, Indiana, U.S.	2 minor or none
Jan. 2, 1975	Beech E18S		Rockford, Illinois, U.S.	1 fatal, 2 serious
Dec. 1, 1974	Boeing 727	Northwest Airlines	Near Stony Brook, New York, U.S.	3 fatal
Jan. 26, 1974	Fokker F-28	THY	Cumaovasi, Turkey	66 fatal, 7 serious
Jan. 6, 1974	Beech 99A		Johnstown, Pennsylvania, U.S.	12 fatal, 5 serious
Oct. 31, 1973	Douglas DC-3	Superior Airways	Wiebenville, Canada	3 minor or none
March 3, 1973	Ilyushin Il-18	Balkan-Bulgarian Airlines	Moscow, Russia	25 fatal
Dec. 6, 1972	Douglas DC-3	Superior Airways	Canada	3 minor or none
March 15, 1972	Aircraft not identified		Brook Park, Ohio, U.S.	1 fatal
Feb. 16, 1972	Beech D18S		Jackson, Michigan, U.S.	2 fatal
Jan. 30, 1972	Douglas DC-3	Douglas Aircraft Company	Boyne Falls, Michigan, U.S.	12 minor or none
Dec. 16, 1971	Beech 65-B80		McCall, Idaho, U.S.	1 serious, 3 minor or none
Dec. 8, 1971	Beech Volpar		Grand Island, Nebraska, U.S.	1 minor or none
March 18, 1971	Beech TC-45H		Chicago, Illinois, U.S.	1 minor or none
Dec. 23, 1970	Beech H18S		Lansing, Michigan, U.S.	2 serious
March 22, 1970	Beech C-45H		Binghamton, New York, U.S.	3 fatal, 8 serious
Feb. 14, 1970	Beech E18S		Kansas City, Kansas, U.S.	1 fatal
Feb. 9, 1970	Hawker Siddeley Comet 4C	UAA	Riem Airport, Munich, Germany	23 minor or none
Jan. 22, 1970	Aero Commander 680 V		Aspen, Colorado, U.S.	8 fatal
Dec. 5, 1969	Lockheed 18 (Lodestar)		Albuquerque, New Mexico, U.S.	11 fatal
Dec. 4, 1969	Aero Commander AC1121B	Ehrenstroms Flyg	Stockholm, Sweden	2 fatal
Oct. 3, 1969	Beech 65-B80		Denver, Colorado, U.S.	5 fatal, 2 serious
March 25, 1969	Cessna 402		Chicago, Illinois, U.S.	8 minor or none

Table 1
Icing-related Commercial Aviation Accidents, 1946–1996 (continued)

Date	Aircraft	Operator	Location	Number of Injuries
Feb. 25, 1969	Fokker F-28	LTU International Airways	Lapenhagen, Netherlands	11 minor or none
Feb. 1, 1969	Beech D18S		Kansas City, Missouri, U.S.	2 serious
Dec. 27, 1968	Douglas DC-9	Ozark Airlines	Sioux City, Iowa, U.S.	3 serious, 65 minor or none
Dec. 18, 1968	Beech G18S		Kenai, Alaska, U.S.	4 serious, 5 minor or none
July 1, 1968	Aero Commander Jet Commander		Drake Field, Arkansas, U.S.	1 fatal
Jan. 15, 1968	Douglas DC-3	UAA	Zifta, United Arab Republic	4 fatal
Oct. 25, 1967	Gates Learjet 23	Executive Jet Aviation	Muskegon, Michigan, U.S.	4 minor or none
March 10, 1967	Fairchild F-27	West Coast Airlines	Klamath Falls, Oregon, U.S.	4 fatal
Nov. 19, 1966	Curtiss C46F		Keflavik, Iceland	2 minor or none
March 18, 1966	Gates Learjet	Mutual Insurance	Lake Michigan, U.S.	2 minor or none
Dec. 20, 1965	Grumman Gulfstream	Northern Consolidated Airlines	Bethel, Alaska, U.S.	8 minor or none
Nov. 20, 1964	Curtiss C46	Zantop Airways	Detroit, Michigan, U.S.	2 minor or none
March 10, 1964	Douglas DC-4	Slick Airways	Boston, Massachusetts, U.S.	3 fatal
March 8, 1964	Douglas DC-3A	Snow Valley Ski	Chicago, Illinois, U.S.	1 fatal, 1 serious, 34 minor or none
Dec. 21, 1963	Convair 440		Midland, Texas, U.S.	4 serious
Jan. 29, 1963	Vickers Viscount 810	Continental Airlines	Kansas City, Missouri, U.S.	8 fatal
Feb. 13, 1960	Curtiss C46	Associated Air Transportation	McGuire Air Force Base, New Jersey, U.S.	57 minor or none
Jan. 18, 1960	Vickers Viscount	Capital Airlines	Charles City, Virginia, U.S.	50 fatal
Feb. 1, 1959	Douglas DC-3	General Airways	Kerrville, Texas, U.S.	3 fatal, 4 serious, 21 minor or none
Dec. 4, 1958	Sud-est SE161 (Languedoc)	AVIACO	Guadarrama Mountains, Spain	21 fatal
April 6, 1958	Vickers Viscount 745	Capital Airlines	Freeland, Michigan, U.S.	47 fatal
Feb. 6, 1958	Airspeed Ambassador	BEA	Riem Airport, Munich, Germany	23 fatal, 12 serious, 9 minor or none
Dec. 6, 1957	L-1049G	Air France	Orly Airport, Paris, France	6 minor or none
Nov. 17, 1957	Vickers Viscount 802	BEAC	Near Copenhagen, Denmark	2 minor or none
Oct. 4, 1957	Douglas DC-3	Eldorado	Fort McMurray, Alberta, Canada	2 serious
Nov. 7, 1956	de Havilland Heron II	Braathens SAFE	Hommelfjell, Tolga, Norway	2 fatal, 10 serious or minor
Jan. 17, 1956	Douglas DC-3C	Quebecair	Oreway, Labrador, Canada	4 fatal, 2 serious, 12 minor or none
Dec. 29, 1955	Lockheed 18 (Lodestar)	Gulf Refining	Near Londonderry, Ohio, U.S.	2 fatal
Feb. 26, 1954	Convair 240	Western	Near Wright, Wyoming, U.S.	9 fatal
Feb. 5, 1954	Curtiss C46F	Flying Tiger	Romulus, Michigan, U.S.	2 minor or none
Jan. 20, 1954	Douglas DC-3A	Zantop Airways	Near Kansas City, Missouri, U.S.	3 fatal
Jan. 7, 1953	Curtiss C46F	Associated Air Transportation	Fish Haven, Idaho, U.S.	40 fatal

Table 1
Icing-related Commercial Aviation Accidents, 1946–1996 (continued)

Date	Aircraft	Operator	Location	Number of Injuries
Nov. 1, 1951	Curtiss C46F	Flying Tiger	Cleveland, Ohio, U.S.	3 minor or none
Aug. 8, 1951	Douglas DC-3	TAA	Barilla Bay, Tasmania, Australia	2 fatal
March 27, 1951	Douglas DC-3 (Dakota)	Air Transport Charter	Near Ringway Airport, Manchester, England	2 fatal, 1 serious
Feb. 23, 1951	Curtiss C46E	Slick Airways	Newhall, California, U.S.	3 minor or none
Feb. 16, 1950	Douglas DC-3	Eastern Airlines	Lexington, Kentucky, U.S.	18 minor or none
Oct. 9, 1949	Curtiss C46F	Slick Airways	Cheyenne, Wyoming, U.S.	3 fatal
March 2, 1949	Douglas C-54B	Trans World Airways	Gander, Newfoundland, Canada	33 minor or none
Jan. 6, 1949	Douglas DC-3C	Coastal Cargo	Brandywine, Maryland, U.S.	2 fatal
Jan. 2, 1949	Douglas DC-3C	Seattle Air Charter	Seattle, Washington, U.S.	14 fatal, 8 serious, 8 minor or none
Dec. 31, 1948	Douglas DC-3C	Air Cargo Express	Cleveland, Ohio, U.S.	2 minor or none
Dec. 19, 1948	Douglas DC-4	Alaska	Minneapolis, Minnesota, U.S.	39 minor or none
Dec. 18, 1948	Douglas DC-3	Reeve Aleutian	Anchorage, Alaska, U.S.	23 minor or none
Oct. 19, 1948	Douglas DC-3	Columbia Air Cargo	Anchorage, Alaska, U.S.	5 minor or none
March 2, 1948	Douglas DC-3	Meteor	Newark, New Jersey, U.S.	2 minor or none
Dec. 21, 1947	Douglas DC-3C	Seattle Air Charter	North Platte, Nebraska, U.S.	30 minor or none
Nov. 19, 1947	Douglas DC-3	Willis Air Service	Richmond, Virginia, U.S.	3 minor or none
Jan. 25, 1947	Douglas DC-3 (Dakota)	Spencer Airways	Croydon, Surrey, England	12 fatal, 4 serious, 7 minor or none
Dec. 19, 1946	Douglas DC-3 (Dakota)	Scottish Airways	Northolt, Middlesex, England	5 minor or none
Sept. 24, 1946	Douglas DC-3	A.R. Lyle	Point Barrow, Alaska, U.S.	9 minor or none

Icing may be one of several causes or factors in an accident that is listed in this table.

Sources: U.S. National Transportation Safety Board, U.K. Civil Aviation Authority's *World Aviation Accident Summary*, Airclaims *Major Loss Record*, *Flight International*, Flight Safety Foundation

Icing-related Commercial Aviation Accidents, 1946–1996 (Summaries)

FSF Editorial Staff

Introduction

Narratives for the icing-related aircraft accidents summarized in this section were drawn from briefs of accidents by the U.S. National Transportation Safety Board (NTSB), individual NTSB accident reports and Volumes 1 and 2 of the U.K. Civil Aviation Authority publication, *World Aviation Accident Summary*; Airclaims *Major Loss Record*; *Flight International*; and Flight Safety Foundation's in-house resources. There may be other icing-related accidents that do not appear in these sources.

For each accident, the editorial staff provides, where available: the aircraft manufacturer and type; aircraft operator; general weather conditions; type of flight plan; specific weather at the accident site; time of day; qualifications of the flight crew; and for landing accidents, the nature of the approach. If any of these elements is missing from the summary, it is because the information was not found in the source material.

Things to Remember

There are several good lessons for aviators in the following accident summaries. They include:

1. During preflight, do not trust your eyes to determine if there is ice on the airplane. The best way to find out is by touch, if that is possible;

2. Any amount of adhering snow or ice on the upper wings is too much for takeoff;

3. Know the holdover time (HOT) for the type of deicing/anti-icing fluid used on your airplane and do not exceed it;

4. In snowy weather, avoid using reverse thrust to back away from the gate. Snow can be blown onto the top of the wings, where it can refreeze as rime ice;

5. Only a small amount of ice on the leading edge of the wing can cause a significant decrease in the angle-of-attack stall margin;

6. Under certain conditions, airframe ice can form on the airplane in a matter of a few seconds;

7. When tailplane ice was present, aircraft have been known to lose pitch control when the wing flaps were extended to their full position;

8. Flying at high angles of attack in icing conditions can allow ice to form on the underside of the wings and fuselage, where it can significantly affect aerodynamic performance but cannot be removed with on-board equipment;

9. Chunks of ice that detach from a jet engine nacelle can be ingested by the engine, where they can cause compressor damage and instant engine failure; and,

10. On aircraft with fuselage-mounted engines, aft of the wings, ice on the wings can break loose as the wings flex on takeoff, and that ice can be ingested by the engines.

Abbreviations and Acronyms Used in This Section

A&P — Airframe and powerplant

ADF — Automatic direction finder

AFM — Aircraft flight manual

ARTCC — Air route traffic control center

AT — Airline transport pilot/Airline transport rating

C — Commercial certificated pilot

CVR — Cockpit voice recorder

EPR — Engine-pressure ratio

FAA — U.S. Federal Aviation Administration

FARs — U.S. Federal Aviation Regulations

FDR — Flight data recorder

FI — Flight instructor

FL — Flight level

G — Gravity

GCA — Ground-controlled approach

IAS — Indicated air speed

IFR — Instrument flight rules

ILS — Instrument landing system

IMC — Instrument meteorological conditions

IR — Instrument rating

METO — Maximum except takeoff

NDB — Nondirectional beacon

OAT — Outside air temperature

PIREP — Pilot weather report

RPM — Revolutions per minute

SIGMET — Significant meteorological information

VFR — Visual flight rules

VHF — Very high frequency

VMC — Visual meteorological conditions

Icing-related Accident Summaries

May 26, 1996 • British Aerospace BAe 146 • Air Wisconsin • Des Moines, Iowa, U.S. • Injuries: none

On a night flight at an altitude of 8,845 meters (29,000 feet) in an area of thunderstorms and turbulence, the aircraft lost power on all four engines. The no. 2 engine was restarted before the aircraft made an emergency landing at Des Moines. The pilot reported that the aircraft was operating in severe icing conditions.

The AFM prohibited flight in icing conditions above 7,930 meters (26,000 feet). The official accident report said that the AFM "required that the thrust management system be disconnected in icing conditions. There were indications that the [thrust management system] was disconnected about 230 seconds after engine rollback began."

The report also found that "the AFM did not provide accurate information concerning 'in cloud' correction factor for the OAT thermometer." The probable cause was the "failure of the flight crew to follow proper procedures, which resulted in an accumulation of ice and subsequent loss of engine power."

Pilot's qualifications: AT, IR with 12,000 total hours of flight time, with 7,500 hours in type.

March 2, 1995 • Cessna 208B • Martinaire • Ardmore, Oklahoma, U.S. • Injuries: 1 minor or none

The official accident report said that ice accretion was beyond the capacity of the aircraft's deicing system. An emergency landing was carried out in a field.

Oct. 31, 1994 • Avions de Transport Regional ATR-72-212 • American Eagle • Roselawn, Indiana, U.S. • Injuries: 68 fatal

It was dusk, and the weather was IMC. The aircraft was in a holding pattern and descending to a newly assigned altitude of 2,440 meters (8,000 feet) when it experienced an uncommanded roll and impacted the ground following a rapid, uncontrollable descent. The aircraft was destroyed. The loss of control was attributed to a sudden, unexpected aileron hinge-moment reversal that occurred after a ridge of ice accreted beyond the deicing boots.

The official U.S. accident report said that Avions de Transport Regional failed to completely disclose to operators adequate information about known effects of freezing precipitation on the ATR-72's operation; that the French Directorate General for Civil Aviation's (DGAC's) oversight of the ATR-42 and ATR-72 had been inadequate, and that it had failed to take necessary corrective action to ensure the aircrafts' airworthiness in icing conditions; and that the DGAC had failed to provide the FAA with timely airworthiness information developed from previous ATR incidents and accidents in icing conditions.

Contributing to the accident were: the FAA's failure to ensure that aircraft icing certification requirements, operational requirements for flight into icing conditions and FAA-published aircraft icing information adequately accounted for the hazards posed by flight in freezing rain and other icing conditions not specified in FARs Part 25, Appendix C; and the FAA's inadequate oversight of the ATR-42 and ATR-72 to ensure continued airworthiness in icing conditions. Pilot qualifications: AT, IR, FI with 7,867 total hours of flight time, with 1,548 hours in type.

Feb. 24, 1994 • Antonov An-12 • North Western Air Transport Directorate • Nalchik, Russia • Injuries: 13 fatal

On the approach to Nalchik, the aircraft pitched up abruptly, then down, and control was lost. The aircraft impacted terrain short of runway. Icing was suspected.

Feb. 24, 1994 • Vickers Viscount 813 • British World Airways • Near Uttoxeter, England • Injuries: 1 fatal, 1 serious

The aircraft took off in darkness in rain and snow. About 50 minutes after takeoff, while the aircraft was flying at an altitude of 4,500 meters (15,000 feet) in clouds, the no. 2 engine failed, and the propeller autofeathered. Less than a minute later, the no. 3 engine started to run down, and the crew requested an immediate descent and navigational assistance from ATC radar.

When engines no. 2 and no. 3 could not be restarted, the crew declared an emergency and requested diversion to Birmingham (England) Airport. No. 2 engine was then restarted, but no. 4 engine failed. The remainder of the flight was conducted with only engines no. 3 and no. 4 operating. The aircraft, unable to maintain altitude, struck the ground and was destroyed by postaccident fire.

The official accident report concluded that the engine failures and the difficulty in restarting the engines resulted from excessive ice accretion in the area of the engine intakes; that the airframe deicing system was handled incorrectly, allowing an accretion of ice and snow during the descent; and that the inability to maintain altitude was the result of ice and snow on the wings and airframe. Pilot's qualifications: AT, IR with 5,121 total hours of flight time, with 1,121 hours in type. Copilot's qualifications: AT, IR with 3,334 total hours of flight time, with 2,181 hours in type.

March 5, 1993 • Fokker F-100 • Palair Macedonian Airlines • Skopje, Macedonia • Injuries: 81 fatal, 16 serious

Weather was IMC, with high humidity and moderate wet snow falling. OAT was 0 degrees C (32 degrees F). Shortly after a daytime takeoff, while climbing through 366 meters (1,200 feet), the aircraft appeared to stall; it banked to the left, dived to the ground, exploded and was destroyed. The aircraft had not been deiced before takeoff.

Jan. 2, 1993 • Saab 340A • Express I • Hibbing, Minnesota, U.S. • Injuries: 31 minor or none

During the night IMC approach, the first officer, who was the pilot flying, asked the captain if he wanted to "pop the [deicing] boots." The captain responded, " ... It's going to the hangar. I'll run 'em on the ground."

On final, a high sink rate developed, and the first officer was unable to arrest the descent with back pressure on the control column. Additional back pressure was applied, and the stall horn sounded. The ensuing hard landing caused substantial damage to the aircraft, including breaking the right main landing gear, rupturing the fuel tank and bending the right-wing rear spar.

Eighteen hours after the accident, 0.48 centimeter (0.19 inch) of rime ice mixed with clear ice was observed on the leading edges of the wing, the horizontal stabilizer and the vertical stabilizer.

The official accident report cited contributing factors to the accident. They included weather conditions that resulted in an accumulation of ice on the aircraft's wing, and the operator's failure to provide adequate training on the airplane's flight characteristics and/or handling techniques under conditions of wing ice contamination. Pilot's qualifications: AT, FI, IR with 5,000 total hours of flight time, with 3,400 hours in type.

March 22, 1992 • Fokker F-28 • USAir • Flushing, New York, U.S. • Injuries: 27 fatal, 9 serious, 15 minor or none

The weather was IMC, with a ceiling of 214 meters (700 feet) and visibility of 1.2 kilometers (0.75 mile) in fog and falling snow. The OAT was 0 degrees C (32 degrees F).

The aircraft had been deiced twice before leaving the gate, but 35 minutes had elapsed between the second deicing and takeoff in darkness. Following rotation at an airspeed 9.3 kilometers per hour (five knots) lower than prescribed, the airplane stalled; it came to rest partially inverted and submerged in the water beyond the runway.

The official accident investigation determined the probable cause of the accident to be the failure of the airline industry and the FAA to provide flight crews with procedures, requirements and criteria compatible with departure delays in conditions conducive to airframe icing, and the decision by the flight crew to take off without positive assurance that the airplane's wings were free of ice accumulation after 35 minutes of exposure to precipitation following deicing. Early rotation was cited as a contributing factor. Pilot's qualifications: AT, IR, FI with 9,820 total hours of flight time, with 2,200 hours in type. Copilot's qualifications: 4,507 total hours of flight time, with 29 hours in type.

The accident report also said, "Accident history shows that nonslatted, turbojet, transport-category airplanes have been involved in a disproportionate number of takeoff accidents where undetected upper wing ice contamination has been cited as the probable cause or the sole contributing factor."

Dec. 27, 1991 • McDonnell Douglas MD-81 • Scandinavian Airlines System • Stockholm, Sweden • Injuries: 8 serious, 121 minor or none

The accident aircraft had arrived in Stockholm the night before. It had been parked outside all night in snow and rain, with temperatures falling to 0 degrees C (32 degrees F) by daybreak. During this time, supercooled fuel in the wing tanks created what the official accident report called "almost optimal" conditions for the formation of clear ice on the wings.

On the preflight inspection, ice was observed on the aircraft surfaces, and deicing was accomplished with Type I deicing fluid. The aircraft took off at one minute before sunrise. Weather at takeoff was a ceiling of 244 meters (800 feet) and visibility of 10 kilometers (6.2 miles) in intermittent snowfall. According to the report, three passengers said that they saw ice coming off the upper sides of the wings as the aircraft took off.

Shortly after rotation, the right engine began to surge violently, followed immediately by surging of the left engine. About a minute later, at an altitude of 1,011 meters (3,318 feet), both engines failed. The crew glided the powerless aircraft to a successful off-airport landing about 10 kilometers (6.2 miles) northeast of the airport.

The report concluded that the deicing procedures used had failed to remove clear ice from the wings; and that during the takeoff roll, chunks of the clear ice had broken off and been ingested by the engines, damaging the compressors and causing the engines to surge destructively. Pilot's qualifications: AT, IR with 8,020 total hours of flight time, with 590 hours in type. Copilot's qualifications: AT, IR with 3,015 total hours of flight time, with 76 hours in type.

Feb. 17, 1991 • Douglas DC-9 • Ryan International Airlines • Cleveland, Ohio, U.S. • Injuries: 2 fatal

While making a night instrument approach to Cleveland, the crew of the accident aircraft was advised and acknowledged that two PIREPs had confirmed the presence of rime icing between 2,135 meters (7,000 feet) altitude and ground level in the local area.

After landing, the crew remained in the cockpit while mail and cargo were transferred. Snow, reported as dry and blowing, fell throughout the 35 minutes that the aircraft was on the ground. The aircraft was not deiced. Shortly after takeoff, at an altitude of 15 meters to 31 meters (50 feet to 100 feet), the aircraft was seen to roll first slightly to the right, then severely to the left. These maneuvers were followed by a steep, almost vertical roll to the right, a sharp increase in pitch and impact with the ground in an inverted attitude.

According to the official accident report, the cause of the accident was degraded aerodynamic lift caused by ice or frozen snow on the wings' leading edges and upper surfaces. The accident board theorized that the flight crew used the aircraft's (hot wing) anti-icing system during the approach to Cleveland, and that falling dry snow had melted and refrozen while the aircraft was on the ground and the anti-icing system was automatically deactivated.

The report said, "According to the [aircraft] manufacturer, a wing upper surface contamination that is only [0.36 millimeters (0.014 inch)] thick, about equal to the roughness of 80-grade sandpaper, can produce a 25-percent loss of wing lift."

Pilot's qualifications: AT, IR with 10,505 total hours of flight time, with 505 hours in type. Copilot's qualifications: AT, IR with 3,820 total hours of flight time, with 510 hours in type.

Jan. 30, 1991 • British Aerospace Jetstream 31 • Carolina Commuter Air • Beckley, West Virginia, U.S. • Injuries: 13 serious, 6 minor or none

En route weather was forecast to include light and occasional moderate rime ice and mixed ice in clouds. The pilots were not aware of the conditions because they had not obtained in-flight weather information or PIREPs. The aircraft was dispatched with an inoperative airframe deicing system.

The flight arrived at Beckley in darkness. Weather was reported as IMC, with 61-meter (200-foot) overcast with visibility of 2.4 kilometers (1.5 miles) in fog and drizzle. During the letdown, light icing was encountered. On final ILS approach, the captain noticed a significant increase in ice accretion, which he countered by using a higher-than-normal approach speed. When full (50-degree) flaps were set, the aircraft began to buffet and pitched nose-down. The captain corrected with full back pressure on the control column, but the aircraft landed hard, collapsing the landing gear, and slid to a stop. The aircraft was destroyed.

The official accident investigation found that the accident was caused by flight into known adverse weather, which resulted in ice accretion on the aircraft and subsequent loss of aircraft control (tailplane stall) when the flaps were extended fully. Pilot qualifications: AT, IR with 5,000 total hours of flight time, with 3,400 hours in type.

Jan. 26, 1990 • Mitsubishi MU-2B-60 • Great Western Aviation • Near Meekatharra, Australia • Injuries: 2 fatal

The aircraft departed Perth, Australia, shortly before midnight on an IFR flight plan. As the flight proceeded, the aircraft climbed to its assigned cruising altitude of 6,400 meters (21,000 feet), where the pilot made a routine position report over Meekatharra. One minute later, the pilot radioed that the aircraft was out of control and descending. Thirty seconds after that, he called again to advise that the aircraft was in ice and spinning down through 2,440 meters (8,000 feet). At 0105, the aircraft impacted the ground in a near-vertical attitude and was destroyed.

The official accident report said, "Analysis of the atmospheric conditions likely to have been encountered by the aircraft ... were conducive to the formation of airframe icing, and that the type of ice would probably have been rime ice or a mixture of rime and glaze ice."

The report concluded that the aircraft probably accrued icing on the airframe that caused the airspeed to decrease to the point where the aircraft stalled and entered a spin; that the pilot was not previously aware of the ice formation; and that he did not take action to prevent the aircraft's speed from decreasing. Pilot's qualifications: C, IR with 11,030 total hours of flight time, with 52 hours in type.

Dec. 26, 1989 • British Aerospace Jetstream 31 • NPA United Express • Pasco, Washington, U.S. • Injuries: 6 fatal

Letting down for a night ILS approach, the aircraft was in icing conditions for about nine and one-half minutes. General weather was VMC, but the airport had a 305-meter (1,000-foot) overcast, visibility 11 kilometers (seven miles) with an OAT of 0 degrees C (32 degrees F).

The Seattle, Washington, ARTCC was using an expanded radar range, and so did not provide precise positioning for the aircraft, whose crew tried to continue an unstabilized approach. Recorded radar data were lost when the aircraft was about four kilometers (2.5 miles) from the airport. Tower personnel next observed the aircraft in a steep, wings-level descent. Before reaching the runway, the aircraft nosed over further, struck the ground and was destroyed.

According to the official accident report, causes of the accident included the icing conditions, improper ARTCC service and improper IFR procedures by the pilot-in-command. The report also said that there was evidence that ice had accreted on the airframe, including the horizontal stabilizers, which may have caused a tailplane stall. Pilot's qualifications: AT, IR with 6,600 total hours of flight time, with 670 hours in type.

Nov. 25, 1989 • Fokker F-28 • Korean Air • Kimpo, Korea • Injuries: 6 serious, 42 minor or none

The official accident report stated, "The aircraft would not become airborne. The left engine lost power due to ice on the wing. The pilot lost directional control and aborted the takeoff." The aircraft overran the runway, caught fire and was destroyed.

March 15, 1989 • Nihon Aeroplane Manufacturing Co. NAMC YS-11 • Mid Pacific Airlines • Purdue University, Indiana, U.S. • Injuries: 2 fatal

On final approach to Purdue University Airport, the aircraft was reported to have suddenly lost altitude and struck the ground 320 meters (1,050 feet) short of the runway. The aircraft was destroyed. Weather at the time was 763-meter (2,500-foot) ceiling, 24 kilometers (15 miles) visibility and an OAT of 0 degrees C (32 degrees F). The official accident report said that the aircraft may have stalled following ice accretion on its tail.

March 3, 1989 • Fokker F-28 • Air Ontario • Dryden, Ontario, Canada • Injuries: 24 fatal, 45 serious

The aircraft was fully loaded and had taken on fuel at Dryden. Light snow had been falling while the aircraft was being serviced, but the snowfall became heavy while the aircraft waited for takeoff clearance, a period of about 10 minutes.

On its takeoff run, the aircraft was reported by witnesses to have labored down the runway, seeming to lack power. Shortly after becoming airborne, the aircraft struck terrain in a wooded area near the runway. The aircraft broke into three pieces and was destroyed by postaccident fire. The FDR and CVR were extensively damaged, and the tapes were later found to have melted.

Survivors and other witnesses said that the wings had accumulated a layer of wet snow prior to takeoff.

Dec. 21, 1988 • Cessna 207 • Baker Aviation • Kotzebue, Alaska, U.S. • Injuries: 6 minor or none

The air taxi pilot reported that he had encountered freezing drizzle and other icing conditions en route, and that, as a result, his aircraft had accumulated about one centimeter (0.38 inch) of ice before he started his daylight approach. At the beginning of the landing flare, the aircraft stalled, and the pilot was unable to regain control. The aircraft's right wing struck the runway, causing substantial damage to the aircraft.

The pilot said that the accident might have been prevented if he had showed greater concern for the ice on the airplane by approaching the landing with excess airspeed and a lower-than-normal flap setting.

Probable causes for the accident were listed in the official accident report as improper in-flight planning and an inadvertent stall. Contributing factors were the low ceiling, icing conditions and ice on the wings. Pilot qualifications: C, FI, IR with 1,707 total hours of flight time, with 83 hours in type.

Dec. 16, 1988 • Mitsubishi MU-2B-60 • Broughton Air Services • Near Leonora Airfield, Australia • Injuries: 10 fatal

The twin-turboprop aircraft departed Bellvue Mine, Australia, in daylight. Its destination was Kalgoorlie, Australia, a trip of about one hour's duration. The en route weather forecast that was given to the pilot cited the presence of tall cumulus clouds and possible thunderstorms, but no mention was made of the possibility of aircraft icing.

About 15 minutes after takeoff, the pilot requested traffic information for a climb from his present altitude of 6,000 meters (19,500 feet) to 6,400 meters (21,000 feet). He also mentioned that there were large clouds in the area. After being advised that there was no traffic, the pilot said that he was climbing to the new flight level. That was the last communication received from the aircraft. Seven minutes later, the aircraft crashed into terrain and was destroyed by impact forces and postaccident fire.

The official accident report said that "with a cloud base of [2,700 meters to 3,400 meters (9,000 feet to 11,000 feet)] and an ambient temperature of -14 degrees C [-25 degrees F] at FL 195, the aircraft would have been operating in icing conditions. There was, therefore, a high probability of accretion of rime and/or clear ice on the airframe when operating in cloud."

The report concluded that the pilot probably flew into icing conditions and did not become aware of the accretion of airframe ice prior to his loss of control of the aircraft; that the aircraft stalled as a result of wing ice contamination; and that the aircraft struck ground in a left-hand spin in a near-vertical attitude.

Pilot's qualifications: C, IR with 6,249 total hours of flight time, with 134 hours in type.

Jan. 10, 1988 • NAMC YS-11 • Tao Domestic • Honshu, Japan • Injuries: 52 minor or none

During the takeoff run in snow showers, the elevator controls were too heavy for the pilot to rotate the aircraft. The pilot aborted the takeoff. The aircraft overran the runway and came to rest in the sea about 30 meters (98 feet) from the shore, incurring substantial damage.

The accident report said that ice or slush on the controls may have affected elevator control. The pilot had determined that ground deicing was not necessary. The pilot was reported to have been a captain in this type of aircraft for less than six months.

Dec. 17, 1987 • Swearingen SA-226 • Avair • Chantilly, Virginia, U.S. • Injuries: 1 serious, 7 minor or none

Letting down through a cloud layer at night, the aircraft acquired apparent rime ice on its wing surfaces. The captain elected not to use engine-inlet anti-icing. On final approach in VMC, the left engine lost power, followed by a power loss on the right engine. The aircraft made an emergency landing in an open field. The landing gear collapsed during rollout, and the aircraft was substantially damaged.

Ice chunks matching the shape of the leading edge of the right wing and the shape of the propeller spinner were found lying near the aircraft.

Probable causes for the accident were cited in the accident report as: improper in-flight planning and failure to use an anti-icing system. Factors included the weather, wing ice, landing in an open field and the time (night). Pilot qualifications: AT, IR, 7,200 total hours of flight time, with 400 hours in type.

Nov. 23, 1987 • Beechcraft 1900 • Ryan Air Service • Near Homer, Alaska, U.S. • Injuries: 18 fatal, 3 serious

En route, 7.6 centimeters (three inches) of ice accreted on the leading edges of the aircraft's wings, and full stabilizer nose-down trim was necessary to maintain level flight. As the flaps were lowered on final approach, the crew lost control of the aircraft. The aircraft impacted terrain short of the runway and was destroyed.

Investigation showed that the aircraft's center of gravity was 20 centimeters to 28 centimeters (eight inches to 11 inches) behind the aft limit.

Nov. 15, 1987 • McDonnell Douglas DC-9-14 • Continental Airlines • Denver, Colorado, U.S. • Injuries: 28 fatal, 28 serious, 26 minor or none

The weather was IMC, with a 153-meter (500-foot) ceiling, visibility of 0.8 kilometer (0.5 mile) in fog and falling snow and an OAT of -2 degrees C (28 degrees F). Twenty-seven minutes had elapsed since the aircraft had been deiced at the gate. Company procedures called for repeat deicing when in icing conditions if a delay exceeds 20 minutes. On takeoff, the first officer (the pilot flying) overrotated the aircraft. Aircraft control was lost; the aircraft stalled, impacted the runway and was destroyed.

The official accident report cited the causes of the accident as failure to remove ice or frost from the aircraft prior to takeoff, and abrupt rotation. The report also said that the crew members were inexperienced in their respective positions. The captain had 33 hours experience as a DC-9 captain; the first officer had only 36 hours of jet experience, all in the DC-9. Pilot's qualifications: AT, IR, with 12,125 total hours of flight time, with 166 hours in type.

Oct. 15, 1987 • International (Aeritalia and Aerospatiale) ATR-42 • Aero Transporti Italiani • Mount Crezzo, Italy • Injuries: 37 fatal

Icing conditions were forecast for the flight. The aircraft was climbing at an IAS of 246 kilometers per hour (133 knots) when the flight crew identified ice accumulation. At an altitude of 4,880 meters (16,000 feet), the aircraft became uncontrollable, rolling from 40 degrees to more than 90 degrees, left and right. The elevator controls were unable to keep the aircraft from pitching down, suggesting that tailplane ice had formed. The aircraft flew into the ground and was destroyed.

Feb. 21, 1987 • Fokker F-28 • Reykjavik, Iceland • Injuries: 6 minor or none

On final approach to landing, the pilot flared the airplane too far above the runway. The aircraft stalled and dropped onto the paved surface from about 4.6 meters (15 feet) in the air, causing substantial damage to the aircraft. A postflight inspection revealed a thin strip of ice on the leading edges of both wings.

Jan. 18, 1987 • Fokker F-27 • British Midland Airways • Castle Donington Race Track, England • Injuries: 3 serious

The crew was conducting training NDB instrument approaches. Icing was reported moderate to severe in stratus clouds that extended from 305 meters (1,000 feet) to 1,067 meters (3,500 feet). OAT was about -4 degrees C (25 degrees F).

The aircraft was on a single-engine approach at an altitude of about 122 meters (400 feet) when it banked steeply, first to one side and then to the other, then collided with the ground and was destroyed. An examination immediately after the accident revealed 2.5 centimeters (one inch) of horn-shaped clear ice on the leading edges of all surfaces. Radar indicated that the IAS of the aircraft was unlikely to have been less than 198 kilometers per hour (107 knots) during the approach. (The flaps-up stalling speed of the F-27 is 178 kilometers per hour [96 knots]).

Jan. 6, 1987 • Aerospatiale Caravelle 12 • Transwede • Stockholm, Sweden • Injuries: 27 minor or none

The aircraft lifted off normally. At an altitude of about 10 meters (33 feet), the aircraft pitched down and struck the runway, collapsing the landing gear and destroying the aircraft. The official accident report said that snow or ice on the horizontal stabilizer may have gone unnoticed in the preflight inspection and recommended that rules for the removal of snow and ice from aircraft before departure be strengthened.

Dec. 15, 1986 • Antonov An-24 • CAAC • Near Lanzhou, China • Injuries: 6 fatal, 18 serious, 20 minor or none

Severe airframe icing was encountered during climbout. The right engine failed, and the propeller was feathered. The aircraft returned for landing but impacted terrain during the approach and was destroyed.

May 16, 1986 • Beech 99C • Centennial Airlines • Laramie, Wyoming, U.S. • Injuries: 9 minor or none

By the time the daylight IMC flight reached its destination, moderate to heavy ice accretion had formed on the aircraft. When the pilot flared the aircraft for landing, it stalled, bounced on the runway and veered into a lighting fixture. The left landing gear collapsed, and the aircraft skidded to a stop, substantially damaged.

The weather at the time of the accident was 122-meter (400-foot) ceiling, visibility of eight kilometers (five miles), with fog and blowing snow. OAT was 1 degree C (34 degrees F). The official accident report listed the probable causes of the accident as: icing conditions, failure to control airspeed and inadvertent stall. Snow was listed as a contributing factor. Pilot qualifications: AT, IR, 2,530 total hours of flight time, with 1,809 hours in type.

Jan. 31, 1986 • Shorts SD3-60 • Aer Lingus Commuter • East Midlands Airport, England • Injuries: 2 serious, 34 minor or none

En route to East Midlands, the crew of this twin-turboprop aircraft was advised of reported severe icing conditions between 915 meters and 2,135 meters (3,000 feet and 7,000 feet) altitude in the area. During the descent from their 2,745-meter (9,000-foot) cruising altitude, the crew activated the anti-icing systems for several accessories, but, in keeping with their normal operating procedures, did not use the wing and tail deicing systems. At this time, the freezing level was at 305 meters (1,000 feet).

The aircraft was well established on a night ILS approach when, at an altitude of 305 meters, it began divergent rolling oscillations to the left and right and entered into a very high rate of descent. The captain was able to regain control of the aircraft, but not before it struck power cables. The aircraft then made contact with the ground and was destroyed.

The official accident report cited a significant accretion of airframe ice as the probable cause of the accident, degrading the aircraft's stability and control characteristics. Possible contributing factors included the difficulty in detecting clear ice at night, turbulence and delay in the application of go-around power.

Pilot's qualifications: AT, IR with 7,528 total hours of flight time, with 123 hours in type. Copilot's qualifications: AT, IR with 4,299 total hours of flight time, with 1,240 hours in type.

Dec. 15, 1985 • Cessna C-207 • Ryan Air Service • Napaskiak, Alaska, U.S. • Injuries: 4 serious

Weather was IMC. The pilot attempted to make a VFR landing at dusk in freezing drizzle, rain and fog. During the approach, the aircraft's windshield became covered with ice, and the pilot was unable to keep the runway in sight. He abandoned the approach. When he applied power to go around, the aircraft lost altitude, struck terrain and was damaged substantially.

The probable causes for the accident cited in the official accident report were: poor preflight and in-flight planning, continuing a VFR flight into unknown IMC, windshield ice, overconfidence and disregarding the weather evaluation. Contributing factors included the current weather conditions, improper weather evaluation, improper use of the pitot system and the time of day. Pilot qualifications: C, IR with 2,568 total hours of flight time, with 2,000 hours in type.

Dec. 15, 1985 • Douglas DC-3 • Dillingham, Alaska, U.S. • Injuries: 3 minor or none

After takeoff in VMC, the aircraft was not performing as expected, so the pilot landed straight ahead beyond the runway.

The aircraft sustained substantial damage. Witnesses said that the pilot had failed to clean a thick coating of ice off the aircraft before takeoff.

Dec. 12, 1985 • Douglas DC-8 • Arrow Air • Gander, Newfoundland, Canada • Injuries: 256 fatal

The accident flight arrived at Gander at 0904. Passengers were deplaned, the aircraft was refueled, and supplies were loaded. Prior to reboarding the passengers, the flight engineer was seen conducting a visual inspection of the external portions of the aircraft.

Weather at Gander included light freezing drizzle, snow grains or snow; a ceiling of 366 meters (1,200 feet); and visibility of 16 kilometers (10 miles). OAT was -4 degrees C (26 degrees F). The aircraft was not deiced before takeoff, although airport authorities later reported that other aircraft taking off from Gander that morning had requested deicing.

Witnesses to the takeoff reported that the aircraft gained little altitude after rotation. Other witnesses said that the aircraft pitched up and entered a right bank as it crossed over the end of the airfield. The aircraft struck downsloping terrain about one kilometer (3,000 feet) beyond the end of the runway and was destroyed by postaccident fire.

The official accident report concluded that during the aircraft's approach to Gander, weather conditions were conducive to ice accretion on the leading edges of the wings; and that while on the ground at Gander, the aircraft was exposed to freezing and frozen precipitation capable of causing roughening on the upper wing surfaces.

The report cited as the most probable cause of the accident an increase in drag and reduction in lift that resulted in a stall at higher-than-normal airspeed at an altitude so low that recovery was impossible. The most probable cause of the stall was cited as ice contamination on the leading edges and upper surfaces of the wing.

Pilot's qualifications: AT, IR with 7,001 total hours of flight time, with 1,081 hours in type. Copilot's qualifications: C, IR with 5,549 total hours of flight time, with 918 hours in type.

March 12, 1985 • de Havilland DHC-6 • Sea Airmotive • Barter Island, Alaska, U.S. • Injuries: 2 serious, 2 minor or none

About 0.8 kilometer (0.5 mile) from the departure end of a temporary winter landing strip, the aircraft lost flying speed and contacted the terrain in a steep nose-down attitude. Marginal weather conditions prevailed, with icing reported. Investigation revealed that both wing leading edges were covered with about 0.5 centimeter (0.2 inch) of ice. An A&P mechanic who arrived on the scene shortly after the accident said that the switch for the deicing boots was in the "off" position.

Feb. 5, 1985 • Douglas DC-9-15 • Airborne Express • Philadelphia, Pennsylvania, U.S. • Injuries: 2 serious

The aircraft was parked on the ramp for 39 minutes in light freezing drizzle mixed with ice pellets and snow. Prior to the night takeoff, the flight crew made a visual inspection, observed no ice and declined an offer to have the aircraft deiced.

After takeoff, the aircraft entered an uncommanded left roll and both engines experienced compressor stalls. The captain attempted to abort the takeoff. The aircraft touched down on the tail skid and right wing tip. It traveled about 610 meters (2,000 feet) on the ground before coming to rest, sustaining substantial damage. An investigation determined that an 0.38-centimeter (0.15-inch) thick layer of ice had been on the wings.

The official accident report said that when a DC-9-15 aircraft experiences an aerodynamic stall, the engines are susceptible to compressor stall. Cited in the report as probable causes of the accident were: wing ice, failure to remove ice or frost from the aircraft and inadvertent stall. Contributing factors included the adverse weather and the time of day. Pilot qualifications: AT, IR, 7,500 total hours of flight time, with 1,800 hours in type.

Feb. 5, 1985 • Douglas DC-3 • BO-S-AIRE Airlines • Charlotte, North Carolina, U.S. • Injuries: 2 minor or none

Witnesses said that ice was on the aircraft before the pilot attempted an instrument departure at night in freezing rain with the OAT of -2 degrees C (29 degrees F). During climbout, the pilot was unable to maintain elevator control and returned to Charlotte. The aircraft overshot the runway and sustained substantial damage. Investigation determined that the windshield was covered with ice.

According to the official accident report, there was also ice on the elevator surfaces. The report listed the probable causes of the accident as failure to remove ice or frost from the aircraft prior to takeoff and disregarding the weather evaluation. Pilot's qualifications: AT, IR with 4,700 total hours of flight time, with an unknown number of hours in type.

Feb. 4, 1985 • Beech 65-A80 • North Pacific Airlines • Soldotna, Alaska, U.S. • Injuries: 9 fatal

The crew made a night instrument approach into a field obscured by a 92-meter (300-foot) overcast, fog, freezing drizzle and a visibility of 1.2 kilometers (0.75 mile). The OAT was -3 degrees C (26 degrees F). The crew executed a missed-approach procedure, during which time they reported that the aircraft had accumulated a heavy load of ice.

While the aircraft was being vectored, a weather observer advised the crew that the weather at Soldotna had fallen below minimums and recommended diverting to nearby Kenai, Alaska. The crew did not acknowledge the message. The aircraft collided with trees in high terrain. There was evidence that the aircraft was circling when it impacted, an unauthorized maneuver in that area.

Investigation revealed recurring problems with the aircraft's anti-icing system, which was partially inoperative, and the absence of two deicing boots from the propeller blades. The official accident report cited the probable causes of the accident as: improper in-flight planning, improper missed-approach procedure and failure to maintain minimum descent altitude. Contributing factors included inadequate anti-icing/deicing systems, operation with known deficiencies in equipment, flight into known adverse weather, wing ice and failure to fly to an alternate destination. Pilot qualifications: AT, IR with 7,288 total hours of flight time, with 2,985 hours in type.

Jan. 13, 1984 • Fokker F-27 • Pilgrim Airlines • New York, New York, U.S. • Injuries: 1 serious, 23 minor or none

Weather at the departure airport was VMC, with a reported ceiling of 824 meters (2,700 feet) overcast, visibility 11.3 kilometers (seven miles) and an OAT of -4 degrees C (26 degrees F).

The takeoff was made in daylight. As the captain raised the landing gear, the propeller on the left engine autofeathered, and the captain reduced power on that engine. Then the right engine lost power, and the aircraft began to descend. The captain put the landing gear lever back down. The aircraft struck the runway before the landing gear became fully extended and slid about 366 meters (1,200 feet) before stopping. The aircraft was damaged substantially.

The accident report said that the probable causes of this accident were the flight crew's failure to use engine anti-ice on the inbound flight to John F. Kennedy International Airport (JFK), New York; the captain's failure to conduct a thorough preflight inspection; and the flight crew's decision to use engine anti-ice on takeoff from JFK, which led to power losses on both engines.

Pilot's qualifications: AT, IR with 7,012 total hours of flight time, with 799 hours in type. Copilot's qualifications: C, IR with 3,161 total hours of flight time, with 179 hours in type.

Dec. 21, 1983 • Beechcraft 200 • Detroit, Michigan, U.S. • Injuries: 4 minor or none

Rime ice accreted on the aircraft during an ILS approach to Runway 15, and a high sink rate developed. The aircraft made a hard landing 45 meters (148 feet) short of the runway and was damaged substantially. Investigation showed that the right side of the windshield was covered with ice, and that 1.3 centimeters (0.5 inch) of ice remained unbroken on the horizontal stabilizer. After the accident, the stabilizer deicer boots were cycled and functioned properly.

Contributing factors cited in the official accident report were low ceiling, fog and snow, airframe icing, windshield icing, failure to maintain flying speed and improper landing flare.

Jan. 13, 1982 • Boeing 737-222 • Air Florida • Washington, D.C., U.S. • Injuries: 78 fatal, 6 serious, 3 minor or none

Daytime weather included a 61-meter (200-foot) ceiling, visibility 0.8 kilometer (0.5 mile) in falling snow and an OAT below freezing. The aircraft was deiced with a solution of heated ethylene glycol and water without the engine-inlet plugs or pitot-static covers installed. Contrary to procedures, reverse thrust was used to help during pushback from the gate. After pushback, the flight was delayed 49 minutes in continuing snowfall. While waiting, the aircraft was positioned near the exhaust of an aircraft ahead.

On the takeoff run, an anomaly was noted in the engine instrument readings, but the captain elected to continue the takeoff. The aircraft did not become airborne until about 610 meters (2,000 feet) and 15 seconds past the normal lift-off point. The aircraft initially climbed but failed to accelerate. The aircraft settled, hit a bridge, plunged into a frozen river and was destroyed.

Investigation revealed that engine-inlet probes had become blocked by ice, resulting in false high readings for EPR, a measure of engine thrust; and that the aircraft experienced possible pitch-up caused by snow and ice on the wings. The official accident report listed the probable causes of the accident as: wing ice, improper planning, miscellaneous ice, failure to use anti-icing systems and failure to abort the takeoff. The accident report said that the crew had limited experience in cold-weather operations. Pilot qualifications: C, IR with 8,300 total hours of flight time, with 1,852 hours in type.

Dec. 16, 1981 • Boeing 727 • Sterling Airways • Gander, Newfoundland, Canada • 180 minor or none

The charter flight did not accelerate normally on takeoff. The pilot flying rotated the aircraft below proper rotation speed as it neared the end of the runway. The aircraft struck threshold lights and nine sets of approach lights before climbing away. The crew flew the aircraft to Gander, where they landed without further incident.

The investigation concluded that the aircraft's decreased performance was caused by erroneous engine gauge readings caused by icing of the engine-inlet pressure probes.

Jan. 16, 1981 • Douglas DC-6A • Northern Air Cargo • Near Gambell, Alaska, U.S. • Injuries: 3 minor or none

The pilot continued a daytime VFR flight into adverse weather conditions. The aircraft encountered freezing rain, and ice formed on the windshield. While flying at normal cruise, the pilot misjudged his altitude and the clearance of the aircraft from an ice pack (a mound of sea ice); as he turned to reverse course, the aircraft's wing tip hit the ice pack. The aircraft remained airborne, but damage to the aircraft was substantial. Pilot's qualifications: AT, IR with 11,000 total hours of flight time, with 8,000 hours in type.

Dec. 25, 1980 • Dee Howard 500 • Toronto, Ontario, Canada • Injuries: 3 minor or none

The airport surfaces were covered with 0.63 centimeter to five centimeters (0.25 inch to two inches) of slush, and OAT was near the freezing point. Before departure, the aircraft surfaces were deiced but the landing gear was not. After takeoff, the landing gear was raised immediately.

In-flight temperatures were well below freezing. At Toronto, the flight's destination, the aircraft made a normal visual approach and touched down at about 185 kilometers per hour (100 knots). As the aircraft slowed, it suddenly yawed to the right, pitched forward onto the propeller blades and came to a stop. The tail then fell heavily to the runway, causing substantial damage to the aircraft.

Investigation showed that both main wheels were locked by ice on touchdown. The left-hand wheel broke free after skidding about 61 meters (200 feet). The right-hand wheel remained locked until the aircraft stopped.

April 24, 1980 • Beech 18S • Cedar Rapids, Iowa, U.S. • Injuries: 1 minor or none

The weather at Cedar Rapids Municipal Airport was ceiling and visibility unlimited, with unfavorable wind conditions (a left quartering headwind of 28 kilometers per hour [15 knots]). Just after touchdown, a chunk of airframe ice fell off the left wing. The left wing rose; the right wing dipped, striking the runway and causing substantial damage to the right wing tip. Pilot's qualifications: AT, IR with 2,590 total hours of flight time, with 1,650 hours in type.

March 2, 1980 • On Mark B-26 Invader • California, U.S. • Injuries: 4 fatal

The aircraft, which was operating near its aft center-of-gravity limit, went out of control, spun and was destroyed on impact with the ground. The official accident report attributed the accident to airframe icing.

Feb. 16, 1980 • Bristol Britannia 253F • Redcoat Air Cargo • Billerica, Massachusetts, U.S. • Injuries: 7 fatal, 1 serious

The aircraft took off from Logan International Airport, Boston, Massachusetts, in daylight and light snow and fog, with a ceiling of 122 meters (400 feet) and visibility of 0.8 kilometer (0.5 mile). A valid SIGMET for the Boston area reported moderate to severe icing in precipitation. Pilots had reported wind shear and turbulence in the Boston area.

Shortly after takeoff, the crew of the aircraft reported that the aircraft was having difficulty climbing. The aircraft reached an altitude of about 519 meters (1,700 feet) and then descended into the ground and was destroyed.

The official accident report said that the probable cause of the accident was degraded aerodynamic performance beyond the flight capabilities of the aircraft, resulting from an accumulation of ice and snow on the airframe before takeoff and a further accumulation when the aircraft was flown into moderate to severe icing conditions. Contributing factors were the failure of the crew to get an adequate preflight weather briefing, and the failure of the U.S. National Weather Service to advise the flight crew of the SIGMET.

Nov. 23, 1979 • Scottish Aviation Twin Pioneer • Anchorage, Alaska, U.S. • Injuries: 2 minor or none

After becoming airborne on a ferry flight, the aircraft was unable to climb or accelerate. The pilot aborted the takeoff. The aircraft struck the airport boundary chain-link fence and received substantial damage. Investigation revealed frost and ice on the wings, horizontal stabilizer and elevator. The pilot was not type-rated and had only five hours as a copilot in the accident aircraft make and model.

Nov. 19, 1979 • Cessna Citation • Castle Rock, Colorado, U.S. • Injuries: 2 fatal, 1 serious

The aircraft was on an ILS landing approach when it disappeared from the radar display. Radio transmissions from the flight crew had not indicated any problems. The wreckage was found 11.3 kilometers (seven miles) outside the outer marker.

The aft fuselage and right wing were destroyed by ground fire. The engine instrument gauges indicated a low-RPM power setting. Most anti-ice switches were found in the "off" position. Improper IFR operation, bad weather and suspected airframe icing were cited in the official accident report as contributing factors.

The pilot had been upgraded to captain six days earlier. The copilot had been certified two days prior to the accident.

April 4, 1979 • Beech E18 • Newburgh, New York, U.S. • Injuries: 1 serious

The aircraft arrived from Boston, Massachusetts, U.S., in darkness. Weather at Stewart Airport was 214-meter (700-foot) ceiling, with visibility of 4.8 kilometers (three miles) or less in fog and an OAT of 3 degrees C (37 degrees F). The pilot was advised to hold for traffic and was warned of icing conditions at the holding altitude. The pilot missed his first approach. During go-around, the aircraft stalled, mushed (a wings-level, nonflying descent) into the ground and was destroyed. The pilot's qualifications: AT, IR with 3,897 total hours of flight time, with 99 hours in type.

March 17, 1979 • Tupolev Tu-104 • Aeroflot • Near Moscow, Russia • Injuries: 90 fatal

While on scheduled passenger service from Moscow to Odessa, Russia, the aircraft was reported to have crashed in freezing rain and fog. The aircraft was destroyed.

Feb. 12, 1979 • Frakes Mohawk 298 • USAir • Clarksburg, West Virginia, U.S. • Injuries: 2 fatal, 8 serious, 15 minor or none

The daytime IFR flight was scheduled from Benedum Airport in Clarksburg to Washington, D.C., U.S. Local weather was falling snow and calm winds, with a visibility of 1.2 kilometers (0.75 mile) or less. The aircraft took off with accumulated snow on the wings and tail surfaces. On initial climb, the pilot lost control, and the aircraft crashed into the ground in an inverted attitude. Pilot's qualifications: AT, IR with 4,029 total hours of flight time, with 529 hours in type.

Jan. 19, 1979 • Learjet 25D • Massey Ferguson • Detroit, Michigan, U.S. • Injuries: 6 fatal

The aircraft crashed during an attempted night landing on Runway 9 at Detroit (Michigan, U.S.) Metropolitan Wayne County Airport. During the descent to the airport, the aircraft flew in moderate to severe icing conditions. Shortly before the Learjet was to land, a McDonnell Douglas DC-9 was cleared for takeoff. Witnesses saw the Learjet cross the threshold in a normal landing attitude and seconds later roll violently. The Learjet was in a steep right bank when the wing-tip tank struck the runway 805 meters (2,640 feet) from the threshold and the aircraft burst into flames.

The official accident report determined that the probable cause of the accident was the pilot's loss of control, which may have been caused by the wake turbulence of the departing aircraft, by a premature stall due to an accumulation of wing ice, by a delayed application of engine thrust during an attempted go-around or by any combination of these factors.

Jan. 19, 1979 • Piper Aerostar 601 • Grand Rapids, Michigan, U.S. • Injuries: 4 fatal, 2 serious

After a reportedly accurate weather briefing by flight service personnel, the pilot initiated the night IFR flight from Lansing, Michigan, to Marquette, Michigan, in adverse weather conditions. En route, sleet and freezing rain caused a buildup of ice on the airframe and windshield, and the pilot elected to make an unscheduled landing at Grand Rapids. Weather there was a 153-meter (500-foot) ceiling with visibility of 3.2 kilometers (two miles) or less in fog and an OAT of -6 degrees C (21 degrees F). On final approach, the pilot flared the aircraft well above the runway. The aircraft stalled, collided with the ground in uncontrolled flight and was destroyed. Pilot's qualifications: C, IR with 2,646 total hours of flight time, with 195 hours in type.

Dec. 7, 1978 • Cessna 401A • Rockford, Illinois, U.S. • Injuries: 2 minor or none

After a previous en route stop in Chicago, Illinois, the aircraft was on a daytime IFR flight from Rockford to Minneapolis, Minnesota, U.S. (According to the official accident report, there is no record of the pilot having received a weather briefing while on the ground in Chicago.) The aircraft acquired airframe ice and airframe buffeting began. The pilot elected to make an emergency landing at Greater Rockford Airport, where the weather was freezing drizzle, 244-meter (800-foot) ceiling and visibility 3.2 kilometers (two miles) or less in fog. The pilot leveled off too high over the runway, stalled and made a hard landing that caused substantial damage to the aircraft. Pilot's qualifications: C, IR with 1,504 total hours of flight time, with 427 hours in type.

Dec. 4, 1978 • de Havilland DHC-6 • Steamboat Springs, Colorado, U.S. • Injuries: 2 fatal, 14 serious, 6 minor or none

The pilot departed on a night flight from Steamboat Springs to Denver, Colorado, in adverse weather conditions that included sleet, freezing rain and downdrafts and updrafts. OAT at the time of the accident was -3 degrees C (26 degrees F). In normal cruise, with visibility obstructed by blowing snow, the aircraft struck a mountain in controlled flight at an altitude of 3,212 meters (10,530 feet) above mean sea level. The aircraft was destroyed; the wreckage was not recovered until the next day.

According to the official accident report, the weather exceeded the aircraft's capability to maintain flight. Pilot's qualifications: AT, IR with 7,340 total hours of flight time, with 3,904 hours in type.

Dec. 4, 1978 • Gates Learjet 25B • Anchorage, Alaska, U.S. • Injuries: 5 fatal, 2 serious

Weather was reported as a measured ceiling of 702 meters (2,300 feet), visibility 48 kilometers (30 miles) and OAT 1 degree C (33 degrees F). The wind was 26 kilometers per hour (14 knots) gusting to 41 kilometers per hour (22 knots). SIGMETs and pilot observations in the area warned of low-level turbulence.

As the aircraft flared on a daylight landing, the left wing tip lightly contacted the runway. Power was reapplied; the aircraft then pitched up, rolled to the right, rolled back to the left and struck the ground inverted. The aircraft was destroyed.

Probable causes listed in the official accident report were improper operation of flight controls and unfavorable wind conditions. Icing conditions, airframe ice and inadequate pilot weather briefing were cited as contributing factors to the accident. Pilot's qualifications: C, IR with 7,000 total hours of flight time, with 650 hours in type. Copilot's qualifications: C, with 2,635 total hours of flight time, with 21 hours in type.

Dec. 2, 1978 • Douglas DC-3 • Des Moines, Iowa, U.S. • Injuries: 2 serious

Weather at Des Moines was reported as 244 meters (800 feet) overcast, visibility 3.2 kilometers (two miles) in freezing drizzle, OAT -8 degrees C (18 degrees F) and winds of 26 kilometers per hour (14 knots) gusting to 37 kilometers per hour (20 knots).

During a daytime radar surveillance landing approach, the aircraft struck the upslope of an embankment about 92 meters (300 feet) short of the runway. The pilots said that their visibility was restricted by windshield icing. Icing was also found on other aircraft surfaces.

Nov. 27, 1978 • Douglas DC-9 • Trans World Airways • Newark, New Jersey, U.S. • Injuries: none

The weather was blowing snow and rain, with an OAT of -3 degrees C (27 degrees F). The aircraft was not deiced prior to its departure. Shortly after takeoff, at an altitude of 20 meters (65 feet), control of the aircraft was lost. The aircraft struck the ground in a tail-low attitude and came to rest about 850 meters (3,800 feet) from the point of first impact. Damage to the aircraft was minor.

Nov. 16, 1978 • Beech G18S • Hays, Kansas, U.S. • Injuries: 2 fatal

Weather at Hays was freezing drizzle, with a ceiling of 61 meters (200 feet) and visibility of 4.8 kilometers (three miles) or less in fog. The OAT was -1 degree C (31 degrees F). Approaching the airport at night, the aircraft failed to maintain flying speed on final approach. The aircraft stalled, spun, collided with the ground in uncontrolled flight and was destroyed. Pilot's qualifications: C, FI, IR with 2,574 total hours of flight time, with 1,095 hours in type.

Mar. 18, 1978 • Beech A65 Queen Air • Vernair Transport Services • Near Angmagssalik, Greenland • Injuries: 2 fatal

On a night IMC ferry flight from Sondestrom Fjord (BGSF) to Reykjavik, Iceland, at an altitude of 3,355 meters (11,000 feet), the pilot declared an emergency, stating that the aircraft was encountering severe airframe icing, that the right engine had failed, and that the aircraft was unable to maintain altitude.

Eight minutes later, the pilot informed BGSF that the aircraft was at 2,440 meters (8,000 feet) and still descending; the pilot requested a course that would take the aircraft over water. The aircraft was vectored to Kulusuk, a VFR day-only airfield on the east coast of Greenland, where the weather was reported as visibility of 0.8 kilometer (one-half mile) in blowing snow, temperature of -4 degrees C (26 degrees F) and winds of 56 kilometers per hour (30 knots) gusting to 74 kilometers per hour (40 knots).

The pilot made three attempts at an NDB approach to Kulusuk. On the third attempt, the aircraft collided with a mountain at 519 meters (1,700 feet) elevation. At the time, the aircraft was 549 meters (1,800 feet) below the minimum safe altitude for that area.

The official accident report cited the cause of the accident as the inability of the aircraft to maintain altitude because of airframe ice and the loss of one engine. Contributing factors were the lack of a published civil aviation approach procedure (cloud penetration) for Kulusuk, and turbulent weather. The accident board theorized that the crew saw some lights and initiated a visual approach to what they mistakenly thought was the airfield.

Feb. 19, 1977 • Aero Commander 680 FL • Savoonga, Alaska, U.S. • Injuries: 2 serious, 1 minor or none

A VFR daylight flight was continued into adverse weather that included sleet and freezing rain. The aircraft was circling its destination airfield in weather below field minimums — ceiling 153 meters (500 feet), visibility less than 1.6 kilometers (one mile) and an OAT of -12 degrees C (10 degrees F) — when the pilot experienced a whiteout, which is a loss of orientation with the visual horizon caused by overcast sky and sunlight reflecting off snow. The aircraft collided with the ground in controlled flight and was destroyed. The official accident brief said that propeller ice and airframe ice were among the probable causes of the accident. Pilot's qualifications: C, IR with 19,076 total hours of flight time, with 321 hours in type.

Jan. 31, 1977 • Chase YC122 • Anchorage, Alaska, U.S. • Injuries: 1 fatal, 2 serious

After this twin-reciprocating-engine military cargo aircraft took off, witnesses saw it roll into a steep right turn and nose-low attitude. This was followed by a nose-high attitude that was maintained until the aircraft impacted a street, slid into a house and was destroyed. The copilot reported that the aircraft was going in and out of a ragged ceiling at about 122 meters (400 feet).

A postaccident inspection revealed that the aircraft wing and tail surfaces were covered with heavy hard frost. The operator said that a broom had been used to remove the frost two hours prior to takeoff.

The pilot-in-command had flown the aircraft only three times. The copilot was making his first flight.

Jan. 15, 1977 • Vickers Viscount • Linjeflyg • Near Bromma Airport, Stockholm, Sweden • Injuries: 22 fatal

The aircraft was on final approach to the airport. At an altitude of about 351 meters (1,150 feet) and at a distance of about five kilometers (3.1 miles) from the airport, it suddenly pitched down and went into a vertical dive. The aircraft impacted terrain in a residential area and was destroyed.

The cause of the accident was determined to be ice on the leading edge of the horizontal stabilizer, which resulted in flow separation and stabilizer stall. Contributing factors were the failure to inform the flight crew of the risk of severe icing in the Stockholm area; and maintaining a too-low temperature on the tailplane anti-icing mechanism, which resulted from reduced power settings for an extended period on engines no. 2 and no. 3.

Jan. 13, 1977 • Douglas DC-8 • Japan Airlines • Anchorage, Alaska, U.S. • Injuries: 5 fatal

The cargo flight departed Moses Lake, Washington, U.S., in daylight bound for Tokyo, Japan. On initial climb, the aircraft stalled, impacted the ground and was destroyed by postaccident fire. The official accident report cited the probable causes of the accident as alcoholic impairment of the pilot and the presence of airframe ice.

In remarks, the report said, "Failure of other flight crew members to prevent captain from attempting the flight." Pilot's qualifications: International Certificate, IR with 23,252 total hours of flight time, with 4,040 hours in type.

Nov. 29, 1976 • de Havilland DH-104 • Albany, New York, U.S. • Injuries: 6 minor or none

Weather was 122-meter (400-foot) ceiling, visibility restricted to 1.6 kilometers (one mile) or less in fog and falling snow, with an OAT of 0 degrees C (32 degrees F). After takeoff at daybreak on an IFR flight plan, the aircraft stalled on initial climb. It mushed into the ground and received substantial damage.

According to the official accident report, the causes of the accident were the presence of airframe ice and the failure to maintain flying speed. The report also said that the pilot had received a weather forecast that was substantially correct. Pilot's qualifications: AT, IR with 17,120 total hours of flight time, with 210 hours in type.

March 16, 1976 • Beech 99 • Wappingers Falls, New York, U.S. • Injuries: 1 serious, 8 minor or none

The aircraft took off on an IFR flight plan in daylight. Weather was falling sleet and snow with visibility of 0.8 kilometer (0.5 mile) or less. On initial climb, the aircraft's left wing dropped; the aircraft leveled momentarily, and then the right wing dropped. The aircraft stalled, mushed into the ground and was destroyed by postaccident fire.

The accident causes cited in the official accident report included poor judgment, inadequate preflight planning and initiating flight into adverse weather. Contributing factors were slush on the runway, snow, icing conditions and an improperly loaded aircraft — 167 kilograms (368 pounds) over allowable gross weight. Pilot's qualifications: AT, IR with 14,159 total hours of flight time, with 3,343 hours in type.

Nov. 24, 1975 • Beech E18S • Fort Wayne, Indiana, U.S. • Injuries: 1 minor or none

The weather at Baer Field was 61-meter (200-foot) ceiling, with visibility limited to 1.2 kilometers (0.75 mile) or less in fog and falling snow and an OAT of 1 degree C (33 degrees F).

The pilot attempted to take off with a 0.3 centimeter to 0.5 centimeter (0.13 inch to 0.19 inch) coating of rough (rime) ice on the upper surfaces of the aircraft. The aircraft became airborne, but on initial climb it stalled and struck the ground, sustaining substantial damage. The official accident report cited the pilot's inadequate preflight preparation as one of the causes of the accident. Pilot's qualifications: C, IR with 7,400 total hours of flight time, with 3,125 hours in type.

March 12, 1975 • Beech 95-C55 • Gaylord, Michigan, U.S. • Injuries: 1 minor or none

En route IMC conditions resulted in an ice-covered windshield by the time the aircraft arrived at its destination. Local weather at the accident site was a 275-meter (900-foot) ceiling with visibility of 1.6 kilometers (one mile) or less in falling snow. The OAT was -4 degrees C (25 degrees F). The aircraft landed in daylight, touched down adjacent to the runway in deep snow and was damaged substantially.

The official accident report noted that the aircraft was not equipped with anti-icing or deicing equipment. The probable causes of the accident also included attempting operation with known deficiencies in equipment. Pilot's qualifications: C, FI, IR with 2,710 total hours of flight time, with 360 hours in type.

Feb. 21, 1975 • Gates Learjet 25 • Albuquerque, New Mexico, U.S. • Injuries: 9 minor or none

The pilot delayed action in aborting the takeoff. The aircraft's drag chute deployed and failed. The aircraft overran the runway and collided with a dirt bank, receiving substantial damage. Airframe icing, weather conditions and hydroplaning on a wet runway surface were cited as causal factors in the official accident report.

Jan. 31, 1975 • Cessna 402B • Dodge City, Kansas, U.S. • Injuries: 1 serious, 2 minor or none

The aircraft left Wichita, Kansas, in daylight bound for Dodge City Municipal Airport in sleet and freezing rain. Weather at

Dodge City was 122 meters (400 feet) overcast with 3.2 kilometers (two miles) visibility in fog and freezing drizzle and an OAT of -6 degrees C (21 degrees F).

After a missed approach, the aircraft was unable to sustain flight because of the ice accumulation. The aircraft collided with the ground in controlled flight and was destroyed. The official accident report said that at the time of the accident the windshield was fully iced over and the windshield deicer was turned off. Pilot's qualifications: C, IR with 2,600 total hours of flight time, with 320 hours in type.

Jan. 14, 1975 • Beech TC-45J • Evansville, Indiana, U.S. • Injuries: 2 minor or none

The mail flight took off downwind in darkness on a snowy runway. On initial climb, the aircraft stalled and mushed into the ground, substantially damaged. The official accident report cited as the accident's causes inadequate preflight planning, the presence of airframe ice and failure to abort the takeoff. Pilot's qualifications: C, IR with 7,800 total hours of flight time, with 48 hours in type.

Jan. 2, 1975 • Beech E18S • Rockford, Illinois, U.S. • Injuries: 1 fatal, 2 serious

The aircraft was circling in the traffic pattern at Greater Rockford Airport at night in sleet and freezing rain. The ceiling was 305 meters (1,000 feet), visibility was 4.8 kilometers (three miles) or less in blowing snow, with an OAT of -2 degrees C (28 degrees F). The aircraft stalled, rolled sharply to the left, impacted the ground and was destroyed. Loss of control, according to the official accident report, was caused by an accretion of moderate rime ice on the wing during the aircraft's descent to the airport. Pilot's qualifications: C, FI, IR with 2,295 total hours of flight time, with 383 hours in type.

Dec. 1, 1974 • Boeing 727 • Northwest Airlines • Near Stony Brook, New York, U.S. • Injuries: 3 fatal

The aircraft impacted terrain 12 minutes after leaving John F. Kennedy International Airport, Jamaica, New York, on a night ferry flight. Three crew members, the only persons aboard the aircraft, died in the crash. The aircraft was destroyed.

The aircraft stalled at an altitude of 7,500 meters (24,800 feet) and entered an uncontrolled, spiralling descent. Throughout the stall and descent, the flight crew did not recognize the actual condition of the aircraft and did not take the measures necessary to return the aircraft to level flight. At an altitude of 1,000 meters (3,500 feet), a large portion of the left horizontal stabilizer separated from the aircraft, which made control of the aircraft impossible.

The official accident report determined that the probable cause of this accident was the loss of control of the aircraft because the flight crew failed to recognize and correct the aircraft's high-angle-of-attack, low-speed stall and its descending spiral. The stall was precipitated by the flight crew's improper reaction to erroneous airspeed and Mach indications, which had resulted from a blockage of the pitot heads by atmospheric icing. Contrary to standard operational procedures, the flight crew had not activated the pitot head heaters.

Jan. 26, 1974 • Fokker F-28 • THY • Cumaovasi, Turkey • Injuries: 66 fatal, 7 serious

The aircraft took off from Cumaovasi for Izmir, Turkey, shortly after 0700. According to the report, the pilot-in-command made a preflight walk-around inspection of the aircraft.

Witnesses reported that shortly after takeoff, when the aircraft was only eight meters to 10 meters (25 feet to 30 feet) above the ground, it suddenly yawed to the left and pitched nose-down. It contacted the ground in a nearly level attitude, disintegrated, caught fire and was destroyed.

The report said, "The aircraft stalled on takeoff due to over-rotation and frost accretion on the wings."

Jan. 6, 1974 • Beech 99A • Johnstown, Pennsylvania, U.S. • Injuries: 12 fatal, 5 serious

The aircraft took off from Pittsburgh, Pennsylvania, in darkness at a weight greater than the allowable gross takeoff weight and with the aircraft center of gravity beyond the aft limit. The weather at its intended destination, Johnstown-Cambria Airport, was snow and fog, with a reported ceiling of 61 meters to 122 meters (200 feet to 400 feet) and visibility less than 3.2 kilometers (two miles).

On final approach, the aircraft dropped below the glide slope for unknown reasons. In attempting to regain altitude, the aircraft stalled, impacted the ground in uncontrolled flight and was destroyed. The official accident report cited airframe ice as a factor in the accident. Pilot's qualifications: AT, IR with 6,331 total hours of flight time, with 383 hours in type.

Oct. 31, 1973 • Douglas DC-3 • Superior Airways • Wiebenville, Canada • Injuries: 3 minor or none

The aircraft took off with frost on the wings, and control could not be maintained after it became airborne at low airspeed. The aircraft collided with trees on the side of the landing strip and was substantially damaged.

March 3, 1973 • Ilyushin Il-18 • Balkan-Bulgarian Airlines • Moscow, Russia • Injuries: 25 fatal

While on an instrument approach to Moscow/Sheremetyevo Airport, the aircraft went into a steep dive about 4.8 kilometers (three miles) from the end of the runway. The aircraft struck the ground and was destroyed by fire.

The official accident report cited the probable causes of the accident as tailplane icing, probably because of the absence of leading-edge heating (the actual operation of the tailplane anti-icing system could not be determined because of the destruction of the aircraft); the setting of full flaps, which caused a deterioration of airflow past the underside of the tailplane; and a negative G load of 0.6 to 0.5, caused by an upward pitching maneuver to correct a deviation from glidepath.

Dec. 6, 1972 • Douglas DC-3 • Superior Airways • Canada • Injuries: 3 minor or none

While airborne, the captain was attempting to remove ice from the windshield with a scraper. The aircraft entered a spiral, and the pilot's corrective action was so violent that a high-speed stall ensued. The aircraft struck the ground in a nose-down attitude and was destroyed.

March 15, 1972 • Aircraft not identified • Brook Park, Ohio, U.S. • Injuries: 1 fatal

The pilot reported for duty about 13 hours before the accident. The flight departed in early morning darkness for Cleveland, Ohio. En route, the aircraft encountered unforecast icing conditions, and airframe ice formed. The pilot decided to make an unscheduled landing at Brook Park, where the weather was freezing drizzle, 92-meter (300-foot) ceiling, 3.2 kilometers (two miles) visibility in fog, and the OAT was 0 degree C (32 degrees F).

The official accident report said that during the ILS approach, the pilot did not compensate for the airframe icing. The aircraft failed to maintain flying speed. It stalled, mushed into the ground and was destroyed. Pilot's qualifications: AT, IR with 3,891 total hours of flight time, with 510 hours in type.

Feb. 16, 1972 • Beech D18S • Jackson, Michigan, U.S. • Injuries: 2 fatal

The night was clear when the aircraft took off. According to the official accident report, an observer saw ice on the aircraft before (and after) the accident. During climb, the aircraft's right engine failed for undetermined reasons. The aircraft did not maintain flying speed; it stalled, impacted the ground and was destroyed. The official accident report cited weather and airframe ice as contributing factors in this accident. Pilot's qualifications: AT, IR with 6,566 total hours of flight time, with an unknown number of hours in type.

Jan. 30, 1972 • Douglas DC-3 • Douglas Aircraft Company • Boyne Falls, Michigan, U.S. • Injuries: 12 minor or none

The crew observed ice on their aircraft's wings, and deicing fluid was applied to the wings. A passenger who was in the cockpit prior to taxi said that there was extensive frost on the inside of the windshield. The runway used for the daylight takeoff was 1,281 meters (4,200 feet) long, 24 meters (80 feet) wide and had been scraped clean of snow. Weather was reported as clear, with the wind from 270 degrees at 9.2 kilometers per hour (five knots) and an OAT of -18 degrees C (0 degrees F).

Witnesses reported that the pilot had his head out the side window for the first 214 meters (700 feet) of the takeoff roll. At a measured distance of 482 meters (1,580 feet) from the threshold, the aircraft departed the right side of the runway at a 20-degree angle and struck a snow bank, causing substantial damage to the nose section and left engine's propeller blades. The official accident report said, " [The accident aircraft] was the seventh aircraft to operate this runway in a short time span."

Probable causes of the accident were cited as: inadequate preflight preparation, failure to maintain directional control and weather-induced obstructions to vision.

Dec. 16, 1971 • Beech 65-B80 • McCall, Idaho, U.S. • Injuries: 1 serious, 3 minor or none

The daylight flight was from Missoula, Montana, U.S., to Boise, Idaho, in IMC. While en route, the aircraft encountered freezing drizzle and began to accumulate moderate to severe icing on unprotected airframe areas. Unable to maintain altitude because of the ice, the pilot elected to make an emergency landing at an airport in McCall.

Weather at McCall was freezing drizzle and a ceiling of 305 meters (1,000 feet). OAT was -7 degrees C (20 degrees F). On final approach, the pilot lowered the landing gear prematurely, undershot the runway and collided with a snowbank. The aircraft sustained substantial damage. Pilot's qualifications: AT, IR with 3,477 total hours of flight time, with 1,215 hours in type.

Dec. 8, 1971 • Beech Volpar • Grand Island, Nebraska, U.S. • Injuries: 1 minor or none

The pilot departed on an IFR night flight from Des Moines, Iowa, U.S., to Grand Island with a preflight forecast of icing conditions both en route and at the destination.

Weather at Grand Island was freezing drizzle and snow, with a ceiling of 92 meters (300 feet), visibility of 4.8 kilometers (three miles) or less in fog and an OAT of 0 degrees C (32 degrees F). The aircraft's deicing equipment was inadequate for the amount of ice that accumulated on the airframe and windshield. The pilot made a hard landing on the runway, overloading the landing gear. On rollout, the landing gear collapsed, causing substantial damage to the aircraft. Pilot's qualifications: AT, IR with 3,690 total hours of flight time, with 480 hours in type.

March 18, 1971 • Beech TC-45H • Chicago, Illinois, U.S. • Injuries: 1 minor or none

The ceiling was 31 meters (100 feet) and the visibility was 0.4 kilometer (0.25 mile) or less. The snow-covered aircraft made a daylight takeoff from O'Hare International Airport, Chicago, in falling snow and in a 90-degree crosswind. The aircraft was 160 kilograms (352 pounds) over its maximum allowable gross takeoff weight, and the aircraft's center of gravity was 15 centimeters (six inches) aft of acceptable limits.

The aircraft encountered ground water on its takeoff run and swerved, but continued on its takeoff run and became airborne. Shortly thereafter, the aircraft stalled and mushed into the ground, causing substantial aircraft damage. Pilot's qualifications: C, FI, IR with 2,350 hours of flight time, with 285 hours in type.

Dec. 23, 1970 • Beech H18S • Lansing, Michigan, U.S. • Injuries: 2 serious

The mail flight's night ILS approach was inhibited by a 92-meter (300-foot) overcast and visibility of 3.2 kilometers (two miles) or less in fog. The OAT was -4 degrees C (25 degrees F). The official accident report said that the aircraft had been flying through sleet and freezing rain en route. On final approach to Lansing Airport, the aircraft failed to maintain flying speed, stalled and was destroyed. Pilot's qualifications: AT, IR with 6,267 total hours of flight time, with 2,535 hours in type.

March 22, 1970 • Beech C-45H • Binghamton, New York, U.S. • Injuries: 3 fatal, 8 serious

The aircraft took off in daylight with an accumulation of snow on the aircraft's wings and with snow falling. The weather was a 92-meter (300-foot) ceiling with visibility of 0.8 kilometer (0.5 mile) or less. OAT was 1 degree C (33 degrees F). On initial climb, after the landing gear was retracted, the pilot attempted to abort the takeoff and land straight ahead with wheels intentionally up. The aircraft stalled, mushed into the ground and was destroyed. Pilot's qualifications: AT, IR with 6,630 total hours of flight time, with 106 hours in type.

Feb. 14, 1970 • Beech E18S • Kansas City, Kansas, U.S. • Injuries: 1 fatal

The aircraft was on an IFR night flight. As the aircraft approached Kansas City, snow and freezing drizzle were encountered, and the aircraft accumulated ice on the airframe and windshield. Weather at the airport was 366 meters (1,200 feet) overcast with visibility of 6.4 kilometers (four miles) or less in fog. The OAT was -6 degrees C (22 degrees F).

The official accident report said that the pilot was aware of the icing conditions, but that the aircraft had limited deicing capability because of the failure of an engine-driven vacuum pump. On initial approach, the aircraft failed to maintain flying speed; the aircraft struck the ground in uncontrolled flight and was destroyed. Pilot's qualifications: C, IR with 2,014 total hours of flight time, with 1,133 hours in type.

Feb. 9, 1970 • Hawker Siddeley Comet 4C • UAA • Riem Airport, Munich, Germany • Injuries: 23 minor or none

The takeoff was abandoned at an altitude of about 9.2 meters (30 feet) because of airframe buffeting. The aircraft sank back onto the runway, then plowed through the boundary fence. The landing gear was torn off, and the aircraft was destroyed.

Probable causes listed in the official accident report include: the failure of the flight crew to remove the airfoil ice prior to the attempted takeoff; the improper use of wing deicing during taxi, resulting in a ridge of ice on the upper side of the wing near the leading edge; and improper operation of the flight controls, resulting in an overrotation.

Jan. 22, 1970 • Aero Commander 680 V • Aspen, Colorado, U.S. • Injuries: 8 fatal

During the daylight flight from Denver, Colorado, in icing conditions (sleet and freezing rain), the pilot failed to follow proper procedures for airborne deicing and anti-icing. The aircraft windshield was covered with ice. When the aircraft arrived at Sardy Field, the weather was a 1,525-meter (5,000-foot) ceiling with visibility of eight kilometers (five miles) or more in falling snow and an OAT of -1 degree C (30 degrees F).

The pilot missed his first approach. There was no formal go-around procedure in the flight company's manual. The pilot failed to follow the company's informal go-around procedure. The aircraft struck a mountain that was obscured from the pilot's view by windshield ice, and the aircraft was destroyed. Pilot's qualifications: AT, IR with 5,865 total hours of flight time, with 525 hours in type.

Dec. 5, 1969 • Lockheed 18 (Lodestar) • Albuquerque, New Mexico, U.S. • Injuries: 11 fatal

While operating in IMC, the aircraft made an uncontrolled descent during which its design limits were exceeded. The left wing failed and separated; the aircraft crashed and was destroyed.

The official accident report listed the probable causes as: operation with known equipment deficiencies (no deicers fitted to aircraft) and continued VFR flight into adverse weather conditions. Factors included airframe icing, sleet and freezing rain.

The report said, "The flight was operated in IFR conditions but the pilot was rated for VFR only."

Dec. 4, 1969 • Aero Commander AC1121B • Ehrenstroms Flyg • Stockholm, Sweden • Injuries: 2 fatal

Shortly after takeoff, the aircraft stalled. It struck the ground, collided with a building outside the airport and was destroyed.

The preliminary investigation found that takeoff was made with frost on the wings, and that the maximum takeoff weight and the rear center-of-gravity limit were both exceeded.

Oct. 3, 1969 • Beech 65-B80 • Denver, Colorado, U.S. • Injuries: 5 fatal, 2 serious

After normal cruise, the aircraft approached Stapleton International Airport in Denver in daylight. Weather at the airport was a 92-meter (300-foot) ceiling, with visibility limited to 1.2 kilometers (0.75 mile) or less in falling snow and an OAT of 1 degree C (33 degrees F). (The 92-meter ceiling was above the decision height for an ILS approach to Runway 26 left, but below the minimum descent altitude for an airport surveillance radar approach). The pilot was offered and accepted the air surveillance radar approach.

After failing in his first landing attempt, the pilot executed a missed-approach procedure. During the go-around, the left engine failed from ice induction. The aircraft was unable to maintain flying speed, stalled and was destroyed when it struck the ground. The official accident report cites airframe ice as a contributing factor to the accident. Pilot's qualifications: C, IR with 2,062 total hours of flight time, with 148 hours in type.

March 25, 1969 • Cessna 402 • Chicago, Illinois, U.S. • Injuries: 8 minor or none

The weather was a 244-meter (800-foot) ceiling with visibility of less than 4.8 kilometers (three miles) in fog, sleet and freezing rain. The OAT was 1 degree C (33 degrees F). The aircraft took off with patches of snow on the wings in daylight. When the pilot discovered that the aircraft would not climb, he aborted the takeoff. The aircraft hit the fence at the airport perimeter, causing substantial damage to the aircraft. The official accident report listed airframe ice as a contributing factor in this accident. Pilot's qualifications: AT, IR with 3,750 total hours of flight time, with 510 hours in type.

Feb. 25, 1969 • Fokker F-28 • LTU International Airways • Lapenhagen, Netherlands • Injuries: 11 minor or none

The aircraft was covered with a thin layer of ice. The pilot judged the ice accretion not significant enough to order its removal before the flight. The official accident report said, "During takeoff, the aircraft was rotated to a pitch angle well in excess of the recommended flight handbook data. Because of the ice on the wing surfaces, the aircraft stalled and while banking to the right lost height."

The right wing tip hit the runway, causing substantial damage to the aircraft. Causal factors listed in the official accident report included: improper flight preparation, improper operation of flight controls and icing conditions.

Feb. 1, 1969 • Beech D18S • Kansas City, Missouri, U.S. • Injuries: 2 serious

The pilot failed to make adequate preflight preparation and took off from Kansas City Municipal Airport at greater than the aircraft's allowed gross takeoff weight and with frost on the wings. The weather at the time was fog, with visibility of less than 3.2 kilometers (two miles) and an OAT of -8 degrees C (17 degrees F).

On initial climb, the aircraft encountered sleet and freezing rain. Ice accumulated on the airframe, and altitude could not be maintained. The aircraft stalled, mushed into the ground and was destroyed. Pilot's qualifications: C, IR with 1,188 total hours of flight time, with 991 hours in type.

Dec. 27, 1968 • Douglas DC-9 • Ozark Airlines • Sioux City, Iowa, U.S. • Injuries: 3 serious, 65 minor or none

Weather at Sioux City Airport was freezing drizzle, with a 244-meter (800-foot) ceiling and visibility of 4.8 kilometers (three miles) or less in fog. The pilot failed to follow approved procedures and made a daylight IFR takeoff with ice on the airframe.

After takeoff, as the landing gear began to retract, the aircraft rolled sharply and violently to the right to an angle of bank estimated by the flight crew to have been 90 degrees. The pilot leveled the wings, but the left roll continued, and the left wing struck the runway. The pilot discontinued the takeoff and leveled the wings again before the aircraft stalled, struck the ground and was destroyed. Pilot's qualifications: AT, IR with 19,146 total hours of flight time, with 63 hours in type.

Dec. 18, 1968 • Beech G18S • Kenai, Alaska, U.S. • Injuries: 4 serious, 5 minor or none

Kenai weather was a ceiling of 519 meters (1,700 feet), with visibility of 4.8 kilometers (three miles) or less and an OAT of -9 degrees C (16 degrees F). Circling the airport in daylight, the aircraft encountered heavy icing in snow and ice fog. The pilot failed to maintain flying speed; the aircraft stalled during an attempt to align with the runway in a poorly planned approach and was destroyed. Pilot's qualifications: C, IR with 2,525 total hours of flight time, with 470 hours in type.

July 1, 1968 • Aero Commander Jet Commander • Drake Field, Arkansas, U.S. • Injuries: 1 fatal

Both engines flamed out at 12,505 meters (41,000 feet) in daylight and sleet and freezing rain. Repeated efforts to restart the engines during an emergency descent were unsuccessful. Circling for a landing without power, the pilot was forced to dive the aircraft to maintain airspeed. A wing contacted the ground, and the aircraft struck the ground short of the runway and was destroyed.

The official accident report determined that the probable cause was improper operation of powerplant and powerplant controls; failure to use carburetor heat/deicing equipment; and miscellaneous factors that included engine icing.

Jan. 15, 1968 • Douglas DC-3 • UAA • Zifta, United Arab Republic • Injuries: 4 fatal

The nonscheduled cargo flight was preparing for a night flight from Cairo, Egypt, to Beirut, Lebanon, in an aircraft with no deicing equipment. En route weather was forecast as occasional thunderstorms, turbulence and moderate to severe icing conditions, which had been confirmed by a pilot's report and two SIGMETs. After an undetermined delay to wait for the weather to improve, the aircraft took off in early morning daylight.

Twenty-five minutes later, the pilot contacted Cairo Approach Control. He advised that the aircraft was experiencing icing and that the flight would return to Cairo. Shortly thereafter, the pilot repeated the message, adding that there was ice accretion on the aircraft. At 0754, 34 minutes after takeoff, the aircraft impacted terrain.

The accident report said that the accident was caused by ice accretion on the lifting surface of the aircraft, accompanied by moderate to severe turbulence that resulted in the pilot's loss of aircraft control and the disintegration of the aircraft's main parts in the air. Contributing factors cited were the load of the aircraft, which exceeded the approved load by about 500 kilograms (1,102 pounds), and the effect of probable shifting cargo on the aircraft's center of gravity.

Oct. 25, 1967 • Gates Learjet 23 • Executive Jet Aviation • Muskegon, Michigan, U.S. • Injuries: 4 minor or none

The aircraft had no wing or empennage deicers. It was circling to land when both engines failed following compressor stalls caused by engine ice ingestion. The aircraft was ditched in a lake and was destroyed. The official accident report cited the causes of the accident as attempting flight operations with known deficiencies in equipment and improper flight planning. Airframe icing was cited as a contributing factor.

March 10, 1967 • Fairchild F-27 • West Coast Airlines • Klamath Falls, Oregon, U.S. • Injuries: 4 fatal

Freezing rain had fallen overnight, and there was airframe ice on the aircraft. In preparation for flight, the ice was not removed, nor was deicing fluid applied. The aircraft took off in early morning darkness on an IFR clearance and climbed to altitude. Shortly after takeoff, the aircraft became uncontrollable and struck the face of a mountain at an altitude of about 1,300 meters (4,500 feet).

According to the official accident report, the probable cause of the accident was the pilot's loss of control due to ice accretion on airframe surfaces. The report also said that pilot had been accurately briefed on the weather situation. Pilot's qualifications: AT, IR with 9,271 total flight hours and 4,684 in type.

Nov. 19, 1966 • Curtiss C46F • Keflavik, Iceland • Injuries: 2 minor or none

The aircraft was covered with snow. The pilot received permission from the tower to taxi on the runway at high speed to determine if the relative wind would blow the snow off. The aircraft reached an IAS of 92 kilometers per hour (50 knots), and much of the snow did blow away. The pilot then taxied the aircraft back to the downwind end of the runway and, with the tower's clearance, took off.

Shortly after becoming airborne, before the landing gear was retracted, the aircraft began a roll to the left. When full-right rudder and full-right aileron failed to stop the roll, the pilot throttled back on the right engine and put the wheels back on the runway.

The aircraft rolled off the paved surface and encountered soft earth. The right landing gear buried and folded under the right wing, and the aircraft was destroyed. No probable causes for the accident were cited in the official accident report.

March 18, 1966 • Gates Learjet • Mutual Insurance • Lake Michigan, U.S. • Injuries: 2 minor or none

The aircraft was successfully ditched in daylight following a double engine failure caused by engine inlet icing. The official accident report cited the pilot's failure to use nacelle heating in icing conditions as the cause of the accident. The aircraft sustained substantial damage.

Dec. 20, 1965 • Grumman Gulfstream • Northern Consolidated Airlines • Bethel, Alaska, U.S. • Injuries: 8 minor or none

After an inadequate preflight preparation, the aircraft took off in daylight. Liftoff was premature; shortly after becoming airborne, the aircraft stalled and collided with the ground, sustaining substantial damage. Although the weather at the time of takeoff was clear, the official accident report cited airframe ice as a contributing factor in the accident. In addition, the report said that the aircraft was improperly loaded. Pilot's qualifications: AT, IR with 2,500 total hours of flight time, with 215 hours in type.

Nov. 20, 1964 • Curtiss C46 • Zantop Airways • Detroit, Michigan, U.S. • Injuries: 2 minor or none

In predawn darkness, ground personnel deiced the aircraft. Five centimeters to eight centimeters (two inches to three inches) of snow were swept from the wings and tail, and an 8-to-1 alcohol and ethylene glycol mixture was applied to the underlying layer of rough, crusted ice. The pilots indicated that when they arrived at the aircraft they did not see any ice on the wings or tail but noted what appeared to be loose snow on top of the fuselage, and they found ice and snow on the windshield.

The weather for the airport was 702 meters (2,300 feet) overcast with visibility of 16 kilometers (10 miles) in light snow and an OAT of -3 degrees C (26 degrees F). The runway used for takeoff had been described several hours earlier as covered with rough ice and crusted snow about 0.6 centimeter (0.25 inch) deep.

Witnesses said that the aircraft appeared slow to become airborne. Shortly after takeoff, as the power was being reduced, the aircraft began to vibrate. The pilot restored takeoff power, but the aircraft settled to the ground past the end of the runway with landing gear and flaps up. A small fire erupted in the left-engine area but was extinguished with foam. The aircraft was destroyed.

Investigation revealed a crust of rough opaque ice or frozen snow averaging about 0.33 centimeter (0.13 inch) thick on the upper surface of the right wing. Examination of the aircraft wreckage revealed no evidence to indicate mechanical malfunction or failure of the aircraft prior to ground impact.

Probable cause of the accident was a loss of lift during takeoff caused by airframe icing. Inadequate deicing procedures and preflight inspection were cited in the official accident report as contributing factors.

March 10, 1964 • Douglas DC-4 • Slick Airways • Boston, Massachusetts, U.S. • Injuries: 3 fatal

The weather at the airport was 214 meters (700 feet) overcast with a visibility of 3.2 kilometers (two miles) in fog and sleet. On a daylight ILS approach with radar advisory, rime ice accretion on the horizontal stabilizer caused a loss of balancing air forces. The aircraft suddenly pitched nose-down, made an uncontrolled collision with the ground and was destroyed. Pilot’s qualifications: AT, FI, IR with 6,000 total hours of flight time, with 815 hours in type.

March 8, 1964 • Douglas DC-3A • Snow Valley Ski • Chicago, Illinois, U.S. • Injuries: 1 fatal, 1 serious, 34 minor or none

Ice was accreting on the aircraft during its ILS approach to O’Hare International Airport, Chicago. The aircraft’s deicing equipment was not being used. The aircraft then encountered a vortex wake from a departing large jet, and the ILS approach was discontinued. The aircraft flew into an occupied house near the airport and sustained substantial damage.

The official accident report said that the probable cause of this accident was the failure of the crew to use available deicing equipment and engine power to maintain positive control of the aircraft under conditions of rapid airframe ice accretion and vortex-induced turbulence.

Dec. 21, 1963 • Convair 440 • Midland, Texas, U.S. • Injuries: 4 serious

The IFR flight departed in daylight from Houston, Texas, to Midland. The preflight weather briefing reported freezing drizzle at Midland. The flight was conducted above all clouds at an assigned altitude of 4,880 meters (16,000 feet). Weather at Midland when the flight arrived was: 61-meter (200-foot) ceiling, visibility less than 3.2 kilometers (two miles), light falling snow grains, fog and an OAT of -3 degrees C (27 degrees F).

The crew conducted an ILS approach. Witnesses reported that immediately after the aircraft broke out of the overcast, it began a series of up-and-down pitch oscillations, with the third downward pitch continuing until the aircraft struck the ground, where it was destroyed by postaccident fire. Witnesses also reported that, after the fire was brought under control, they observed rime ice on the left-wing leading edge. This ice accumulation was measured nine hours later and found to be 1.3 centimeters (0.5 inch) thick and 6.4 centimeters (2.5 inches) wide throughout its length.

Examination of the wreckage failed to disclose any evidence of mechanical failure. The wing and empennage anti-icers and the propeller deicers were in the “off” position, and the crew said that wing and empennage anti-icers were not used during the approach. The crew also said that the approach was normal until the flaps were extended from the approach to the landing position, at which time the oscillations began.

On the basis of these findings, the official accident report concluded that an accumulation of rime ice on the tail airfoil surfaces resulted in a loss of pitch control when the flaps were extended to the full position. The probable cause of the accident was cited as the failure of the crew to properly use the deicing and anti-icing capabilities of the aircraft in known icing conditions.

Jan. 29, 1963 • Vickers Viscount 810 • Continental Airlines • Kansas City, Missouri, U.S. • Injuries: 8 fatal

The aircraft was flying on an IFR flight plan in sleet and freezing rain. Weather at Kansas City Municipal Airport was 915 meters (3,000 feet) overcast and eight kilometers (five miles) visibility; the OAT was -8 degrees C (17 degrees F).

While the aircraft was on approach to a night landing, undetected ice on the horizontal stabilizer, in conjunction with the aircraft’s airspeed and configuration, caused a loss of pitch control. The aircraft collided with terrain in uncontrolled flight and was destroyed. Pilot’s qualifications: AT, IR with 18,611 total hours of flight time, with 3,409 hours in type.

Feb. 13, 1960 • Curtiss C46 • Associated Air Transportation • McGuire Air Force Base (MAFB), New Jersey, U.S. • Injuries: 57 minor or none

The flight to MAFB encountered light-to-moderate icing over Charleston, West Virginia, U.S., and wing deicers and propeller anti-icers were activated. By the time the flight reached Baltimore, Maryland, U.S., aircraft engine power settings had to be constantly increased to maintain altitude, eventually reaching METO power. This caused a sharp, unplanned increase in fuel consumption. During the final approach to MAFB, the aircraft stalled, settled onto the ground and came to rest 366 meters (1,200 feet) short of the runway threshold. The aircraft sustained substantial damage.

Investigation determined that the flight was improperly continued to its destination, overflying a suitable alternate airport, despite known inadequate fuel reserves and severe icing conditions; that the flight crew was not properly briefed on the terminal and en route weather; and that the flight crew did not properly monitor the weather while en route.

Jan. 18, 1960 • Vickers Viscount • Capital Airlines • Charles City, Virginia, U.S. • Injuries: 50 fatal

While en route from Washington, D.C., to Norfolk, Virginia, U.S., the aircraft collided with the ground and burned near Charles City, Virginia. Investigation indicated that arming of the engine ice protection system was delayed while flying through icing conditions, causing an eventual power failure in all four engines. The no. 3 and no. 4 engines had been restarted when the aircraft struck terrain.

Feb. 1, 1959 • Douglas DC-3 • General Airways • Kerrville, Texas, U.S. • Injuries: 3 fatal, 4 serious, 21 minor or none

The flight made an en route stop in Pueblo, Colorado, U.S., where a weather briefing indicated that icing conditions existed over the route and were expected to continue. After the flight departed Pueblo for Kerrville, a series of radio communications from the aircraft indicated that airframe ice was accruing, and that the accretion was becoming critical. Approaching its destination, the aircraft's fuel was exhausted. The aircraft impacted trees about 11 kilometers (seven miles) from the airport and the aircraft was destroyed by postaccident fire.

The accident board determined the probable cause of the accident to be the captain's poor judgment in continuing into known and dangerous icing conditions.

Dec. 4, 1958 • Sud-est SE 161 (Languedoc) • AVIACO • Guadarrama Mountains, Spain • Injuries: 21 fatal

The IFR flight took off for Madrid, Spain, in daylight with an assigned cruising altitude of 2,900 meters (9,500 feet). The forecast freezing level was 2,200 meters (7,200 feet). Two en route radio transmissions were made from the aircraft to air traffic control, during which the crew reported that the VHF radio was out of order, but did not indicate any problems with the weather. About 10 minutes after the last radio report, the aircraft struck a mountain peak 2,000 meters (6,500 feet) high and the aircraft was destroyed.

According to the official accident report, if the accident was caused by meteorological factors, icing would have been the factor most directly responsible. Severe airframe icing could have created a sudden change in the aircraft's aerodynamic characteristics, triggering a stall without giving the captain time to take recovery action. The report stated, "Under severe icing conditions, the mechanical deicing equipment is practically inoperative."

Other possible factors were turbulence and the possibility that the captain decided to descend to escape icing conditions, mistakenly believing that he had already passed the mountain peak.

April 6, 1958 • Vickers Viscount 745 • Capital Airlines • Freeland, Michigan, U.S. • Injuries: 47 fatal

On a landing approach in restricted visibility, a steep turn was made to align the aircraft with the runway. The aircraft stalled and entered a spin at an altitude too low to allow for recovery. The aircraft struck the ground and was destroyed. The official accident report said that the probable cause of the accident was an undetected accretion of ice on the horizontal stabilizer that, in conjunction with a specific airspeed and aircraft configuration, caused a loss of pitch control.

Feb. 6, 1958 • Airspeed Ambassador • BEA • Riem Airport, Munich, Germany • Injuries: 23 fatal, 12 serious, 9 minor or none

After the aircraft had been on the ground for two hours in falling snow, the flight crew attempted a takeoff from Munich on a daylight flight to Manchester, England. The aircraft never became airborne. It ran off the end of the runway, through a maneuvering area, and struck a house and a wooden hut. The aircraft was destroyed.

The accident investigation concluded that during the two-hour stop at Munich, a rough layer of ice formed on the upper surface of the wings as a result of the snowfall. This layer of ice impaired the aerodynamic efficiency of the wings, greatly increasing the airspeed necessary for takeoff.

Dec. 6, 1957 • L-1049G • Air France • Orly Airport, Paris, France • Injuries: 6 minor or none

Three Air France captains and an instructor pilot were performing a semiannual check flight at night. The fourth and final landing was an ILS approach. Weather was IMC, with a ceiling of 60 meters (200 feet), and visibility of 1.6 kilometers (one mile). According to witnesses, after making a normal approach, the aircraft tilted sharply to the left, touched the ground 400 meters (1,312 feet) short of the runway and then climbed a few meters. The aircraft then struck the runway and broke in pieces. The aircraft came to a halt outside the runway after the separation of the left wing and the right wing tip.

According to the official accident report, the accident resulted from excessive corrective maneuvers performed at the time of contact with the runway. The report also said that icing on the aircraft might have reduced its aerodynamic qualities.

Nov. 17, 1957 • Vickers Viscount 802 • BEAC • Near Copenhagen, Denmark • Injuries: 2 minor or none

While the turboprop aircraft was holding an altitude of 1,068 meters (3,500 feet) in clouds at night, three of its four engines lost power, and the propellers autofeathered. The aircraft made an off-airport landing and was destroyed. Loss of power was attributed to flameouts caused by lumps of ice breaking off the engine cowlings and entering the air intakes.

Oct. 4, 1957 • Douglas DC-3 • Eldorado • Fort McMurray, Alberta, Canada • Injuries: 2 serious

The aircraft was en route to Port Radium, Northwest Territories, at an altitude of 2,745 meters (9,000 feet) when it encountered light rime ice, which was disposed of by the aircraft's deicing equipment. The aircraft then encountered freezing rain, and the buildup of ice was so rapid that the ice could not be removed with the deicing equipment.

The aircraft was cleared to descend to 2,135 meters (7,000 feet). During the descent the ice accretion continued. The aircraft could not maintain 2,135 meters; it continued to descend, running through rain squalls. At an altitude of about 1,373 meters (4,500 feet), severe turbulence was encountered. The aircraft flew into trees and was destroyed.

According to the official accident report, the probable cause of the accident was the continuation of the flight into an area of freezing precipitation, where the accumulation of ice and severe turbulence resulted in partial loss of control. A contributing factor was weather more severe than had been forecast.

Nov. 7, 1956 • de Havilland Heron II • Braathens SAFE • Hommelfjell, Tolga, Norway • Injuries: 2 fatal, 10 serious or minor

After takeoff, the daylight IFR flight first entered clouds at 763 meters (2,500 feet). At its cruising altitude of 2,440 meters (8,000 feet), the aircraft began to experience light icing, and the pilot noticed that the IAS was 37 kilometers per hour (20 knots) below normal.

"From this point on," the official accident report said, "it appears that the icing increased rapidly," even though the deicing systems for the wing and tailplane were in use. The aircraft began to lose altitude. It flew into terrain at an elevation of about 1,350 meters (4,500 feet) and was destroyed. At the time of the accident, the aircraft was in heavy fog, with the windshield covered by ice that reduced crew visibility.

The accident report said that the accident was caused by the unusually heavy icing, and that a severe downdraft immediately prior to the crash may have been a contributing factor.

Jan. 17, 1956 • Douglas DC-3C • Quebecair • Oreway, Labrador, Canada • Injuries: 4 fatal, 2 serious, 12 minor or none

About one and one-half hours after takeoff, moderate to heavy rime ice was encountered on a night flight, and the crew flew the aircraft higher in an attempt to escape icing conditions. About 30 minutes later, the starboard engine failed and its propeller was feathered.

The aircraft could not maintain altitude on one engine and began a slow descent. High terrain was ahead, so the captain elected to return to Oreway, the flight's departure point. The aircraft flew into the ground near the Oreway airport and was destroyed.

The investigation determined that the cause of the accident was the aircraft's inability to maintain altitude on one engine in icing conditions.

Dec. 29, 1955 • Lockheed 18 (Lodestar) • Gulf Refining • Near Londonderry, Ohio, U.S. • Injuries: 2 fatal

The aircraft flew into terrain in daylight and was destroyed by ground fire. The official accident report stated, "The ... probable cause of this accident was the accumulation of enough ice to result in loss of control and the subsequent shedding of vertical surfaces from the tail group of the aircraft."

Feb. 26, 1954 • Convair 240 • Western • Near Wright, Wyoming, U.S. • Injuries: 9 fatal

The flight was routine until about five minutes before the crash. Weather in the area at the time was moderate to severe turbulence with severe icing conditions. The aircraft made a rapid descent, struck at a high speed in a near-level attitude and was destroyed.

Feb. 5, 1954 • Curtiss C46F • Flying Tiger • Romulus, Michigan, U.S. • Injuries: 2 minor or none

A considerable amount of ice accreted en route. When power was reduced over the end of the runway, the aircraft dropped in and bounced about six meters (20 feet). Power was applied for go-around, and the gear was retracted. When the flaps were raised, the aircraft settled in on its underside and slid to a stop on the turf.

Jan. 20, 1954 • Douglas DC-3A • Zantop Airways • Near Kansas City, Missouri, U.S. • Injuries: 3 fatal

The cargo flight was making an ADF approach to Fairfax Airport, Kansas City, in early morning darkness when it struck the ground 122 meters (400 feet) short of the runway and was destroyed. The official accident report cited low-altitude loss of control, resulting from an ice accretion on the airframe and the use of deicer boots at low air speeds, as the cause of the accident.

Jan. 7, 1953 • Curtiss C46F • Associated Air Transportation • Fish Haven, Idaho, U.S. • Injuries: 40 fatal

The aircraft began to encounter light to moderate turbulence and light rime ice at the assigned cruising altitude of 3,965 meters (13,000 feet). Lower altitudes were reported as worse, with moderate to heavy turbulence and icing. The crew of another flight, preceding this one by a few minutes, reported that they had avoided the turbulence in the area by increasing their altitude to 4,118 meters (13,500 feet). But the accident flight did not request a higher altitude.

Evidence indicated that the aircraft, for reasons unknown, descended into an area of high terrain where there was turbulence and icing. The aircraft flew through trees on a mountain, wings level, and was destroyed.

Nov. 1, 1951 • Curtiss C46F • Flying Tiger • Cleveland, Ohio, U.S. • Injuries: 3 minor or none

The aircraft encountered unreported icing conditions en route to Cleveland. As the ice accreted on the aircraft, the left airspeed indicator failed, and the right one became erratic. The final approach was made at above-normal airspeed to allow for the effects of ice on the airfoils, and touchdown was made about halfway down the runway. Braking action on the slippery runway was poor, and the aircraft overran the runway and through the boundary fence, causing substantial damage to the aircraft.

Aug. 8, 1951 • Douglas DC-3 • TAA • Barilla Bay, Tasmania, Australia • Injuries: 2 fatal

The aircraft took off at night on a scheduled flight to Cambridge, Tasmania. One and six-tenths kilometers (one mile) north of the airport, the aircraft flew into the waters of Barilla Bay and was destroyed. The accident was caused by a loss of control during a low-altitude turn. The loss of control was attributed in the official accident report to the presence of ice on the aircraft's surfaces.

March 27, 1951 • Douglas DC-3 (Dakota) • Air Transport Charter • Near Ringway Airport, Manchester, England • Injuries: 2 fatal, 1 serious

The aircraft was operating a night newspaper service from Ringway Airport, England, to Nutts Corner Airport in Belfast, Ireland. Following an erratic takeoff in falling snow, the aircraft swung to left and failed to gain height. One or both of the engines were heard to cut out intermittently. The aircraft struck a tree near the end of the runway and dived into the ground.

The official accident report determined that the probable cause of the accident was the inability of the aircraft to gain height shortly after becoming airborne. The captain's failure to use the heat controls allowed ice formation in the carburetor intakes, which led to a loss of engine power. The effect of the extended landing gear and the presence of snow on the wings were possible contributing factors.

Feb. 23, 1951 • Curtiss C46E • Slick Airways • Newhall, California, U.S. • Injuries: 3 minor or none

The night flight encountered icing conditions more severe than forecast. The pilots attempted to return to the departure point, but the aircraft had apparently picked up so much ice that altitude could not be maintained. The pilots made a forced landing alongside a highway in mountainous terrain. The aircraft hit a large iron pole, sheared a power-line pole, skidded to a stop and was destroyed.

Feb. 16, 1950 • Douglas DC-3 • Eastern Airlines • Lexington, Kentucky, U.S. • Injuries: 18 minor or none

During letdown into Lexington, ice accreted on the leading edges of the aircraft's wings and on the propeller blades. To offset the reduced effectiveness of the wings and propellers, the pilot increased airspeed on his approach. After the aircraft landed without incident, only the left engine was secured for ramp loading operations. No action was taken to remove ice from the aircraft.

When ramp loading was completed, the aircraft took off again. It stalled shortly after it became airborne, and the pilot was unable to regain control. The aircraft touched down, rolled through a gully and came to rest in normal landing attitude. Damage to the aircraft was substantial.

Oct. 9, 1949 • Curtiss C46F • Slick Airways • Cheyenne, Wyoming, U.S. • Injuries: 3 fatal

The scheduled destination for the IFR flight was Denver, Colorado, U.S., but weather eventually forced the flight to its second alternate at Cheyenne. Icing conditions were forecast en route, with the freezing level at 2,440 meters (8,000 feet).

Reported weather at Cheyenne when the flight arrived was a 275-meter (900-foot) ceiling with visibility limited in sleet. The flight crew reported severe turbulence and ice accretion immediately on beginning the letdown. During final approach, the aircraft went out of control, crashed four kilometers (2.5 miles) from the airport and was destroyed. The aircraft's wings and tailplane surfaces were not equipped with deicer boots.

The official accident report stated, “Since wings and tail surfaces of aircraft were not equipped with deicer boots, the captain showed poor judgment in [making the flight] under existing conditions.” The report cited the probable cause of the accident as “the loss of control of the aircraft during an instrument approach ... under conditions of heavy icing and severe turbulence.”

March 2, 1949 • Douglas C-54B • Trans World Airways • Gander, Newfoundland, Canada • Injuries: 33 minor or none

The aircraft was letting down to Gander in icing conditions. The windshield deicer had been turned off because a leaking seal allowed alcohol fumes to enter the cockpit. As a result, except for a small corner on the pilot’s side, the windshield was heavily coated with ice.

The captain elected to make a GCA rather than go to an alternate airport. After he acquired visual contact with the field, he continued the approach using both GCA and visual references. The aircraft dropped below the glideslope and collided with a power line short of the runway. The right wing struck the ground, causing substantial damage to the aircraft. The aircraft remained airborne and landed on the runway.

The probable cause of the accident was cited in the official accident report as an attempt to continue the approach under conditions of restricted cockpit visibility caused by ice accretion on the windshield.

Jan. 6, 1949 • Douglas DC-3C • Coastal Cargo • Brandywine, Maryland, U.S. • Injuries: 2 fatal

The aircraft was first observed in level flight at a high altitude. The aircraft then began to go in and out of several spins to the left, recovering briefly each time. At about 915 meters (3,000 feet) altitude, the aircraft leveled off; the right horizontal stabilizer was seen to be bent upward and the elevators were missing altogether. Shortly thereafter, the aircraft went into a diving left turn, impacted terrain and burned.

The pilot had reported icing conditions, and the official accident report said that evidence indicated that the pilot lost control of the aircraft because of ice. Severe air loads were subsequently encountered, either during the spin or the attempted recovery, which caused the failure of the right horizontal stabilizer and the elevators.

Jan. 2, 1949 • Douglas DC-3C • Seattle Air Charter • Seattle, Washington, U.S. • Injuries: 14 fatal, 8 serious, 8 minor or none

Takeoff was impeded by ground fog, low visibility, and snow and ice on the wings. Attempts to clean the wings were only partially successful. Although visibility was below the field minimums, takeoff clearance was given to the pilot.

For about 305 meters (1,000 feet), the takeoff run appeared normal. Then, as the airplane became airborne, it swerved to the left. The left wing then struck the ground and dragged for 36 meters (117 feet). The aircraft righted, made contact with the ground in a landing attitude and struck a revetment hangar. A postaccident fire destroyed the aircraft.

The primary cause for the accident cited in the official accident report was “attempting takeoff with ice on wings.”

Dec. 31, 1948 • Douglas DC-3C • Air Cargo Express • Cleveland, Ohio, U.S. • Injuries: 2 minor or none

On initial climb, the left engine stopped and the propeller was feathered. The pilot began a shallow left turn in an attempt to line up with a runway, apparently intending to abort the flight. The aircraft lost altitude and struck the ground in a left wing–down attitude, receiving substantial damage.

Investigation revealed ice in the fuel line and the main fuel strainer. An accumulation of ice was found on the leading edges of the wings, and considerable ice accretion was found on the leading edges of the horizontal stabilizers.

Dec. 19, 1948 • Douglas DC-4 • Alaska • Minneapolis, Minnesota, U.S. • Injuries: 39 minor or none

On an instrument approach with reduced meteorological visibility and ice on the windshield, the plane landed with 1,068 meters (3,500 feet) of runway remaining. Glare ice and snow on the runway made braking ineffective. The aircraft went off the end of the runway at 24 kilometers per hour to 32 kilometers per hour (15 miles per hour to 20 miles per hour). The underside of the left wing struck an approach light, causing substantial damage to the aircraft. The plane was taxied to the ramp.

Dec. 18, 1948 • Douglas DC-3 • Reeve Aleutian • Anchorage, Alaska, U.S. • Injuries: 23 minor or none

Prior to takeoff, a check was made for ice on the wings and control surfaces. They were all free of ice except for the wing deicing boots, which had a layer of ice about 0.6 centimeter (0.25 inch) thick. This ice was not removed.

After takeoff and wheels-up, the aircraft could not gain altitude and began to settle. It finally contacted the ground, struck three parked aircraft with its wing tips and came to rest about 122 meters (400 feet) beyond the end of the runway, damaged substantially.

The captain’s failure to have all the ice removed from the wings was cited in the official accident report as a contributing cause of the accident.

Oct. 19, 1948 • Douglas DC-3 • Columbia Air Cargo • Anchorage, Alaska, U.S. • Injuries: 5 minor or none

After three hours on the ground in Anchorage, snow had accumulated on the aircraft's wings. An attempt was made to remove the snow with brooms. Shortly thereafter, the aircraft took off. Observers noted that the takeoff used up the entire 1,208-meter (3,960-foot) runway. Unable to gain altitude, the aircraft entered a 30-degree bank to the left, dragged its left wing through a stand of small trees and bushes and landed in the brush, sustaining substantial damage.

An investigation revealed that the aircraft was 942 kilograms (2,076 pounds) heavier than the weight shown on the aircraft's weight-and-balance form. It was also determined that the snow had not been completely cleared from the wings before takeoff.

March 2, 1948 • Douglas DC-3 • Meteor • Newark, New Jersey, U.S. • Injuries: 2 minor or none

En route to Newark, the aircraft was exposed to icing conditions for about 40 minutes. Shortly thereafter, the flight crew contacted Newark to request an emergency landing, which was approved. The first approach was missed. On the second approach, visual contact was made. As the aircraft passed over the approach lights, it stalled, shearing off the light supports and severing the right wing of the aircraft. The plane bounced onto the end of the runway, continued its rollout under control and was taxied to a parking area.

Dec. 21, 1947 • Douglas DC-3C • Seattle Air Charter • North Platte, Nebraska, U.S. • Injuries: 30 minor or none

While making an instrument approach in a light drizzle, visible ice accreted on the aircraft's wings. The ice was cleared off by deicers. Later in the approach, at an IAS of 195 kilometers per hour (105 knots), the aircraft suddenly stalled and fell off to the left. Full power was applied, and partial recovery was made. The aircraft contacted the runway in a tail-high attitude, striking the left wing tip, tearing off the propellers and causing substantial damage to the aircraft.

Investigators concluded that ice remained on the under surfaces of the wings, adversely affecting their lift.

Nov. 19, 1947 • Douglas DC-3 • Willis Air Service • Richmond, Virginia, U.S. • Injuries: 3 minor or none

The flight crew attempted a takeoff with the aircraft's wings covered by a light coating of snow, which they apparently expected would blow off. According to the official accident report, the snow continued to adhere and adversely affected lift. The left wing dipped; the plane settled into the ground, still within the area of the airport, sustaining substantial damage.

Jan. 25, 1947 • Douglas DC-3 (Dakota) • Spencer Airways • Croydon, Surrey, England • Injuries: 12 fatal, 4 serious, 7 minor or none

The aircraft took off with snow or frost adhering to its lifting surfaces. Almost immediately after becoming airborne, the aircraft banked to the right; then it rolled to the left, where the angle of bank approached 40 degrees and the port wing tip was about 0.6 meter (two feet) off the ground.

The aircraft then rolled again to the right, the result of hard starboard rudder applied to avoid flying into a hangar. It bounced on its right main landing gear and flew into a parked aircraft. Both aircraft were destroyed by postaccident fire.

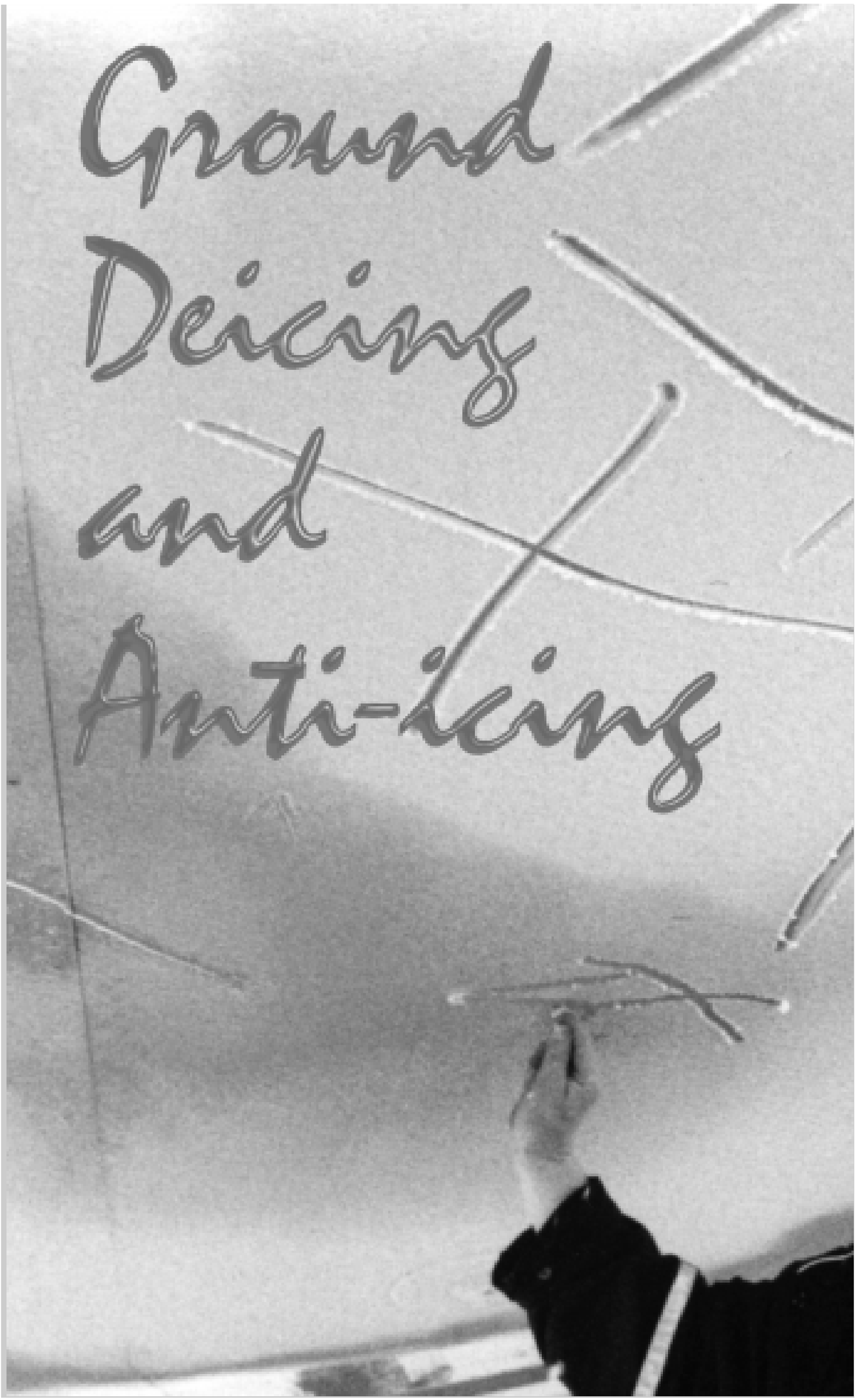
The official accident report cited the snow and frost on the wing surfaces as a contributory cause of the accident.

Dec. 19, 1946 • Douglas DC-3 (Dakota) • Scottish Airways • Northolt, Middlesex, England • Injuries: 5 minor or none

The aircraft failed to reach the normal rate of climb after takeoff. It passed over the airport boundary in a pronounced tail-down attitude, struck telegraph wires and finally came to rest on the top of a block of houses near the airport. The aircraft was destroyed. The accident report cited the pilot's taking off when the aircraft was almost entirely covered with snow as a probable cause of the accident.

Sept. 24, 1946 • Douglas DC-3 • A.R. Lyle • Point Barrow, Alaska, U.S. • Injuries: 9 minor or none

The aircraft was landing in a 22 kilometers per hour (14 miles per hour) crosswind with light rime ice on the wings. The pilot brought the tail down quickly, and the aircraft veered. The pilot then attempted to take off again. When he found the aircraft uncontrollable, he cut the power and dropped in hard, causing substantial damage to the aircraft.♦


Ground
Deicing
and
Anti-icing

Manual of Aircraft Ground De/Anti-Icing Operations

International Civil Aviation Organization (ICAO)

FSF editorial note: See current holdover time tables based on data from the Society of Automotive Engineers (SAE), the International Standards Organization (ISO), the Association of European Airlines (AEA), the relevant flight operations manual and/or the appropriate civil aviation authority.

The International Civil Aviation Organization (ICAO) *Manual of Aircraft Ground De/Anti-Icing Operations* has been reproduced, in part, in this issue of *Flight Safety Digest*. The International Air Transport Association (IATA) Global De/Anti-Icing Industry Forum is making additional recommendations to revise the current ICAO manual.

To purchase the most up-to-date version of the manual, contact:

International Civil Aviation Organization
Attention: Document Sales Unit
1000 Sherbrooke Street West, Suite 400
Montreal, Quebec, Canada H3A 2R2
Telephone: (514) 954-8219
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Table of Contents

Foreword

A review of the recent history of airplane accidents in the air transportation industry reveals a substantial number which are related to winter operations. An examination of these accidents shows a strong need for formally developed regulations and procedures governing aeroplane de/anti-icing operations. This document comprises a summary of information essential to the planning and execution of de/anti-icing operations during conditions which are conducive to aeroplane icing on the ground.

Reference material used to prepare this publication includes documentation from regulatory authorities, airlines, aeroplane manufacturers, equipment and fluid manufacturers, plus industry, academic, standardization and professional associations. Detailed information from these sources is used throughout the text and such sources are shown in the list of references. However, no reference is made to any specific instructions or recommendations given by aeroplane, equipment or fluid manufacturers and these must also be taken into consideration.

The primary purpose of this document is to provide international de/anti-icing standardization within the civil aviation industry. A general description of the various factors relating to aeroplane icing on the ground is provided. This document addresses the minimum procedural requirements necessary to conduct safe and efficient operations during those conditions which require aeroplane de/anti-icing activities. Each operator is responsible for complying with the requirements imposed by aeroplane, equipment and fluid manufacturers, regulatory and environmental authorities and individual operator programmes.

The International Air Transport Association (IATA) convened a Global De/Anti-Icing Task Force which met for the first time in Helsinki in September 1992. This Task Force subsequently became the IATA Global De/Anti-Icing Industry Forum in October 1993. In a co-operative effort between IATA and ICAO, a drafting group was formed to develop a “stand alone” ground de/anti-icing document which 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.

Glossary of Terms and Abbreviations

Glossary of Terms

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

Clear ice. A coating of ice, generally clear and smooth, but with some air pockets. It is formed on exposed objects at temperatures below or slightly above the freezing temperature by the freezing of supercooled drizzle, droplets or raindrops.

Cold-soak effect. The wings of aircraft are said to be "coldsoaked" 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. Whenever precipitation falls on a cold-soaked aeroplane when 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. 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 flights, temperature of refuelled fuel and time since refuelling.

Critical surfaces. A surface of the aeroplane which shall be completely free of ice, snow, slush or frost before takeoff. The critical surfaces shall be determined by the aeroplane manufacturer.

De-icing. The process which removes ice, snow, slush or frost from aeroplane surfaces. This may be accomplished by mechanical methods, pneumatic methods or through the use of heated fluids. Mechanical methods may be preferred under extremely cold conditions or when it has been determined that the frozen contaminant is not adhering to the aeroplane surfaces. When using heated fluids and optimum heat transfer is desired, fluids should be applied at a distance from aeroplane surfaces in accordance with the approved operator procedure and fluid manufacturer specifications.

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

One step de/anti-icing. This procedure is carried out with an anti-icing fluid which is typically heated. The fluid is used to de-ice the aeroplane and remains on the aeroplane surface to provide anti-icing capability. Type I or Type II fluids can be used, but the protection provided by Type I fluid is less than that provided by Type II fluid.

Two step de/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. After de-icing, a separate overspray of anti-icing fluid is applied to protect the aeroplane's critical surfaces, thus providing maximum anti-icing protection.

Drizzle. Fairly uniform precipitation composed exclusively of fine drops very close together. Drizzle appears to float while following air currents although, unlike fog droplets, it 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 which freeze upon contact with exposed objects and form a coating of rime/glaze.

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

Frost. Referred to as "hoar frost". A deposit of ice having a crystalline appearance, generally assuming the form of scales, needles or fans. Frost is formed by sublimation, i.e. when water vapour is deposited on surfaces whose temperatures are at or below freezing.

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

Holdover time. Holdover time (HOT) is the *estimated* time 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. 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 are based on time and do 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 which, 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 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.

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

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. When the ambient temperature is below or well below freezing.

Wet snow. When the ambient temperature is near or above freezing.

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.

Abbreviations

AEA	Association of European Airlines
APU	Auxiliary power unit
ATC	Air traffic control
DIN	Deutsches Institut fuer Normung
FP	Freezing point
FPD	Freezing point depressant
ISO	International Organization for Standardization
OAT	Outside air temperature
SAE	Society of Automotive Engineers

Manual of Aircraft Ground De/Anti-Icing Operations

International Civil Aviation Organization

Chapter 1
Introduction

1.1 Recent accidents in commercial air transport operations and in general aviation indicate that misconceptions exist regarding the effect on aeroplane performance and flight characteristics of slight surface roughness on flight surfaces, caused by ice and snow accumulations. The effectiveness of freezing point depressant (FPD) ground de/anti-icing fluids is often misunderstood. During development of this document, it was recognized that guidance information should be directed to all segments of aviation including aeroplane manufacturers, airline operators, engineering, maintenance and service organizations. In particular it is intended to be used by flight crew of all aeroplane types and categories plus aeroplane maintenance and service personnel. Information contained in this document is general in nature. It is intended to increase the basic understanding and to facilitate the development of standardized procedures and guidance for the various segments of the aviation industry.

1.2 Civil aviation regulations have been established in some States since 1950, 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.

1.3 Wind tunnel and flight tests indicate that ice, frost or snow formations on the leading edge and upper surface of a wing, having a thickness and surface roughness similar to medium or coarse sandpaper, can reduce wing lift by as much as 30 per cent and increase drag by up to 40 per cent. These changes in lift and drag will significantly increase stall speed, reduce controllability and alter aeroplane flight characteristics. Thicker or rough ice accumulations in the form of frost, snow or ice deposits can have increasing effects on lift, drag, stall speed, stability and control, but the primary influence is surface roughness relative to critical portions of an aerodynamic surface. Ice on critical surfaces and the airframe may also break away during take-off and be ingested into engines, possibly damaging fan and compressor blades. Ice forming on pitot tubes and static ports or on angle of attack vanes may give false attitude, airspeed, angle of attack and engine power information for air data systems. It is therefore imperative that take-off not be attempted unless it has been ascertained that all critical surfaces of the aeroplane are free of adhering snow, frost or other ice formations. This vital requirement is known as the “Clean Aircraft Concept”.

1.4 Most aeroplanes used in commercial air transport operations, as well as some other aeroplane types, are certificated for flight in icing conditions. Aeroplanes so certificated have been designed and demonstrated to have the capability of penetrating supercooled cloud icing conditions in the forward flight regime. This capability is provided either by ice protection equipment installed on critical surfaces such as the leading edge or by demonstration that 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 to weather conditions on the ground 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 considered airworthy and are certificated only after extensive analyses and testing have been accomplished. With the exception of analyses and testing to ascertain the flight characteristics of an aeroplane during flight in icing conditions, all analyses and certification testing are conducted with a clean aeroplane flying in a clean environment. If ice formations are present, other than those considered in the certification process, 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 Common practice developed by the aviation industry over many years of operational experience is to de/anti-ice an aeroplane prior to take-off. Various techniques of ground de/anti-icing aeroplanes were also developed. The most modern of these techniques is the use of FPD fluids to aid the ground de/anti-icing process and to provide a protective film of FPD fluid (anti-icing) to delay formation of frost, snow or other ice.

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. In the case of 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 in a condition for safe flight.

1.7 The only method currently known of positively ascertaining that an aeroplane is clean prior to take-off is by close inspection. Under conditions of precipitation, fog or where moisture can be splashed, blown or sublimated on to critical surfaces in sub-freezing weather, many factors influence whether and how much ice, frost or snow may accumulate and result in surface roughness. Moreover, even in above-freezing weather conditions, for aeroplanes which 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 wing tanks being well below zero. This cold-soak effect may cause ice to form on the wing surfaces. Most of the factors that influence the cold-soak effect are listed below:

a) ambient temperature;

b) relative humidity;

c) precipitation type and rate;

d) fog type and density;

e) heat radiation;

f) wind speed and direction;

g) aeroplane surface temperature (including the temperature of fuel in wing tanks);

h) presence of de-icing fluid;

i) de/anti-icing fluid type and temperature;

j) de/anti-icing fluid aqueous solution (strength);

k) de/anti-icing fluid application procedure;

l) holdover times (and taxiing times from gate to departure runway);

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, fully or partially in hangar).

1.8 It is essential for personnel to understand and have a thorough knowledge of:

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/anti-icing;

c) the capabilities and limitations of these procedures;

d) the variables that will influence the effectiveness of these procedures;

e) the critical areas of the particular aeroplane; and

f) recognition that final assurance for a safe take-off rests in a thorough pre-takeoff inspection or check.

Chapter 2
The Clean Aircraft Concept

2.1 During conditions conducive to aeroplane icing during ground operations, take-off shall not be attempted when ice, snow, slush or frost is adhering to the wings, propellers, control surfaces, engine inlets or other critical surfaces. This standard is known as the "Clean Aircraft Concept". In this document, the Clean Aircraft Concept deals solely with the fixed wing aeroplane.

2.2 Test data indicates that ice, snow, slush or frost formations having a thickness and surface roughness similar to medium to coarse sandpaper on the leading edge or upper surfaces of a wing can significantly reduce wing lift and increase drag.

2.3 These changes in lift and drag significantly increase stall speed, reduce controllability and alter aeroplane flight characteristics. Thicker or rougher frozen contaminants can have increasing effects on the lift, drag, stall speed, stability and control of the aeroplane. The primary influence is created by any roughness located on critical portions of an aerodynamic surface. These adverse effects on the aerodynamic properties of the airfoil may result in a sudden departure from the commanded flight path and may not be preceded by any cockpit indications or aerodynamic warnings to the pilot.

2.4 There are a large number of variables that have been identified which can influence the formation of ice and frost and the accumulation of snow and slush causing surface roughness on an aeroplane. These variables include ambient temperature; aeroplane skin temperature; precipitation rate and moisture content; temperature; the fluid/water ratio of the de/anti-icing fluid; relative humidity; and wind velocity and direction. They can also affect the de-icing capabilities of de-icing fluids and the anti-icing capabilities of anti-icing fluids. Fluids used for anti-icing should not be considered to have unlimited or defined anti-icing capabilities.

2.5 Numerous techniques for complying with the Clean Aircraft Concept have been developed. Proper and adequate de-icing, followed by an application of appropriate anti-icing fluid, provides the best protection against contamination. A visual or physical check of critical aeroplane surfaces to confirm that the treatment has been effective and that the aeroplane is in compliance with the Clean Aircraft Concept must be accomplished.

Chapter 3
Aeroplane Icing on the Ground

3.1 Safe aeroplane operations during all types of weather conditions are of utmost concern to all air carriers, airport authorities and air traffic control.

3.2 Many atmospheric and ambient conditions can cause aeroplane icing on the ground. Some of these conditions are frost, snow, freezing fog, freezing drizzle, freezing rain and the cold-soak effect. The latter type of icing can occur at ambient temperatures well above the freezing point. It is also important to understand that mixed and changing atmospheric conditions can overlap during aeroplane operations on the ground requiring constant vigilance by both flight and ground crews.

3.3 Other conditions which are conducive to icing contamination on aeroplane surfaces are:

a) operations on ramps, taxiways and runways contaminated by water, slush or snow. These substances may be deposited on aeroplane surfaces by wind, aeroplane operations, jet blast and/or by ground support equipment; and

b) warm aeroplane surfaces exposed to frozen precipitation during below freezing conditions. The warm aeroplane surfaces may cause melting and refreezing of the precipitation.

3.4 In extremely severe blizzard or freezing rain conditions, normal de/anti-icing procedures may be ineffective in providing sufficient protection for continued operations.

Chapter 4
Aeroplane Ground De/Anti-Icing Fluids

4.1 The basic function of de/anti-icing fluids is to lower the freezing point of freezing precipitation as it collects on the aeroplane and thus delay the accumulation of ice, snow, slush or frost on critical surfaces. There are two principal classes of de/anti-icing fluids; they are known as Type I and Type II fluids. Type I fluids are of a relatively low viscosity which changes only as a function of temperature. Type II fluids, however, contain a thickener system and are, therefore, of a higher viscosity which changes as a function of shear force, fluid/water ratio and temperature. Generally, Type II fluids have better anti-icing properties than Type I fluids.

4.2 All de/anti-icing fluids must meet the *use* criteria established by the operator, fluid manufacturer and aeroplane manufacturer. All de/anti-icing fluids must also be manufactured in accordance with ISO specifications.

Type I Fluids

4.3 Currently, Type I fluids are available in concentrated or diluted (ready to use) forms. Concentrated Type I fluids contain a minimum of 80 per cent glycol. The glycols are monoethylene, diethylene or monopropylene glycols (or a mixture of these glycols). The remainder consists of water and inhibitors, but most fluids also contain wetting and anti-corrosion agents.

4.4 Concentrated Type I fluids must be diluted with water to achieve a freezing point which is in accordance with the appropriate application procedure. Due to aerodynamic performance and/or freezing-point considerations, Type I fluids are not used in an undiluted condition and are usually heated to enhance their de-icing capabilities.

Type II Fluids

4.5 Currently, undiluted Type II fluids contain at least 50 per cent, by volume, of monoethylene, diethylene or propylene glycol (or a mixture of these glycols), wetting agents, inhibitors and a thickener system. The remainder of the mixture is water. The high viscosity of the fluid combined with the wetting agents result in a thick coating when sprayed on the aeroplane. To provide maximum anti-icing protection, Type II fluids should be used in an undiluted condition. However, Type II fluids are also used in a heated and diluted condition for de/anti-icing applications.

4.6 Type II fluids show a loss of viscosity once exposed to a design level of shear force. The air flow during the take-off roll exposes these fluids to the shear force design level, causing a loss of viscosity, thereby allowing the fluid to flow off the critical portion of the wings prior to rotation.

4.7 Falling precipitation will steadily dilute both Type I and Type II fluids until the fluid coating freezes. By increasing the viscosity of the fluid (as in Type II), a higher film thickness and, hence, a greater volume of fluid can be applied. The greater volume of fluid can absorb more freezing precipitation before its freezing point is reached and therefore its holdover time is increased. This protective advantage becomes important during freezing precipitation conditions when longer taxi times are expected.

4.8 If an aeroplane has to be reprotected, under no circumstances shall that aeroplane which has previously been anti-iced receive a further coating of anti-icing fluid directly on top of the existing coating. When it becomes necessary to apply another coating of anti-icing fluid, the aeroplane surfaces must first be de-iced again before the final coating of anti-icing fluid is applied.

Handling of Anti-Icing Fluids

4.9 Both Type I and Type II fluids must be handled in accordance with fluid manufacturers' recommendations, health and environmental regulations and operator requirements.

4.10 The protective properties of Type II fluids will be degraded when the fluid is subjected to contamination, improper transportation or storage, excessive heating or when exposed to excessive shear forces during fluid transfer or use.

4.11 Quality control methods for handling de/anti-icing fluids, as specified in the approved operator programme, must be strictly followed at all times.

Chapter 5
Holdover Times

5.1 Holdover time (HOT) is the estimated time 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.

5.2 There are numerous factors which have been identified that can affect the de/anti-icing capabilities and holdover times of de/anti-icing fluids. These factors include, but are not limited to:

a) type and rate of precipitation;

b) ambient temperature;

c) relative humidity;

d) wind direction and velocity;

e) aeroplane surface (skin) temperature; and

f) de/anti-icing fluid (type, fluid/water ratio, temperature).

Therefore, fluids used for anti-icing must not be considered to have anti-icing qualities for a specific period of time.

5.3 The actual holdover time begins when the final application of anti-icing fluid commences and ends when the applied fluid loses its effectiveness.

5.4 Holdover times should be published by the operator in the form of a table or diagram, to account for the various types of ground icing conditions which may be encountered and the different types and concentrations of the fluids used. A range of holdover times for a particular condition is recommended to account, to some degree, for the variation in the existing local meteorological conditions, particularly the aeroplane skin temperature and the rate of precipitation being encountered.

5.5 At the completion of aeroplane de/anti-icing, the pilot-in-command will be provided with the following information:

a) fluid type;

b) fluid/water ratio (Type II only);

c) start time of the last step in the de/anti-icing procedure; and

d) confirmation that the aeroplane is in compliance with the clean aircraft concept.

This basic information will assist the pilot-in-command to estimate an appropriate holdover time.

5.6 The ISO holdover time tables, displayed in the Attachment, give examples of the time frames of protection that can be expected under various weather conditions. The times of protection represented in these tables are to be used as *guidelines* only and are normally used in conjunction with pre-takeoff check procedures.

Caution: Due to the many variables that can influence holdover times, the time of protection will be shortened or lengthened depending on the intensity of the weather conditions. High wind velocity and jet blast can also cause a degradation of the protective film of anti-icing fluid. If these conditions occur, the time of protection may be shortened considerably. This may also be the case when the aeroplane skin temperature is significantly lower than the outside air temperature.

Chapter 6
De/Anti-Icing Check Procedures
Ground De/Anti-Icing Checks

6.1 The pilot-in-command is responsible for ensuring that the aeroplane complies with the Clean Aircraft Concept prior to take-off. Certain checks are required to enable this responsibility to be properly discharged. These checks can be grouped under three main headings:

a) checks prior to the application of de/anti-icing fluids;

b) checks after the application of de/anti-icing fluids; and

c) special checks.

Checks Prior to the Application of De/Anti-Icing Fluids

6.2 The first check in this process is the walk-around or pre-flight check, normally accomplished by the ground or flight crew. The aeroplane critical surfaces, fuselage and landing gear shall be checked for ice, snow, slush or frost in accordance with an approved operator plan. If ice, snow, slush or frost is discovered, de/anti-icing of the aeroplane must be accomplished.

Checks After the Application of De/Anti-Icing Fluids

6.3 A check to ensure compliance with the Clean Aircraft Concept is made immediately following the application of de/anti-icing fluids and is accomplished by a qualified person in accordance with the approved operator plan and procedures.

The pre-takeoff check, which is the responsibility of the pilot-in-command, ensures that the representative surfaces of the aeroplane are free of ice, snow, slush or frost just prior to take-off. This check shall be accomplished as close to the time of take-off as possible and is normally made from within the aeroplane by visually checking the wings or other critical surfaces.

6.4 The pre-takeoff check procedures are a critical part of the ground operation and become the only means by which the pilot-in-command can ensure that the aeroplane is in compliance with the Clean Aircraft Concept prior to takeoff. If stipulated by the regulatory authority, aeroplane manufacturer, operational specification or if requested by the pilot-in-command, an external check of aeroplane critical surfaces shall be conducted by a qualified ground person.

6.5 The pilot-in-command has the responsibility to continuously monitor the weather and aeroplane condition to ensure compliance with the Clean Aircraft Concept. If this requirement cannot be satisfied, by either an internal or external check of aeroplane critical surfaces, then another de/ anti-icing of the aeroplane must be accomplished. Special equipment or procedures may be required to carry out this check at night or under severe weather conditions.

Special Checks

6.6 A check for the presence of clear ice, frequently caused by cold-soaked fuel in wing tanks, may be required during rain or high humidity conditions and for certain types of aeroplanes. This type of ice is very difficult to detect, especially in conditions of poor lighting or when the wings are wet. Special check procedures are required to detect this type of icing and shall be included in the approved operator programme.

Chapter 7 Responsibilities

7.1 The regulatory authority ensures that every operator shall have an approved de/anti-icing programme or procedures. The programme shall require that air carrier operations comply with the Clean Aircraft Concept.

7.2 The regulatory authority ensures that relevant and appropriate meteorological and other data are readily available to the respective aerodrome users. This shall be any time prior to or during aerodrome winter operations which require de/anti-icing activities. The data shall include, but not be limited to:

a) runway condition reports;

b) aerodrome taxiway/apron condition reports; and

c) aerodrome sequence reports.

7.3 The de/anti-icing programme shall clearly define areas of responsibility for the operator. All persons involved in ground de/anti-icing activities shall be trained and qualified in the procedures, communications and limitations of their area of responsibility. The de/anti-icing programme shall cover all locations within the operator's route network including contract de/anti-icing accomplished by others.

Operator

7.4 Ground de/anti-icing is, technically, a part of the operation of the aeroplane. The person in charge of the de/anti-icing procedure is responsible for accomplishing this procedure and verifying the results of the de/anti-icing treatment. Additionally, the de/anti-icing application information reported to the flight deck crew is also a part of the technical airworthiness of the aeroplane.

7.5 The person responsible for the de/anti-icing process must be clearly designated. This person shall check the aeroplane for the need to de-ice and initiate de/anti-icing if required and is responsible for the correct and complete de/anti-icing treatment of the aeroplane. The final responsibility for accepting the aeroplane after de/anti-icing rests, however, with the pilot-in-command.

7.6 To ensure compliance with the Clean Aircraft Concept, the pilot-in-command shall evaluate:

a) actual and forecast weather conditions;

b) taxi times and conditions;

c) de/anti-icing fluid characteristics; and

d) other relevant factors.

The pilot-in-command is responsible for continuously monitoring the condition of the aeroplane after de/anti-icing has been completed and that the aeroplane complies with the Clean Aircraft Concept at the time of take-off.

Chapter 8 Aerodrome De/Anti-Icing Facilities

Overview

8.1 Safe and efficient aeroplane operations are of primary importance in the development of any aerodrome de/anti-icing facility. Design considerations should include siting, sizing, environmental issues and the operational needs of aerodrome users in an effort to maximize the de/anti-icing capacity while maintaining maximum safety and efficiency.

8.2 The design of a de/anti-icing facility should, to the extent practicable, meet the needs of air carriers and other elements of the aviation community, as outlined in aeroplane ground de/anti-icing programmes. The goal of this effort should be that the facility be designed such that it offers the maximum in safety, efficiency and flexibility to the user.

Need For a Facility

8.3 Aerodrome de/anti-icing facilities are required at aerodromes where ground snow and icing conditions can be expected to occur. This would include aerodromes which serve aeroplanes that can develop frost or ice on critical surfaces as a result of having very cold fuel in their fuel tanks, even though the aerodrome itself is not experiencing ground icing conditions.

Size, Capacity and Number of De/Anti-Icing Facilities

8.4 There are numerous factors which affect the basic design of any de/anti-icing facility. In determining the de/anti-icing operational capacity of the aerodrome, it is recommended that the aerodrome have facilities with a de/anti-icing capability equivalent to the maximum peak hour departure rate that can be managed by the ATC units during de/anti-icing operations.

8.5 Environmental concerns are becoming increasingly important in the design of any facility. It therefore follows that de/anti-icing facilities must be designed in accordance with local environmental rules and regulations. Environmental factors which have to be considered are:

a) protecting the environment against toxic substances;

b) the isolation and collection of used glycol and any other de/anti-icing contaminants to prevent runoff into the normal aerodrome storm drainage system; and

c) recycling the used glycol.

8.6 The size and number of de/anti-icing facilities on an aerodrome shall be determined by, but not necessarily limited to, all of the following factors.

a) *Methods and procedures used*. The aerodrome should plan for the use of the two-step de/anti-icing procedure for all de/anti-icing operations even though some operators may choose to use the one-step procedure on some occasions. As the most lengthy of the two procedures, the two-step procedure increases estimated processing times and may therefore require more and larger de/anti-icing facilities. This method of planning should help to ensure that the aerodrome is able to achieve the maximum aeroplane departure flow rates.

b) *Variations in meteorological conditions*. Precipitation type, rate and frequency all affect aerodrome de/anti-icing operations. Aerodromes which normally experience heavy snowfalls or freezing rain will require more de/anti-icing facilities in order to maintain aeroplane departure flow rates. When these conditions frequently occur, consideration should also be given to locating de/anti-icing facilities as close to the runway as is practical.

c) *Types of aeroplanes receiving treatment*. The application time required to de/anti-ice various types of aeroplanes, for the same weather conditions, can vary substantially. Narrow body aeroplanes require less time than their wide body counterparts. Aeroplanes with centre-mounted fuselage engines require more time than aeroplanes with only wing-mounted engines.

d) *Performance capabilities of mobile de-icing vehicles*. Mobile de-icing vehicles with reduced tank capacities and limited fluid heating capabilities can increase application times and adversely affect aeroplane departure flow rates. Locating remote pad facilities with storage capabilities as close as practical to the runway can mitigate operational limitations caused by this type of equipment.

e) *Bypass taxi capability*. To further maximize departure flow rates for all aeroplanes, the location and size of de/anti-icing facilities should be such that they allow for bypass taxiing during de/anti-icing operations.

Facility Location

8.7 The primary consideration in determining the location of an aerodrome de/anti-icing facility is the time required to taxi from the facility to the take-off runway. This is because the taxi time begins at the conclusion of the anti-icing process and ends with the take-off. The taxi time should be such that throughout the time required for an aeroplane to taxi to the runway and take off, the holdover time of the de/anti-icing fluid used remains in effect.

8.8 In calculating the taxi time from the de/anti-icing facility to the departure runway, operators should bear in mind that taxi times are slower in winter. They should also consider whether there are any other time-related factors specific to the aerodrome.

8.9 Other factors which might affect the location of an aerodrome de/anti-icing facility are:

a) environmental issues and considerations;

b) types of fluid applicators (mobile de/anti-icing vehicles or gantry types);

c) access for mobile de/anti-icing vehicles or other de/anti-icing operations support vehicles;

d) types and size of aeroplanes required to be de/anti-iced;

e) normal taxi routes in use on the aerodrome;

f) airspace protection and obstacle clearance;

g) safety clearances on ground; and

h) navigation/approach aid clearances on ground.

Terminal de/anti-icing

8.10 For some aerodromes, de/anti-icing facilities at gates or adjacent to the terminal can adequately meet the de/anti-icing demands of the aerodrome user and still allow acceptable taxi times to the departure runway during ground icing conditions.

Off-terminal de/anti-icing

8.11 De/anti-icing facilities away from the terminal are recommended when terminal de/anti-icing facilities (including apron facilities) cause excessive gate delays and taxi times.

Remote pad de/anti-icing facilities

8.12 Remote de/anti-icing facilities located near departure runway ends or along taxiways are recommended when taxi times from terminals or off-terminal de/anti-icing locations frequently exceed holdover times. The correct design of these facilities can also improve flow control by permitting re-treatment of aeroplane critical surfaces without the aeroplane having to return to more distant treatment sites.

Clearance and Separation Standards for De/Anti-Icing Facilities

8.13 All de/anti-icing facilities shall be designed, sited and sized in accordance with the clearance and separation standards established by the local regulatory authority. Additionally, proximity to fixed and moveable objects must be considered.

Chapter 9 Air Traffic Control (ATC)

9.1 The regulatory authority shall provide a comprehensive air traffic control plan which relates to winter operations and de/anti-icing activities.

Air Traffic Control Winter Operations Plan

9.2 The ATC winter operations plan shall provide for the management of safe and efficient aeroplane movements within the aerodrome traffic area during winter operations and de/anti-icing activities. The plan shall meet the needs of the aerodrome users while complying with the requirements of the individual aeroplane and ground de/anti-icing programmes and facilities.

9.3 This plan shall provide for the implementation of an ATC programme during winter operations and de/anti-icing activities which will ensure optimum aeroplane arrival and departure “flow through” rates. Details of the ATC winter operations plan shall be included in all ATC controller’s manuals.

9.4 The ATC plan shall provide for the shortest possible taxi time to the departure runway for take-off after the completion of the de/anti-icing of an aeroplane.

9.5 In developing the plan, full account should be taken of the relevant climatological information pertaining to the aerodrome concerned. The plan shall provide for the distribution of necessary meteorological information from a reliable meteorological source to support the management of safe and efficient aeroplane operations and de/anti-icing activities.

9.6 The winter operations plan shall, if necessary, contain provisions for secondary de/anti-icing. In addition, it may also contain provisions for centralized de/anti-icing and remote pad de/anti-icing at the aerodrome.

9.7 It is the responsibility of the regulatory authority to coordinate the merging of the ATC winter operations plans of contiguous national areas.

Chapter 10 De/Anti-Icing Communications

10.1 The communications between ground and flight crews are an integral part of the de/anti-icing process and must be included in every de/anti-icing procedure.

10.2 Prior to starting the de/anti-icing process, it is essential that the ground and flight crews verify that the aeroplane is properly configured in accordance with the manufacturer’s recommendations and the operator’s procedures.

10.3 Upon completion of the de/anti-icing procedure and the associated check of the aeroplane, which ensures that it complies with the Clean Aircraft Concept, the following information shall be communicated to the flight crew:

a) fluid type;

b) fluid/water ratio (Type II fluids only);

c) start time of the last step in the de/anti-icing procedure; and

d) confirmation that the aeroplane is in compliance with the Clean Aircraft Concept.

10.4 This information shall be recorded and communicated directly to the flight crew, in the prescribed order above. The communication shall be in either written or verbal form and examples of this communication would be as follows:

a) “Type II, 75/25, 1630 and clean aeroplane check complete”; and

b) “Type I, 1630 and clean aeroplane check complete”.

10.5 Communications regarding any de/anti-icing related activities; i.e. holdover times, taxi times, ATC flow control rates, etc., which occur between flight crews and ATC, as a result of aerodrome winter operations and de/anti-icing activities, shall follow communications procedures as outlined in the ATC winter operations plan.

Chapter 11
De/Anti-Icing Methods

11. 1 De/anti-icing is generally carried out by using heated fluids dispensed from spray nozzles mounted on specially designed de/anti-icing trucks, de/anti-icing gantry systems, small portable spraying equipment or by mechanical means (brushes, ropes, etc.).

11.2 De/anti-icing fluids are applied close to the skin of the aeroplane to minimize heat loss and the usual techniques employed are as follows:

a) *Fuselage*. Normally, spraying starts with the fuselage. Spray along the top centreline and then outboard. Avoid spraying directly on windows.

b) *Wings and horizontal stabilizers*. Spray from the tip to the root and from the highest point of the surface camber to the lowest point.

c) *Vertical surfaces*. Start at top and work downwards.

d) *Landing gear and wheel bays*. Keep application of de/anti-icing fluid in this area to a minimum. High pressure spraying is not recommended.

e) *Engines/APUs*. Avoid spraying fluids into engines or APUs. Consult manufacturers' recommendations. Ensure engines are free to rotate before start up and that front and back of fan blades are free of ice. Bleed systems must be switched off during de/anti-icing operations when engines or APUs are running.

11.3 De/anti-icing can be carried out as a one-step process using heated Type I or Type II fluid to both de-ice and anti-ice, or as a two-step process using heated Type I fluid or hot water to de-ice followed immediately by Type I or Type II fluid to anti-ice. Temperature restrictions must be observed.

Chapter 12
Ice Detection, Warning and Prevention Systems

12.1 On the basis of their planned function and location, ground ice detection and warning systems may be separated into two principal categories. They are ground-based devices and aeroplane-mounted devices.

12.2 *Ground-based devices* will be designed to detect ice, snow, slush or frost on the critical surfaces of the aeroplane. They will normally consist of area surveying equipment or systems and will meet aeroplane manufacturer, operator and regulatory authority requirements as appropriate. In addition, some systems will have the capability of warning of any weather phenomena which could induce adhering frozen contamination on aeroplane critical surfaces.

12.3 *Aeroplane-mounted devices* are those which are any combination of point sensors, area surveying equipment or performance monitoring devices. They too will be designed to detect ice, snow, slush or frost on the critical surfaces of the aeroplane and will meet aeroplane manufacturer, operator and regulatory authority requirements. Operational requirements of aeroplane-mounted systems ensure a design which will cover the same operational environment for which the aeroplane has been certified. The warning information will be simple, straightforward and consistent with the current display philosophy adopted by the industry.

12.4 The desired intent of systems using aeroplane-mounted devices is to assure the flight crew that aeroplane critical surfaces are free of frozen contaminants prior to take-off.

12.5 During system integration and installation, both the ground-based devices and aeroplane-mounted devices will meet the requirements established by operators, aeroplane manufacturers and regulatory authorities. The design of these devices should be compatible with current de/anti-icing philosophies, fluids and procedures. At this time, these devices are considered to be advisory in nature only.

12.6 All of the information which is provided by either or both of the ground-based or aeroplane-mounted devices should:

a) assist the pilot-in-command in operational decision-making;

b) help to more accurately estimate the duration of the holdover time; and

c) minimize the need to return for a second de/anti-icing.

Chapter 13
Training of Personnel

13.1 To ensure a thorough understanding of all aspects of winter operations, flight and ground crews must be trained and qualified in procedures for safe de/anti-icing operations during ground icing conditions. This training shall include, but is not limited to the following (as applicable to the type of operations conducted):

a) recognition of relevant weather phenomena;

b) effects of ice, snow, slush or frost on aeroplane performance, stability and control;

c) basic characteristics of aeroplane de/anti-icing fluids;

d) general techniques for removing deposits of ice, snow, slush or frost from aeroplane surfaces (de-icing) and for anti-icing these same surfaces;

e) de/anti-icing procedures in general and procedures specifically recommended by the operator, aeroplane manufacturer or fluid manufacturer;

f) de/anti-icing equipment operating procedures;

g) quality control procedures;

h) techniques for recognizing frozen precipitation on aeroplane critical surfaces;

i) de/anti-icing application data and communications procedures;

j) health effects, safety precautions and accident prevention;

k) procedures and responsibilities for checks;

l) use of holdover time tables for de/anti-icing fluids;

m) special provisions and procedures for contract de-icing and anti-icing (if applicable); and

n) environmental considerations for de-icing and anti-icing operations, i.e. locations for de-icing and anti-icing, reporting spillage and hazardous waste control.

13.2 Additionally, training for ground personnel shall include the following:

a) actual hands-on operation of de/anti-icing and anti-icing equipment; and

b) procedures and methods for storage and handling of de-icing and anti-icing fluids.

13.3 The operator shall maintain accurate records of the training and qualifying of both flight and ground personnel. This proof of qualification shall be for both initial and annual recurrent training.♦

Attachment

Table 1
Application of ISO Type I Fluid Mixtures (Minimum Concentrations)

Application — Type I Fluid

Outside Air Temperature		One-step Procedure	Two-step Procedure	
°C	°F	De-icing/Anti-Icing	First Step: De-Icing	Second Step: Anti-Icing1
At or above -3	At or above 26.6	Freezing point of heated[2] fluid mixture should be at least 10°C (18°F) below outside air temperature	Water heated to 60°C (140°F) minimum at the nozzle or a heat mixture of fluid and water	Freezing point of fluid mixture shall be at least 10°C (18°F) below actual outside air temperature
Below -3	Below 26.6		Freezing point of heated fluid mixture shall not be more than 3°C (5.4°F) above actual outside air temperature	

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

2. Clean aircraft may be anti-iced with cold fluid.

Note. — For heated fluids, a fluid temperature of not less than 60°C (140°F) at the nozzle is desirable.

Table 2
Approximate Holdover Times Achieved by ISO Type I Fluid Mixture

Holdover Times — Type I Fluid

Outside Air Temperature		Approximate Holdover Times with Reference to Weather Conditions (minutes)				
°C	°F	Frost	Freezing Fog	Snow	Freezing Rain	Rain on Cold-soaked Wing
At or above 0	At or above 32	18 to 45	12 to 30	6 to 15	2 to 5	6 to 15
0 to -7	32 to 19.4	18 to 45	6 to 15	6 to 15	1 to 3	—
Below -7	Below 19.4	12 to 30	6 to 15	6 to 15	—	—

Note 1. — The user should check the latest ISO holdover data.

Note 2. — Freezing point of an ISO Type I fluid mixture shall be at least 10°C (18°F) below outside temperature.

Table 3
Application of ISO Type II Fluid Mixtures (Minimum Concentrations)

Application — Type II Fluid

Outside Air Temperature		Concentration of ISO Type II Fluid/Water Mixtures (Percentage by Volume)		
		One-step Procedure	Two-Step Procedure	
°C	**°F**	**De-Icing/Anti-Icing**	**First Step: De-Icing**	**Second Step: Anti-Icing[1]**
At or above -3	At or above 26.6	50/50 heated ISO type II	Water heated to 60°C (140°F) minimum at the nozzle or heated mixture of ISO type I or II fluid and water	50/50 ISO type II
Below -3 to -7	Below 26.6 to 19.4		Heated 50/50 or suitable mixture of ISO type I with freezing point not more than 3°C (5.4°F) above actual outside air temperature	
Below -7 to -14	Below 19.4 to 6.8	75/25 heated ISO type II		75/25 ISO type II
Below -14 to -17	Below 6.8 to 1.4	—	Heated 75/25 or suitable mixture of ISO type I with freezing point not more than 3°C (5.4°F) above outside air temperature	100/0 ISO type II
Below -17 to -25	Below 1.4 to -13			
Below -25	Below -13	ISO type II may be used for anti-icing below -25°C (-13°F) provided that a 7°C (12.6°F) buffer is maintained. Consider use of ISO type I where ISO type II cannot be used (see Table 1).		

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

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

Table 4
Approximate Holdover Times Achieved by ISO Type II Fluid Mixtures

Holdover Times — Type II Fluid

Outside Air Temperature		Concentration of ISO Type II Fluid/Water Percentage by Volume	Approximate Holdover Times with Reference to Weather Conditions				
°C	**°F**		**Frost**	**Freezing Fog**	**Snow**	**Freezing Rain**	**Rain on Cold-soaked Wing**
At or above 0	At or above 32	100/0	12 h	1 h 15 min to 3 h	25 min to 1 h	8 min to 20 min	24 min to 1 h
		75/25	6 h	50 min to 2 h	20 min to 45 min	4 min to 10 min	18 min to 45 min
		50/50	4 h	35 min to 1 h 30 min	15 min to 30 min	2 min to 5 min	12 min to 30 min
Below 0 to -7	Below 32 to 19.4	100/0	8 h	35 min to 1 hr 30 min	20 min to 45 min	8 min to 20 min	—
		75/25	5 h	25 min to 1 h	15 min to 30 min	4 min to 10 min	
		50/50	3 h	20 min to 45 min	5 min to 15 min	1 min to 3 min	
Below -7 to -14	Below 19.4 to 6.8	100/0	8 h	35 min to 1 h 30 min	20 min to 45 min	—	
		75/25	5 h	25 min to 1 h	15 min to 30 min		
Below -14 to -25	Below 6.8 to -13	100/0	8 h	35 min to 1 hr 30 min	20 min to 45 min	—	—
Below -25	Below -13	100/0[1]	ISO type II fluid may be used for anti-icing below -25°C (-13°F) provided that a 7°C (12.6°F) buffer is maintained. Consider use of ISO type I fluid where ISO type II cannot be used (see Table 2).				

1. If 7°C (12.6°F) buffer is maintained.

Note. — The user should check the latest ISO holdover data.

Bibliography

1. Recommendations for De/anti-icing Aircraft on the Ground, Association of European Airlines, Eighth Edition, 1992.

2. Large Aircraft Ground De-icing — Pilot Guide, AC 120-58, U.S. Federal Aviation Administration, 30 September 1992.

3. "When in Doubt" — Small and Large Aircraft — Aircraft Critical Surface Training, Transport Canada, January 1994.

4. Aircraft Ground De-icing and Anti-icing (Interim Final Rule), U.S. Federal Aviation Administration, 29 September 1992.

5. Advisory Circular — Ground De-icing and Anti-icing Program — AC 120-60, U.S. Federal Aviation Administration, 19 May 1994.

6. International Standard ISO — 11076:/1993E — Aerospace — Aircraft De-icing/anti-icing Methods with Fluids, International Organization for Standardization, 1 July 1993.

7. Design of Aircraft De-icing Facilities — AC 150/5300-14, U.S. Federal Aviation Administration, September 1993.

Ground Deicing and Anti-icing Program

Advisory Circular (AC) 120-60
U.S. Federal Aviation Administration

FSF editorial note: See current holdover time tables based on data from the Society of Automotive Engineers (SAE), the International Standards Organization (ISO), the Association of European Airlines (AEA), the relevant flight operations manual and/or the appropriate civil aviation authority.

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Federal Aviation Administration

Advisory Circular

Ground Deicing and Anti-icing Program

Advisory Circular (AC) 120-60, May 19, 1994
U.S. Federal Aviation Administration (FAA)

1. Purpose. This advisory circular (AC) provides one means, but not the only means, for obtaining approval of a Ground Deicing and Anti-icing Program, and for ensuring compliance with the Federal Aviation Regulations (FAR) Section 121.629.

2. Related FAR Sections.

a. Part 121, Subpart E — Approval of Routes: Domestic and Flag Air Carriers. Sections 121.105–107.

b. Part 121, Subpart F — Approval of Areas and Routes for Supplemental Air Carriers and Commercial Operators. Sections 121.123–127.

c. Part 121, Subpart G — Manual Requirements. Section 121.135.

d. Part 121, Subpart L — Maintenance, Preventive Maintenance, and Alterations. Sections 121.363(b), 121.365–369, and 121.375.

e. Part 121, Subpart M — Airman and Crewmember Requirements. Sections 121.383(a)(3), 121.401–403, 121.405, 121.415, 121.418–419. 121.422, and 121.427.

f. Part 121, Subpart O — Crewmember Qualifications. Section 121.433.

g. Part 121, Subpart P — Aircraft Dispatcher Qualifications and Duty Time Limitations: Domestic and Flag Air Carriers. Section 121.463.

h. Part 121, Subpart T — Flight Operations. Sections 121.533, 121.537, and 121.539.

i. Part 121, Subpart U — Dispatching and Flight Release Rules. Section 121.629.

j. Special Federal Aviation Regulation No. 58. Advanced Qualification Program.

3. Related Reading Material. The following material should be useful in developing training program subject material and instructions, and procedures for incorporation in the certificate holder's manuals:

a. AC20-117, Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing.

b. AC 120-58, Pilot Guide for Large Aircraft Ground Deicing.

c. FAA publication, Winter Operations Guidance for Air Carriers and Other Adverse Weather Topics.

Note: AC 120-117, AC 120-58, and the FAA publication may be obtained from the Department of Transportation, M-443.2, General Services Section, Washington, DC 20590.

d. Publications of the Society of Automotive Engineers (SAE): Aerospace Materials Specification (AMS) 1424, "Deicing/Anti-icing Fluid, Aircraft, Newtonian — SAE Type I;" AMS 1428, "Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian, Pseudo-Plastic, SAE Type II;" and Aerospace Recommended Practice (ARP) 4737, "Aircraft Deicing/Anti-icing Methods with Fluids, for Large Transport Aircraft." You can obtain copies of these documents by writing to the Society of Automotive

Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096-0001.

e. Publications of the International Standards Organization (ISO): ISO 11075, "Aerospace — Aircraft Deicing/Anti-icing Newtonian Fluids ISO Type I;" ISO 11076, "Aerospace — Aircraft Deicing/Anti-icing Methods with Fluids;" ISO 11077, "Aerospace — Deicing/Anti-icing Self Propelled Vehicles — Functional Requirements;" and ISO 11078, "Aerospace — Aircraft Deicing/Anti-icing Non-Newtonian Fluids ISO Type II." Copies of these documents can be obtained from American National Standards Institute, 11 West 42nd Street, New York, New York, 10036, (212) 642-4900.

4. Background.

a. Accidents Related to Icing. According to information received in 1992 from the National Transportation Safety Board (NTSB), in the last 23 years there have been 15 accidents involving FAR Part 121 operators related to the failure to deice and/or anti-ice aircraft adequately before takeoff. On March 22, 1992, an airplane operated by a U.S. air carrier crashed on takeoff from LaGuardia Airport in a snowstorm during nighttime operations. The NTSB determined that the probable causes of this accident were failure of the airline industry and the Federal Aviation Administration (FAA) to provide flightcrews with procedures, requirements, and criteria compatible with departure delays in conditions conducive to airframe icing and the decision by the flightcrew to take off without positive assurance that the airplane's wings were free of ice accumulation after prolonged exposure to precipitation following deicing.

b. Reassessment of Icing Procedures. Prior to the LaGuardia accident, the FAA and the aviation community, in general, had placed priority on emphasizing the need during icing conditions for the pilot in command (PIC) to ensure a "clean aircraft" before takeoff. The FAA believed that pilot education appeared to be key to combatting the threat of wing icing. The FAA still believes the PIC ultimately must make the decision on whether or not to take off, based on a thorough understanding of factors involved in aircraft icing; however, the FAA has determined that certificate holders conducting operations under FAR Part 121 must provide their PIC's with pertinent information and operator-developed procedures and criteria so that the PIC will be able to make a proper decision.

c. Content of this AC. Accordingly, this AC provides guidance about the program elements that should be incorporated in an certificate holder's approved ground deicing and anti-icing program. It provides guidance and suggestions about methods, but not the only methods, for complying with all pertinent regulations.

5. Definitions. The terms used in this AC are not defined in FAR Part 1. They are defined here for a better understanding of this material.

a. Holdover Time. The estimated time deicing or anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the protected surfaces of an aircraft. Holdover time begins when the final application of deicing/anti-icing fluid commences and expires when the deicing/anti-icing fluid applied to the aircraft loses its effectiveness.

b. Deicing. A procedure by which frost, ice, or snow is removed from the aircraft in order to provide clean surfaces.

c. Anti-icing. A precautionary procedure that provides protection against the formation of frost or ice and accumulation of snow on treated surfaces of the aircraft for a limited period of time.

d. Pretakeoff Check. A check of the aircraft's wings or representative aircraft surfaces for frost, ice, or snow conducted within the aircraft's holdover time.

e. Pretakeoff Contamination Check. A check to make sure the aircraft's wings, control surfaces, and other critical surfaces, as defined in the certificate holder's program, are free of frost, ice, and snow. It must be completed within 5 minutes prior to beginning takeoff. This check must be accomplished from outside the aircraft unless the certificate holder's program specifies otherwise.

f. Outside-the-Aircraft Check. A check to ensure that the wings and control surfaces are free of frost, ice, and snow. It *must* be completed within 5 minutes prior to beginning takeoff. It *must* be accomplished from outside the aircraft.

6. Program Elements. FAR Section 121.629(c) requires a certificate holder's ground deicing and anti-icing program include at least the following elements:

a. Management plan including a detailed description of the operational responsibilities and procedures associated with the implementation and conduct of the certificate holder's ground deicing/anti-icing program.

b. A certificate holder's holdover timetables and procedures for the use of these tables by the certificate holder's personnel.

c. Aircraft deicing/anti-icing procedures and responsibilities, pretakeoff check procedures and responsibilities, and pretakeoff contamination check procedures and responsibilities.

d. Initial and recurrent ground training and testing for flight crewmembers and qualification for all other affected personnel (e.g., aircraft dispatchers, ground crews, contract personnel).

7. Management Plan. FAR Sections 121.533, 121.535, and 121.537 state, respectively, that each domestic, flag, and supplemental air carrier and commercial operator is responsible for operational control. In order to properly exercise operational control (when conditions at an airport are such that frost, ice, or snow may reasonably be expected to adhere to its aircraft), the certificate holder should develop, coordinate with other affected parties, implement, and use a management plan to ensure proper execution of its approved deicing/anti-icing program. The FAA would accept an operator's management plan that identifies the manager responsible for the overall deicing/anti-icing program, identifies each subordinate manager, and describes each manager's functions and responsibilities under the applicable FAR which are needed to properly manage the certificate holder's deicing/anti-icing program. A plan encompassing the elements discussed in the following paragraphs is acceptable:

a. Operations. Determine the management position responsible for ensuring that all the elements of the management plan and the deicing/anti-icing program have been developed, properly integrated, and coordinated; that the plan and program have been disseminated to all those persons who have duties, responsibilities, and functions to perform in accordance with them; and that adequate management oversight of the program continues to be maintained. The following should be considered:

(1) At each airport where operations are expected to be conducted in conditions conducive to ground icing, determine who will be responsible for deciding when ground deicing/anti-icing operational procedures are to be implemented.

(2) Specify the functions, duties, responsibilities, instructions, and procedures to be used by flight crewmembers, aircraft dispatchers or flight followers, and management personnel for safely dispatching or releasing each type aircraft used in its operations while ground deicing/anti-icing operational procedures are in effect. A plan should include a detailed description of how the certificate holder determines that conditions at an airport are such that frost, ice, or snow may reasonably be expected to adhere to the aircraft, and when ground deicing/anti-icing operational procedures must be in effect.

(3) Determine who will be responsible for coordinating the applicable portions of the management plan and the deicing/anti-icing program with the appropriate air traffic control tower (ATCT) personnel and other appropriate airport authorities, including:

(i) Determine who will be authorized to enter into agreements with the manager of the ATCT at each airport regarding air traffic control (ATC) procedures during ground icing conditions, and with each airport's manager regarding aircraft secondary deicing/anti-icing locations and where aircraft may conduct pretakeoff contamination checks; and

(ii) Ensure that a detailed description of the deicing/anti-icing program is incorporated in the certificate holder's manuals for flight crewmembers, dispatchers or flight followers, ground operations personnel, and management personnel to use in conducting operations under ground icing conditions.

b. Maintenance. Determine who is responsible for ensuring that enough trained and qualified personnel, as well as adequate facilities and equipment, are available at each airport where operations are expected to be conducted under conditions conducive to ground icing for the proper deicing and anti-icing of the certificate holder's aircraft. The following should be considered:

(1) Ensure that all necessary maintenance elements of the management plan and the deicing/anti-icing program have been developed, properly integrated, and coordinated; that the maintenance plan and deicing/anti-icing program have been disseminated to all those personnel who have duties, responsibilities, and functions to perform; and that adequate management oversight of the program continues to be maintained.

(2) Detail the functions, duties, responsibilities, instructions, and procedures to be used by its ground personnel, maintenance personnel, and management personnel for safely dispatching or releasing aircraft used in its operations while ground deicing/anti-icing operational procedures are in effect.

(3) Ensure that a detailed description of the maintenance portion of the deicing/anti-icing program is incorporated in the certificate holder's manuals for the use and guidance of maintenance, ground, flightcrew, and management personnel.

8. Holdover Timetables and Procedures for Their Use. FAR Section 121.629(c)(3) requires that the deicing/anti-icing program include holdover timetables and the procedures for the use of these tables by the certificate holder's personnel. An acceptable program includes procedures to be followed in the event that the holdover times, as determined by the PIC from the certificate holder's holdover time tables, are exceeded. Each of these areas is discussed in the following paragraphs and illustrated in figure 1.

Note: The procedures for the use of the holdover timetables requires a pretakeoff check by the flightcrew. To effectively use holdover timetables, they should be available in the cockpit for flightcrews to use.

a. Responsibilities and Procedures. The certificate holder's program should define operational responsibilities and contain procedures for the flightcrew, aircraft dispatchers, flight followers, and maintenance and ground personnel applicable to the use of holdover times and resultant actions if the determined holdover time is exceeded. These procedures should include gate procedures, communication between ground crew and flightcrew to establish the start of holdover time and to relay other pertinent information regarding the deicing/anti-icing process, flight crewmember use of the pertinent holdover timetables, coordination with dispatchers or flight followers, and coordination with ATC.

b. Development of Holdover Timetables. Except as provided in FAR Section 121.629(d), each certificate holder is required under FAR Section 121.629(c)(3) to develop holdover timetables for use by its personnel. These timetables are required to be supported by data acceptable to the Administrator. Currently, the only acceptable data is that developed by SAE and ISO. ARP 4737, "Aircraft Deicing/Anti-icing Methods with Fluids, for Large Transport Aircraft," and ISO 11076, "Aerospace — Aircraft Deicing/Anti-icing Methods with Fluids," contain the tables that are currently considered acceptable for use by the certificate holders to develop their holdover timetables. Holdover times exceeding those specified in the current editions of the SAE and ISO tables are currently not acceptable; however, the certificate holder may require the use of more conservative times than those specified in the SAE and ISO tables. …

c. Use of Holdover Timetables. Holdover time ranges are only an estimate of the time that deicing/anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the protected surfaces of an aircraft. Holdover time begins when the final application of deicing/anti-icing fluid commences and expires when the deicing/anti-icing fluid applied to the aircraft loses its effectiveness. Holdover times vary with weather conditions; the holdover time determined should be appropriate for the existing weather conditions. … It should be noted the SAE and ISO holdover timetables specifically state that holdover time protection will be shortened in heavy weather conditions. The effectiveness of deicing/anti-icing fluids is based on a number of variables (e.g., temperature, moisture content of the precipitation, wind, and aircraft skin temperature). The holdover timetables are to be used for departure planning and in conjunction with pretakeoff check procedures. FAR Section 121.629(c)(3) requires the program include procedures for the use of holdover timetables including conducting pretakeoff check(s). A pretakeoff check as defined in FAR Section 121.629(c)(4) is a check of the aircraft's wings or representative aircraft surfaces for frost, ice, or snow within the aircraft's holdover time. Depending on the length of the holdover time, weather, or other conditions, pretakeoff check procedures may be accomplished several times during the aircraft's holdover time. A pretakeoff check should be accomplished just prior to taking the active runway for departure. Air carrier manuals should contain detailed procedures for using holdover timetables and the conduct of pretakeoff checks in their operations.

d. FAR Section 121.629(c)(3) also requires the certificate holder's program contain procedures for flight crewmembers to increase or decrease the determined holdover time in changing conditions. This requires the flightcrew to maintain a continued awareness of environmental or situational conditions that could affect the determined holdover time. Weather conditions that could result in a change to the determined holdover time include, but are not limited to, a significant rise or drop in ambient temperature, an increase or decrease in precipitation rate or intensity, water content, or density, a change in type of precipitation; e.g., rain to freezing rain, light to heavy snow, or the end of precipitation. Procedures should consider the certificate holder's capability to disseminate information, in real time, concerning changing weather conditions. Additional guidance regarding holdover timetables is contained in AC 20-117, Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing; AC 20-158, Pilot Guide for Large Aircraft Ground Deicing; SAE ARP 4737, "Aircraft Deicing/Anti-icing Methods with Fluids, for Large Transport Aircraft"; and ISO 11076, "Aerospace — Aircraft Deicing/Anti-icing Methods with Fluids."

e. Takeoff After the Holdover Time is Exceeded. Under FAR Section 121.629(c)(3), takeoff after the determined holdover time is exceeded is permitted only if one of the three conditions described in e.(1)(2)(3) exists. The certificate holder's program should detail actions that must be accomplished if the holdover time is exceeded.

(1) A pretakeoff contamination check is completed to make sure that wings, control surfaces, and other critical surfaces, as defined in the certificate

holder's program, are free of frost, ice, and snow. The operator's program must include detailed aircraft type-specific procedures and responsibilities for flightcrew and ground personnel to use while accomplishing this check. This check must be completed within 5 minutes prior to beginning takeoff and must be accomplished from outside the aircraft, unless the certificate holder's program specifies otherwise. Factors determining whether the check can be accomplished from inside the aircraft include the ability of the flightcrew to see aircraft surfaces, lighting conditions, weather conditions, as well as other factors which determine the flightcrew's ability to assess the condition of the aircraft. The certificate holder's program should emphasize that if any doubt exists as to the condition of the aircraft after completing this check from inside the aircraft, the takeoff must not be attempted. If doubt exists, the PIC should request a pretakeoff contamination check be accomplished from outside the aircraft or the aircraft should be redeiced and a new holdover time determined; or

(2) It is otherwise determined by an alternate procedure, that wings, control surfaces, and other critical surfaces, as defined in the certificate holder's program, are free of frost, ice, and snow.

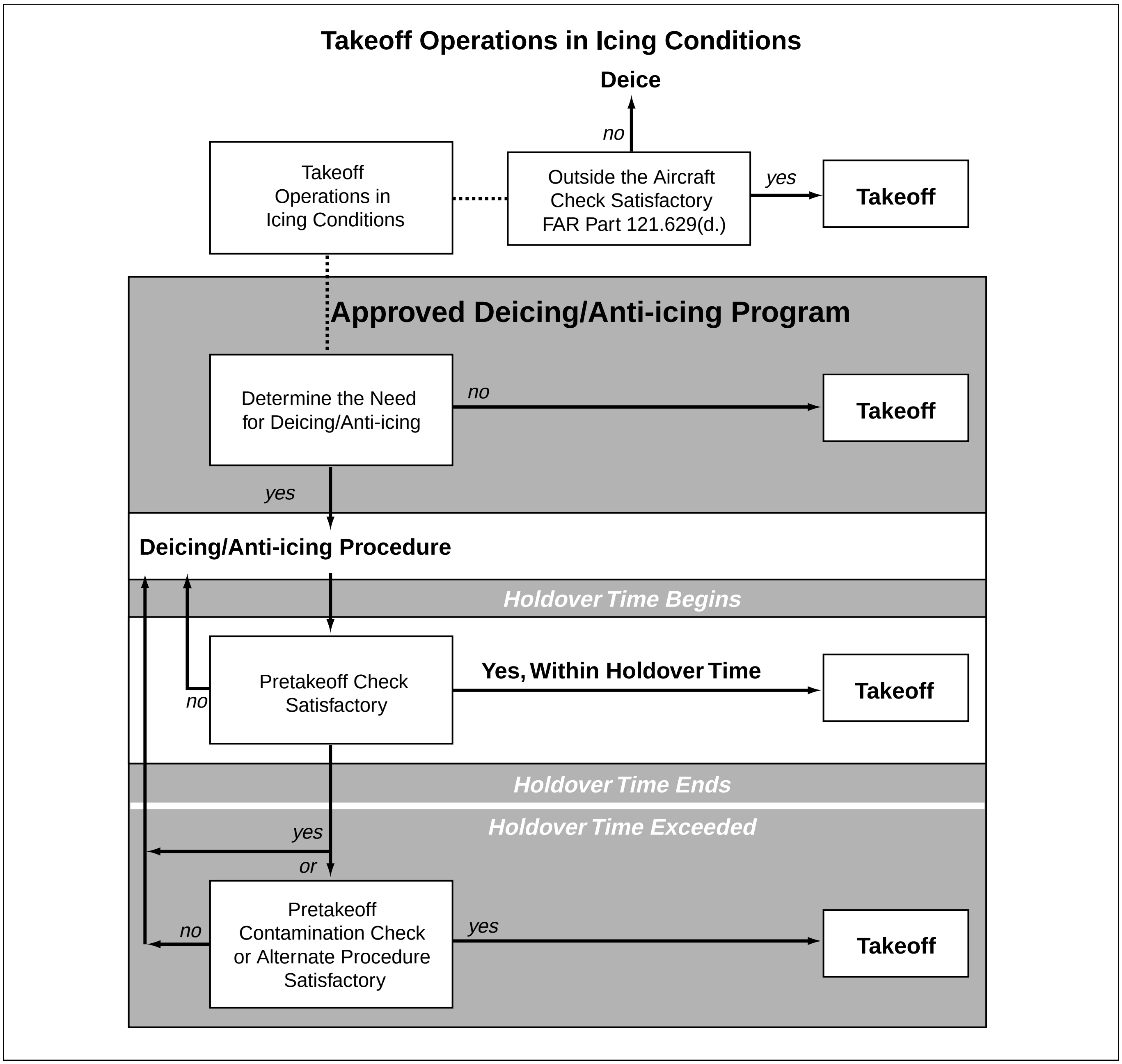

Figure 1

Alternative procedures consist of procedures, techniques, or equipment (such as wing icing sensors) that might be used to establish that the above mentioned surfaces are not contaminated. Any alternative procedure must be approved by the certificate holder's principal operations inspector through the Manager, Air Transportation Division, AFS-200, and the procedures should be included in the certificate holder's approved program; or

(3) The wings, control surfaces, and other critical surfaces have been redeiced and a new holdover time has been determined. Coordination procedures with ATC and ground personnel should be detailed for the accomplishment of this redeicing.

9. Aircraft Deicing/Anti-icing Procedures and Responsibilities, Pretakeoff Check Procedures and Responsibilities, and Pretakeoff Contamination Check Procedures and Responsibilities. Certificate holders' manuals should contain detailed procedures for the deicing and anti-icing process specific to each aircraft type. Certificate holders should have aircraft type-specific instructions and checking guidelines and procedures for the use of their flight crewmembers and other personnel to determine whether or not aircraft surfaces are free of contaminants.

Note: Takeoffs with underwing frost in the area of the fuel tanks within limits established by the aircraft manufacturer, accepted by FAA aircraft certification offices, and stated in aircraft maintenance and flight manuals can be authorized by the FAA.

a. Identification of Critical Aircraft Surfaces. The critical aircraft surfaces which should be clear of contaminants before takeoff should be described in the aircraft manufacturer's maintenance manual or other manufacturer-developed documents, such as service or operations bulletins.

(1) Generally, the following should be considered to be critical aircraft surfaces, if the aircraft manufacturer's information is not available:

(i) Pitot heads, static ports, ram-air intakes for engine control and flight instruments, other kinds of instrument sensor pickup points, fuel vents, propellers, and engine inlets.

(ii) Wings, empennage, and control surfaces.

(iii) Fuselage upper surfaces on aircraft with center mounted engine(s).

(2) Certificate holders should list in the flight manual or the operations manual, for each type of aircraft used in their operations, the critical surfaces which should be checked on flight-crewmember-conducted preflight inspections, pretakeoff checks, and pretakeoff contamination checks.

(3) Critical surfaces should be defined for the use of ground personnel for conducting the check following the deicing/anti-icing process and for any pretakeoff contamination checks that may be accomplished by ground personnel.

b. Identification of Representative Aircraft Surfaces (for use in conducting pretakeoff checks only). Certificate holders should list in the flight manual or the operations manual, for each type of aircraft used in their operations, the representative surfaces which may be checked while conducting pretakeoff checks.

(1) Some aircraft manufacturers have identified certain aircraft surfaces which the flightcrew can readily observe to determine whether or not ice, frost, or snow is accumulating or forming on that surface and, by using it as a representative surface, can make a reasoned judgement regarding whether or not ice, frost, or snow is adhering to other aircraft surfaces. Certificate holder operational experience can also be used to define representative surfaces. In the absence of this information, the following guidelines should be considered in identifying a representative aircraft surface:

(i) The surface can be seen clearly to determine whether or not ice, frost, or snow is forming or accumulating on the surface.

(ii) The surface should be unheated.

(iii) Surfaces such as windshield wipers should also be considered.

(iv) The surface should be one of the first surfaces treated with deicing/anti-icing fluid during the deicing/anti-icing procedure; however, designation of representative surfaces is not limited to treated surfaces.

c. Techniques for Recognizing Contamination on Aircraft Critical or Representative Surfaces. In annual and recurrent training, certificate holders must include aircraft type-specific techniques for flight crewmembers and other personnel for recognizing contamination on critical and representative aircraft surfaces. These type-specific techniques should be used while conducting preflight aircraft icing checks, pretakeoff checks, and pretakeoff contamination checks. Some indications for loss of effectiveness of deicing/anti-icing fluid or contamination on aircraft surfaces include surface freezing or snow accumulation, random snow accumulation, and dulling of surface reflectivity (loss of gloss) caused by the gradual deterioration of the fluid to slush. Deicing/anti-icing fluid manufacturers should also be consulted for information on the fluid characteristics and indications that the fluid is losing its effectiveness.

d. Types of Icing Checks. FAR Section 121.629(c)(4) identifies three different icing checks or procedures which, when applicable, are required to be accomplished under an operator's approved deicing/anti-icing program:

(1) **Aircraft Deicing/Anti-icing Procedure**. The aircraft deicing/anti-icing procedure includes a check of the wings, control surfaces, propellers, engine inlets, and other critical surfaces. This check is an integral part of the deicing/anti-icing procedure. Certificate holders should have procedures which ensure that, following aircraft deicing and anti-icing fluid application, this check is conducted by qualified ground personnel. This check determines if the wings, control surfaces, propellers, engine inlets, and other critical surfaces are free of frost, ice, or snow before pushback or taxi. It should be noted that, for airplanes not equipped with wing clear-ice detectors, a tactile check of airplane surfaces is the only known method to date to verify whether or not the surfaces are uncontaminated. Communication procedures should be established to relay pertinent deicing/anti-icing information and the results of this check to the PIC.

(2) **Pretakeoff Check**. This check is aircraft type-specific and is required under FAR Section 121.629(c)(3) anytime procedures for the use of holdover times are required. It must be accomplished within the holdover time, and is normally accomplished by the flightcrew from inside the cockpit. The aircraft's wings or representative aircraft surfaces are checked for contamination. The surfaces to be checked are determined by manufacturer's data, carrier's operational experience, or guidance contained in this AC. The pretakeoff check is integral to the use of holdover times. Because of the limitations and cautions associated with the use of holdover times, the flightcrew must assess the current weather, other situational conditions, and the aircraft's condition, and not rely on the use of holdover times as the sole determinant that the aircraft is free of contaminants. Several pretakeoff checks may be required during the holdover time period based on factors including the length of the holdover time range, weather, or other conditions. A continued awareness of the aircraft condition should be maintained. A pretakeoff check should be accomplished just prior to taking the active runway for departure.

(3) **Pretakeoff Contamination Check**. FAR Section 121.629(c)(3)(i) states that completing a pretakeoff contamination check is one of the conditions that allows a takeoff after a holdover time has been exceeded. Certificate holders must have appropriate pretakeoff contamination check procedures for flight crewmembers and other qualified ground personnel's use to ensure that the aircraft wings, control surfaces, and other critical surfaces remain free of frost, ice, and snow when a holdover time has been exceeded. The pretakeoff contamination check must be completed within 5 minutes prior to beginning takeoff and must be accomplished from outside the aircraft unless the certificate holder's program specifies otherwise. Reliance on representative surfaces are not satisfactory for determining the aircraft is free of contamination while conducting this check. If any doubt exists concerning the aircraft's condition after completing this check, the aircraft cannot take off unless it is redeiced and a new holdover time determined. The following should be considered while developing procedures for this check.

(i) Certificate holders who operate hard-wing airplanes with aft, fuselage-mounted, turbine-powered engines should conduct pretakeoff contamination checks from outside the airplane, unless otherwise authorized in the certificate holder's approved program. The pretakeoff contamination check for these airplanes should include a tactile check of selected portions of the wing leading edges and the upper wing surfaces. Alternatives to a tactile check procedure may be approved. Alternative procedures must be coordinated with the Manager, Air Transportation Division, AFS-200. As of the date of this AC, only one airplane manufacturer has developed an approved alternative to tactile pretakeoff contamination checks. This procedure is contained in the manufacturer's maintenance manual and details the requirements for conducting this check.

(ii) Operators of other aircraft must conduct this check from outside the aircraft unless they can show that the check can be adequately accomplished from inside the aircraft, as specified in the certificate holder's program. The program must detail procedures and requirements for the conduct of this check. Certificate holders should consider the following in the development of guidelines for conducting pretakeoff contamination checks from inside the aircraft:

(A) Can enough of the wings, control surfaces, and other critical surfaces be seen to accurately determine whether or not they are free of contaminants? This determination should consider the aircraft type, the method of conducting the check — that is, from the cockpit or cabin, and other factors including aircraft lighting and other ambient conditions.

(B) Does the certificate holder have procedures to recognize, and have flight crewmembers been properly trained on these procedures to recognize, changes in weather conditions so they will be able to determine if the wings, control surfaces, and other critical aircraft surfaces could reasonably be expected to remain free of contamination?

10. Initial and Recurrent Ground Training and Testing for Flight Crewmembers and Initial and Recurrent Ground Training and Qualification for Dispatchers.

a. Flight Crewmember Training and Testing. The operator's training program must include a detailed description of initial and annual recurrent ground training and testing for flight crewmembers concerning the specific requirements of the program and the duties, responsibilities, and functions detailed in the program. Flight crewmembers and dispatchers must be trained and tested or qualified on at least the following subjects (after each subject listed, recommendations concerning the content of the training are provided):

(1) **The Use of Holdover Times**. Holdover times are a range of times derived from an analysis of airline experience and laboratory testing of the freeze points of particular types of fluids (currently Type I and Type II) under various temperatures, fluid concentrations, and humidity conditions. A discussion of holdover times should include the following:

(i) Definition of holdover time.

(A) Limitations and cautions associated with the use of holdover times.

(B) Source of holdover time data.

(C) How to determine a specific holdover time from the holdover time range that accounts for "heavy," "medium," or "light" weather conditions.

(D) Adjusting holdover time for changing weather conditions.

(ii) Precipitation category (e.g., fog, drizzle, rain, or snow).

(A) Precipitation intensity.

(B) Duration of precipitation.

(C) Relationship of precipitation change to holdover time.

(iii) Relationship of holdover time to particular fluid concentrations and for different types of fluids.

(iv) When holdover time begins and ends.

(v) Communication procedures.

(A) Communication between ground personnel and the flightcrew to determine the start of holdover time, and the particular holdover timetable to be used. Communications from the ground crew to the cockpit crew should consist of the following information:

(1) Fluid type; e.g., Type I or Type II.

(2) Fluid/water mix ratio.

(3) Start time of final fluid application which is when holdover time begins.

(4) Accomplishment and results of post-deicing/anti-icing check.

(B) ATC coordination.

(C) Dispatch or flight following coordination.

(D) Means for obtaining most current weather information.

(vi) Use of holdover times by the flightcrew.

(vii) Procedures when holdover time is not exceeded.

(A) When, where, and how to accomplish the pretakeoff check.

(viii) Procedures when holdover time is exceeded.

(A) Pretakeoff contamination check; or

(B) Alternate means to determine whether or not surfaces are free of frost, ice, or snow; or

(C) Redeice and determine a new holdover time.

(2) **Aircraft Deicing/Anti-icing Procedures Including Checks to Detect Contaminated Surfaces, and Responsibilities**.

(i) **Deicing** is a procedure by which frost, ice, or snow is removed from the aircraft in order to provide clean surfaces. The procedure can be accomplished by the use of fluids, mechanical means, or by heating the aircraft.

(ii) **Anti-icing** is a procedure by which the application of certain types of anti-icing fluids provides protection against the formation of frost or ice and accumulation of snow on treated surfaces of the aircraft for a limited period of time (holdover time).

(iii) **Deicing/Anti-icing** is a combination of the two procedures above. It can be performed in one or two steps.

(A) One-step deicing/anti-icing is carried out with an anti-icing fluid. The fluid used to deice the aircraft remains on aircraft surfaces to provide limited anti-icing capability.

(B) Two-step deicing/anti-icing consists of two distinct steps. The first step, deicing, is followed by the second step, anti-icing, as a separate fluid application. When it has been determined that the surfaces are clean, anti-icing fluid is applied to protect the relevant surfaces, thus providing maximum possible anti-icing protection (holdover time).

(iv) Safety requirements during fluid application.

(v) Deicing/anti-icing fluid application procedures.

(vi) If applicable, remote deicing procedures.

(A) Aircraft type-specific considerations.

(B) Location-specific procedures.

(vii) **Contractor Deicing/Anti-icing**. In order to comply with the rule, certificate holders who engage in supplemental operations and employ contractor deicing/anti-icing services and who are unable to arrange for the training and qualification of these personnel in advance should have a person assigned to the flights who is fully trained under the certificate holders' approved program to supervise the deicing/anti-icing procedure.

(viii) **Deicing/Anti-icing Checking Procedures and Responsibilities**. The training program should have aircraft type-specific surface contamination check procedures and guidelines to include the following:

(A) **Types of Checks Required**. Each certificate holder should detail the types of checks required and the methods for accomplishing these checks. This includes procedural steps for conducting the check as well as the location, personnel requirements, deicing equipment, and lighting required to accomplish the check.

(1) Flightcrew preflight inspection/cold weather preflight inspection procedures. This is the normal walk around preflight inspection conducted by the flightcrew. This inspection should note any aircraft surface contamination and direct any required deicing/anti-icing operations.

(2) Aircraft deicing/anti-icing procedures include a check performed by qualified ground personnel after the deicing/anti-icing fluid application has been completed. This check is an integral part of the aircraft deicing/anti-icing procedure.

(3) A pretakeoff check is performed by the flightcrew prior to takeoff and within the holdover time. This is a check normally conducted from inside the cockpit. Identification of representative surfaces and continual assessment of environmental and other situational conditions should be included in the operator's program.

(4) Pretakeoff contamination check. This check is accomplished after the holdover time has been exceeded and must be completed within 5 minutes prior to beginning takeoff. Each carrier must define aircraft type-specific pretakeoff contamination check procedures. The check must be conducted from outside the aircraft unless otherwise approved in the carrier's program. Rather than accomplishing this check, the PIC may elect to be redeiced and a new holdover time established.

(B) Identification of critical surfaces or representative surfaces to be checked/inspected during each type of check.

(C) Techniques for recognizing contamination on the aircraft.

(D) Communications procedures to include communications between the flightcrew, ground personnel, ATC, and company station personnel. Communications with ATC should include coordinating deicing/anti-icing of the aircraft with any proposed ATC push-back time and coordinating any other special requirements needed for accomplishing required aircraft checks.

(3) **Aircraft Surface Contamination and Critical Area Identification, and How Contamination**

Adversely Affects Aircraft Performance and Flight Characteristics.

(i) **Aircraft Ground Icing Conditions**. Certificate holders should have a description of the following conditions included in their program that would implement ground deicing/anti-icing operational procedures:

(A) **Inflight Ice Accumulation**. Certificate holders should have procedures for flightcrews of arriving flights to report occurrences of inflight icing to the personnel responsible for executing the certificate holder's deicing/anti-icing program. Inflight ice accumulation could result in a ground deicing situation when flights are scheduled for short turnaround times; i.e., for 30 minutes or less, and when ambient temperatures on the ground are at or below freezing.

(B) **Freezing Precipitation**. Snow, sleet, freezing rain, drizzle, or hail which could adhere to aircraft surfaces.

(C) **Frost**, including hoarfrost which is a crystallized deposit, formed from water vapor on surfaces which are at or below 0˚C (32˚F).

(D) **Freezing Fog**. Clouds of supercooled water droplets that form a deposit of ice on objects in cold weather conditions.

(E) **Snow**. Precipitation in the form of small ice crystals or flakes which may accumulate on, or adhere to, aircraft surfaces.

(F) **Freezing Rain**. Water condensed from atmospheric vapor falling to earth in supercooled drops, forming ice on objects.

(G) **Rain or High Humidity on Cold-soaked Wing**. Water forming ice or frost on the wing surface when the temperature of the aircraft wing surface is at or below 0˚C (32˚F). This ice or frost may freeze over the entire wing surface and on the wing leading edge.

(H) **Rain or High Humidity on Cold-soaked Wing Fuel Tanks**. Water forming ice or frost may form on the wing surface when the temperature of the aircraft wing surface in the vicinity of the wing fuel tanks is at or below 0˚C (32˚F) due to cold-soaked fuel. Certain aircraft are susceptible to the formation of frost or ice on wing upper surfaces when cold-soaked fuel is in the main wing fuel tanks, and the aircraft are exposed to conditions of high humidity, rain, drizzle, or fog at ambient temperatures well above freezing. Under some atmospheric and temperature conditions clear ice may form. The certificate holder's program should include procedures for removing this type of contamination. In certain circumstances, this type of contamination may not require the certificate holder to implement its ground deicing/anti-icing program.

(I) **Underwing Frost**. Takeoff with frost under the wing in the area of the fuel tanks (caused by cold-soaked fuel) within limits established by the aircraft manufacturer, accepted by FAA aircraft certification offices and stated in aircraft maintenance and flight manuals, may be permitted. This type of contamination may not require the certificate holder to implement its ground deicing/anti-icing program.

(ii) **Critical Aircraft Surfaces**. Certificate holders should identify for each type of aircraft used in their operations, the critical surfaces which should be checked on preflight and pretakeoff contamination checks. Information from the aircraft manufacturer (or from this AC if the subject information is not available from the aircraft manufacturer) should be used to determine the critical surfaces for each aircraft type.

(iii) **Representative Aircraft Surfaces**. Certificate holders should identify, for each type of aircraft used in their operations, the representative aircraft surfaces which should be checked during pretakeoff checks. Information from the aircraft manufacturer, or information developed from carrier operating experience, should be used to determine representative surfaces. In the absence of such information, information from this AC can be used to determine representative aircraft surfaces.

(iv) **Effects of Frost, Ice, Snow, and Slush on Aircraft Performance, Stability, and Control**. The certificate holder should obtain information on aircraft performance when undetected frost, ice, snow, or slush could be adhering to aircraft surfaces from the manufacturer of each type of aircraft it uses in its operations and should ensure that its flight crewmembers and aircraft dispatchers understand these effects. Accident data and National Aeronautics and Space Administration studies have confirmed that some aircraft manufacturers' data indicates that the effects of wing contamination may be significantly more pronounced for hard-leading-edge (hard-wing) airplanes than for slatted-leading-edge (slatted-wing) airplanes. This data indicates for airplanes without leading-edge, high-lift devices that the presence of even minute amounts of ice or other contaminates (equivalent to medium grit sandpaper) results in significant loss of wing lift, which causes the airplane to stall at lower-than-normal angles of attack during takeoff. The discussion of these effects should include, but is not limited to, the following subjects:

(A) Increased drag and weight.

(B) Tendency for rapid pitchup and wing roll off during rotation.

(C) Loss of lift.

(D) Stall occurs at lower-than-normal angle of attack.

(E) Buffet or stall occurs before activation of stall warning.

(F) Decreased effectiveness of flight controls.

(4) **Types, Purpose, Characteristics, and Effectiveness of Deicing and Anti-icing Fluids**. There are several kinds of deicing and anti-icing fluids currently available, and each has different characteristics and capabilities. Certificate holders should ensure that their flight crewmembers, aircraft dispatchers, and ground personnel generally understand the purpose and capabilities of the fluids used in the certificate holders' deicing/anti-icing program; and that their flight crewmembers are generally knowledgeable of the characteristics of each type of fluid. Certificate holders should refer to the following SAE publications for additional information on specific deicing and anti-icing methods and procedures and on fluid characteristics and capabilities: AMS 1424, "Deicing/Anti-icing Fluid, Aircraft, Newtonian — SAE Type I;" AMS 1428, "Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian, Pseudo-Plastic, SAE Type III;" and ARP 4737, "Aircraft Deicing/Anti-icing Methods with Fluids, for Large Transport Aircraft;" and the following ISO documents: ISO 11075, "Aerospace — Aircraft Deicing/Anti-icing Newtonian Fluids ISO Type I;" ISO 11076, "Aerospace — Aircraft Deicing/Anti-icing methods with fluids;" ISO 11077, "Aerospace — Deicing/Anti-icing Self Propelled Vehicles — Functional Requirements;" and ISO 11078, "Aerospace — Aircraft Deicing/Anti-icing Non-Newtonian Fluids ISO Type II." The following subjects should be discussed:

(i) Deicing fluids:

(A) Heated water.

(B) Newtonian fluid (SAE/ISO Type I).

(C) Mixtures of water and SAE/ISO Type I fluid.

(D) Mixtures of water and SAE/ISO Type II fluid.

Note: Deicing fluid should be applied heated to assure maximum efficiency.

(ii) Anti-icing fluids:

(A) Newtonian fluid (SAE/ISO Type I).

(B) Mixtures of water and SAE/ISO Type I fluid.

(C) Non-Newtonian fluid (SAE/ISO Type II).

(D) Mixtures of water and SAE/ISO Type II fluid.

Note: SAE/ISO Type II anti-icing fluid is normally applied cold on clean aircraft surfaces, but may be applied heated. Cold SAE/ISO Type II fluid normally provides longer anti-icing protection.

(iii) **Fluid Characteristics.**

(A) **Type I Deicing Fluids.**

(1) Unthickened.

(2) Very limited holdover time.

(3) Applied to form thin liquid film on wing.

(B) **Type II Anti-icing Fluids.**

(1) Thickened.

(2) Longer holdover times in comparison to those of Type I fluids.

(3) Application results in a thick liquid film (a gel-like consistency) on wing.

(4) Air flow over the wing (shear) causes the fluid to progressively flow off the wing during takeoff.

(iv) **Fluid Specifications.**

(A) **SAE and ISO Type I Deicing and Anti-icing Fluids.** The following specifications apply: SAE AMS 1424, Deicing/Anti-icing Fluid, Aircraft, Newtonian — SAE Type I.

1. Monoethylene Glycol (EG).

2. Propylene Glycol (PG).

(B) ISO 11075, Aerospace — Aircraft Deicing/Anti-icing Newtonian Fluids ISO Type I. These fluids have been approved by nearly all aircraft manufacturers for use on their aircraft when properly applied. The ISO and SAE holdover timetables for Type I fluids are applicable to these fluids.

(C) **SAE and ISO Type II Deicing and Anti-icing Fluids.** The following specifications apply: SAE AMS 1428, Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian, Pseudo-Plastic, SAE Type II; and ISO 11078, Aerospace — Aircraft Deicing/Anti-icing, Non-Newtonian Fluids ISO Type II. These fluids have been approved by most of the manufacturers of large transport category airplanes. In order to be classified as meeting SAE-AMS 1428 and ISO 11078 specifications, these fluids must me et certain chemical performance requirements, and the aerodynamic and high humidity and freezing water spray endurance tests that are required of Type II fluids. These fluids should be applied in accordance with appropriate SAE/ISO methods documents. The SAE and ISO holdover timetables for Type II fluids are applicable to these fluids.

(D) **Association of European Airlines (AEA) Deicing and Anti-icing Fluids.** AEA Type I deicing fluid and AEA Type II deicing/anti-icing fluids have been approved by nearly all manufacturers of large transport category airplanes for use on their aircraft when properly applied in accordance with aircraft manufacturers' recommendations. The holdover timetables applicable to SAE and ISO approved fluids may be applied for use with AEA Type I and AEA Type II Freezing Point Depressant (FPD) fluids.

(E) **United States Military Deicing Fluids.** Military Type I and Type II designations have an entirely different meaning than SAE, ISO, or AEA designations. A military Type II fluid does not indicate that the fluid has a longer holdover time than a military Type I fluid. Holdover times have not been established for military deicing fluids. Since holdover timetables do not apply, use of these fluids should only be used in conjunction with a pretakeoff contamination check.

(F) **Other Deicing/Anti-icing Fluids.** Use of any deicing/anti-icing fluid should be in accordance with the aircraft manufacturers recommendations. Holdover timetables are not approved for use for any deicing or anti-icing fluid that does not meet SAE, ISO or AEA approved specifications. Use of any fluid that does not meet these specifications should only be used as a last resort and when used should be in conjunction with a pretakeoff contamination check.

(5) **Deicing/Anti-icing Fluids Handling/ Performance Implications.** The type of fluid used and how completely the fluid flows off the wing during takeoff determines the effects on the following handling/performance factors. The aircraft manufacturer may also provide performance information regarding the use of the different deicing/anti-icing fluids.

(i) Increased rotation speeds/increased field length.

(ii) Increased control (elevator) pressures on takeoff.

(iii) Increased stall speeds/reduced stall margins.

(iv) Lift loss during climbout/increased pitch attitude.

(v) Increased drag during acceleration/increased field length.

(vi) Increased drag during climb.

[**b.** left blank]

c. **Other Affected Ground Personnel Training**. At least the following subjects for ground personnel (i.e., maintenance mechanic, ramp agent, service personnel, and contractors) should be discussed.

(1) **Effects of Frost, Ice, Snow, and Slush on Aircraft Surfaces**. This discussion is intended to provide ground personnel with an understanding of the critical effect the presence of even minute amounts of frost, ice, or snow on flight surfaces and should include, but is not limited to, the following:

(i) Loss of Lift.

(ii) Increased drag and weight.

(iii) Decreased control.

(iv) Aircraft-specific areas.

(A) Engine foreign object damage potential.

(B) Ram-air intakes.

(C) Instrument pickup points.

(D) Leading edge device (LED) aircraft (aircraft that have slats or leading edge flaps) and non-LED aircraft.

(2) **Fluid Characteristics and Capabilities**. Deicing/Anti-icing fluids with differing properties exist and may continue to be developed. To the extent that they are being utilized by an air carrier, they should be addressed in training programs:

(i) General fluid descriptions.

(ii) Composition and appearance.

(iii) Health precautions/environmental considerations.

(iv) Differences between Type I and Type II deicing/anti-icing fluids.

(v) Purpose for each type.

(vi) Capabilities.

(vii) Shearing characteristics in storage and handling.

(viii) Fluid application methods.

(3) **Holdover Times**. A discussion of holdover times should include the following:

(i) Source of holdover time data.

(ii) Precipitation category.

(A) Precipitation intensity.

(B) Duration of precipitation.

(C) Relationship of precipitation change to holdover time.

(iii) Relationship of holdover time to particular fluid concentrations for Type I and Type II fluids.

(iv) Identification of when holdover time begins and ends.

(v) Communication procedures between ground personnel and flightcrew to relay the start time of the final deicing/anti-icing fluid application, the type of fluid used, the fluids/water mix ratio, and confirmation that the post application check was accomplished and that the aircraft is free of all contamination.

(4) **Equipment.** An understanding of the capabilities of the deicing equipment and the qualifications for operation are necessary. The equipment portion of the training program should include the following:

(i) Description of various equipment types.

(ii) Operation of the equipment.

(5) **Preflight Check.**

(i) In the predeparture sequence, ground deicing may be initiated at one or more of the following times:

(A) On overnight aircraft prior to the flightcrew's arrival.

(B) Following a check by the flightcrew and a request for deicing.

(C) After a normal preflight inspection by ground personnel or the flightcrew, and after the crew is onboard the aircraft.

(ii) In each case, the preflight and the decision on whether or not to deice/anti-ice should be based on appropriate consideration of the circumstances and should include the following:

(A) Weather conducive to frost or ice formation or snow accumulation.

(B) Aircraft critical areas (general and aircraft-specific).

(6) **Deicing/Anti-icing Procedures.** Ground personnel should be knowledgeable of deicing and anti-icing application procedures:

Note: For aircraft type-specific procedures, refer to the aircraft operating manual.

(i) One-step deice and two-step deice/anti-ice process.

(ii) Communications from the ground crew to the flightcrew should provide the following information:

(A) Fluid type.

(B) Fluid/water mix ratio.

(C) Start time of final deice/anti-ice application.

(D) Post-application check accomplished.

(iii) Safety requirements and emergency procedures.

(iv) Deicing/Anti-icing prior to aircrew arrival.

(v) Gate deicing procedures.

(vi) Remote deicing procedures.

(A) Aircraft-specific considerations.

(B) Location-specific procedures.

(C) Safety precautions.

(vii) Post-application check procedures.

(7) **Pretakeoff Contamination Check**. This check is accomplished when the holdover time has been exceeded and must be completed within 5 minutes of beginning takeoff. Each carrier must define the content of the pretakeoff contamination check. The check should be conducted from outside the aircraft by qualified ground personnel unless the certificate holder's program authorizes it to be conducted from inside the aircraft by the flightcrew. Training for ground personnel should include the following:

(i) When the check is required.

(ii) The necessary resources, personnel, and equipment to accomplish the check properly.

(iii) Where the check could be accomplished.

(iv) What surfaces must be checked.

(v) Procedures for relaying the condition of the aircraft to the PIC.

(8) **Contractor Deicing**. Many certificate holders use parties other than themselves to perform deicing. The party with whom they reach an agreement to provide deicing services could be another carrier, a fixed-base operator or some other service provider. Training for deicing services should include the following:

(i) An approved contract training program. This program should meet the carrier's own training standards.

(ii) Train-the-trainer program (the carrier trains the contract deicing personnel or designated trainer).

(iii) Alternative procedures at airports where contract service agreements are not present. For example, a trained and qualified flightcrew member or other appropriately qualified certificate holder employee provides supervision and quality control during the deicing/anti-icing process and ensures contractor procedures meet the certificate holder's approved program standards.

(iv) Guidance that the flightcrew will hold the contractor to their own approved program standards.

(9) **Ground Personnel Qualification**. Certificate holders' ground deicing programs should have a qualification program and a quality assurance program to monitor and maintain a high level of competence.

(i) The program should be tailored to the individual airline with each air carrier maintaining its own quality assurance responsibility.

(ii) The program should have a tracking system that ensures that all required training has been satisfactorily completed and recorded for all ground personnel participating in the deicing process. Also, a list naming qualified deicing personnel should be made available to all local managers responsible for deicing.

(iii) An ongoing review plan is advisable to evaluate the effectiveness of the training received by the deicing personnel. Recurrent training should be key to this process.

11. FAR Section 121.629(d), "Outside-the-Aircraft Check" In Lieu of an Approved Ground Deicing/Anti-icing Program. A certificate holder may continue to operate without an approved ground deicing/anti-icing program if it has approved procedures and properly trained personnel for conducting an "outside-the-aircraft check" in accordance with FAR Sections 121.105, 121.123, 121.135(b)(2), 121.415(g), and 121.629(d). Authorization for conducting this check, in lieu of an approved program, should be contained in the certificate holder's operations specifications (OpSpecs). As stated in FAR Section 121.629(d), this check is accomplished when conditions are such that frost, ice, or snow may reasonably be expected to adhere to the aircraft. Under FAR Section 121.629(d), the check must be completed within 5 minutes of beginning takeoff and must be accomplished from outside the aircraft. Certificate holders' manuals and training programs should detail procedures for accomplishing this check.

William J. White, Deputy Director, Flight Standards Service♦

[FSF Editorial Note: Appendix 1, which included holdover time tables, has been omitted in this reprint because the tables are no longer current.]

Pilot Guide: Large Aircraft Ground Deicing

Advisory Circular (AC) 120-58
U.S. Federal Aviation Administration

FSF editorial note: Holdover time tables have been omitted in this report because the tables are no longer current. See current holdover time tables based on data from the Society of Automotive Engineers (SAE), the International Standards Organization (ISO), the Association of European Airlines (AEA), the relevant flight operations manual and/or the appropriate civil aviation authority.

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Preface

This advisory circular (AC) contains recommendations for ensuring the safe operation of large airplanes during icing conditions and guidelines for the development of adequate procedures for the deicing of large airplanes. It is designed for the use of flight crewmembers, maintenance and servicing personnel, and other aviation personnel responsible for ground deicing and aviation safety in general. The guidelines and procedures offered in this AC are advisory in nature and do not carry the force of a regulatory requirement. However, prudent operators will find that this information can further enhance safe operations and procedures.

In addition to a brief summary of the information contained in AC 20-117, "Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing," this AC contains recent information and guidance materials regarding advanced deicing and anti-icing fluids and procedures for their use. It recommends adherence to the *clean aircraft concept* which proposes "get it clean and keep it clean" during operations in adverse weather conditions.

... This AC does not change or interpret agency regulations and does not authorize deviations from regulatory requirements.

David R. Harrington
Acting Director, Flight Standards Service

Introduction

Federal Aviation Regulations (FAR) prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, control surfaces, engine inlets, and other critical surfaces of the aircraft. This rule is the basis for the *clean aircraft concept*. It is imperative that takeoff not be attempted in any aircraft unless the pilot-in-command (PIC) has ascertained that all critical components of the aircraft are free of frozen contaminants.

The clean aircraft concept is essential to safe flight operations. The *PIC has the ultimate responsibility* to determine if the aircraft is clean and that the aircraft is in a condition for safe flight. This requirement may be met if the PIC obtains verification from properly trained and qualified ground personnel that the aircraft is ready for flight. The general consensus of the aviation community is that a critical ingredient in ensuring a safe takeoff in conditions conducive to aircraft icing is visual and/or physical inspection of critical aircraft surfaces and components shortly before takeoff.

Common practice developed by the North American and European aviation communities is to deice and, if necessary, to anti-ice an aircraft before takeoff. This is accomplished most commonly by the use of heated aqueous solutions of Freezing Point Depressant (FPD) fluids for deicing, followed by anti-icing using cold, rich solutions that are thicker and have a lower freeze point. Several different types of FPD fluids have been developed during the past 40 years, and many are in common use today. Each of these various fluids has unique characteristics and requires handling unique to that particular fluid. More recently developed fluids, such as those identified as International Standards Organization (ISO) Type II and Society of Automotive Engineers (SAE) Type II, will last longer in conditions of precipitation and afford greater margins of safety if they are used in accordance with aircraft manufacturers' recommendations.

If improperly used, these fluids can cause undesirable and potentially dangerous changes in aircraft performance, stability, and control.

Ground deicing and anti-icing procedures vary depending primarily on aircraft type, type of ice accumulations on the aircraft, and FPD fluid type. *All pilots should become familiar with the procedures recommended by the aircraft manufacturer* in the Aircraft Flight Manual (AFM) or the maintenance manual and, where appropriate, the aircraft service manual.

FAA AC 20-117 provides a basic understanding of frozen contaminants and how they can affect aircraft performance and flight characteristics. Most aircraft manufacturers provide recommended procedures for deicing and anti-icing the aircraft. *The information contained herein is intended for basic understanding purposes and as a quick-reference guide for pilots and others. The pilot must refer to the specific procedures developed for the aircraft.*

The following list provides key points regarding aircraft deicing and anti-icing procedures.

- Most icing-related accidents have occurred when the aircraft was not deiced before takeoff attempt.
- The deicing process is intended to restore the aircraft to a clean configuration so that neither degradation of aerodynamic characteristics nor mechanical interference from contaminants will occur.
- The decision of whether or not to deice an aircraft is an integral part of the deicing process.
- The ultimate responsibility for the safety of the flight rests with the PIC of the aircraft.
- It is essential that the PIC have a thorough understanding of the deicing and anti-icing process and the approved procedures necessary to ensure that the aircraft is clean for takeoff.
- Heated solutions of FPD, water, or both are more effective in the deicing process than unheated solutions because thermal energy is used to melt the ice, snow, or frost formations.
- Unheated FPD fluids or aqueous solutions, especially SAE and ISO Type II, are more effective in the anti-icing process because the thickness of the final residue is greater.
- The freezing point of the final anti-icing coating should be as low as possible. The recommended minimum ambient temperature vs. freeze point buffers are shown below:

Fluid Type	OAT Range	Buffer
SAE and ISO Type I	All	18°F
SAE and ISO Type II	above 19°F	5°F
SAE and ISO Type II	below 19°F	13°F

OAT = Outside Air Temperature

- Undiluted SAE and ISO Type II fluids contain no less than 50 percent glycols and have a freeze point of -32°C minimum (-25.6°F).
- SAE and ISO Type II fluids have a longer time of effectiveness (up to 45 minutes in light precipitation) than conventional North American or SAE and ISO Type I fluids.

- A post-deicing/anti-icing check should be performed during or immediately following the ground deicing and anti-icing process.

- A pretakeoff check may be required before takeoff roll is initiated. The pilot may need the assistance of qualified ground crews to perform pretakeoff checks.

- Ice, frost, or snow on top of deicing or anti-icing fluids must be considered as adhering to the aircraft. Takeoff should *not* be attempted.

- FPD fluids used during ground deicing are not intended for, and do not provide, ice protection during flight.

- Flight tests performed by manufacturers of transport category aircraft have shown that most SAE and ISO Type II fluid flows off lifting surfaces by rotation speeds (V_R). Some large aircraft experience performance degradation and may require weight or other takeoff compensation. Degradation is significant on small airplanes.

- Some fluid residue may remain throughout the flight. The aircraft manufacturer should have determined that this residue will have little or no effect on aircraft performance or handling qualities in aerodynamically quiet areas. However, this residue should be cleaned periodically.

Clean Aircraft Concept

Test data indicate that ice, snow, or frost formations having 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 percent and increase drag by 40 percent.*

These changes in lift and drag significantly increase stall speed, reduce controllability, and alter aircraft flight characteristics. Thicker or rougher frozen contaminants can have increasing effects on lift, drag, stall speed, stability and control, with the primary influence being surface roughness located on critical portions of an aerodynamic surface. These adverse effects on the aerodynamic properties of the airfoil may result in sudden departure from the commanded flight path and may not be preceded by any indications or aerodynamic warning to the pilot. Therefore, it is imperative that *takeoff not be attempted* unless the PIC has ascertained, as required by regulation, that all critical surfaces of the aircraft are free of adhering ice, snow, or frost formations.

More than 30 factors have been identified that can influence whether ice, snow, or frost may accumulate and cause surface roughness on an aircraft and affect the anti-icing abilities of FPD fluids. These factors include ambient temperature; aircraft surface (skin) temperature; deicing fluid type, temperature, and concentration; relative humidity; and wind velocity and direction. Because many factors affect the accumulation of frozen contaminants on the aircraft surface, FPD fluids used for deicing, anti-icing, or both should *not* be considered to have anti-icing qualities for a finite period. There is always a need for close inspection before takeoff.

Numerous techniques for complying with the clean aircraft concept have been developed by the aviation industry. The consensus of the aviation community is that the primary method of ensuring safe flight operations in conditions conducive to aircraft icing is through visual or physical inspection of critical aircraft surfaces to ascertain that they are clean before takeoff. This consensus is valid regardless of the deicing and anti-icing techniques used.

Practices for Pilots to Ensure a Clean Aircraft

- Be knowledgeable of the adverse effects of surface roughness on aircraft performance and flight characteristics.

- Be knowledgeable of ground deicing and anti-icing practices and procedures being used on your aircraft, whether this service is being performed by your company, a service contractor, a fixed-base operator, or others.

- Do not allow deicing and anti-icing until you are familiar with the ground deicing practices and quality control procedures of the service organization.

- Be knowledgeable of critical areas of your aircraft and ensure that these areas are properly deiced and anti-iced.

- Ensure that proper precautions are taken during the deicing process to avoid damage to aircraft components and surfaces.

- Ensure that a thorough post-deicing/anti-icing check is performed prior to takeoff even though this may also be the responsibility of other organizations or personnel.

- Be knowledgeable of the function, capabilities, limitations, and operations of the ice protection systems installed on the aircraft.

- Perform additional post-deicing checks related to deicing or anti-icing as necessary or as required.

- Be aware that the time of effectiveness of FPD deicing or anti-icing treatments can only be estimated because of the many variables that influence this time (holdover time).

- Be knowledgeable of the variables that can reduce time of effectiveness (holdover time) and the general effects of these variables. See list on page 10 of this AC and AC 20-117.

- Ensure that deicing and anti-icing are performed at the latest possible time before taxi to the takeoff position.

- Do not start engines or engage rotor blades until it has been ascertained that all ice deposits have been removed. Ice particles shed from rotating components may damage the aircraft or injure ground personnel.

- Be aware that certain operations may produce recirculation of ice crystals, snow, or moisture.

- Be aware that operations in close proximity to other aircraft can induce snow, other ice particles, or moisture to be blown onto critical aircraft components, or can cause dry snow to melt and refreeze.

- Do not take off if snow or slush is observed splashing onto critical areas of the aircraft, such as wing leading edges, during taxi.

- Do not take off if positive evidence of a clean aircraft cannot be ascertained.

Post-deicing/Anti-icing Check

Post-deicing/anti-icing checks should be performed during or immediately following the ground deicing and anti-icing process. Areas to be inspected depend on the aircraft design and should be identified in a post-deicing checklist. The checklist should include, at a minimum, all items recommended by the aircraft manufacturer. Generally, a checklist of this type includes the following items:

- Wing leading edges, upper surfaces, and lower surfaces;

- Vertical and horizontal stabilizing devices, leading edges, upper surfaces, lower surfaces, and side panels;

- High-lift devices such as leading-edge slats and leading or trailing-edge flaps;

- Spoilers and speed brakes;

- All control surfaces and control balance bays;

- Propellers;

- Engine inlets, particle separators, and screens;

- Windshields and other windows necessary for visibility;

- Antennas;

- Fuselage;

- Exposed instrumentation devices such as angle-of-attack vanes, pitot-static pressure probes, and static ports;

- Fuel tank and fuel cap vents;

- Cooling and auxiliary power unit (APU) air intakes, inlets, and exhausts; and

- Landing gear.

Once it has been determined through the post-deicing check that the aircraft is clean and adequately protected, the aircraft should be released for takeoff as soon as possible. This procedure is especially important in conditions of precipitation or high relative humidity (small temperature/dew point spread).

Pretakeoff Check

Shortly before the aircraft takes the active runway for takeoff or initiates takeoff roll, a visual pretakeoff check is strongly recommended. The components that can be inspected vary by aircraft design. In some aircraft, the entire wing and portions of the empennage are visible from the cockpit or the cabin. In other aircraft, these surfaces are so remote that only portions of the upper surface of the wings are in view. Undersurface of wings and the undercarriage are viewable only in high-wing-type aircraft. A practice in use by some operators is to perform a visual inspection of wing surfaces, leading edges, engine inlets, and other components of the aircraft that are in view from either the cockpit or cabin, whichever provides the maximum visibility. The PIC may require the assistance of trained and qualified ground personnel to assist in the pretakeoff check.

If any aircraft surfaces have not been treated with FPD fluid, the PIC or another crewmember should look for, and examine any evidence of, melting snow and possible freezing. In addition, any evidence of ice formation that may have been induced by taxi operations should be removed. If the aircraft has been treated with FPD fluids, aircraft surfaces should appear glossy, smooth, and wet. If these checks indicate accumulations of ice, snow, or frost, the aircraft should be returned for additional deicing and, where appropriate, additional anti-icing.

Conducting a pretakeoff check in the manner described requires the PIC and other crewmembers to be knowledgeable of ground deicing procedures and danger signs. The post-deicing check should ensure that ground deicing and anti-icing were conducted in a thorough and uniform manner and that critical surfaces or components not in view from the cockpit or cabin are also clean. The pretakeoff check provides final confirmation for the pilot that the aircraft is free of frozen contaminants.

The decision to take off following pretakeoff check remains the responsibility of the PIC.

Need for a Clean Aircraft

FAR §§ 121.629, 125.221, 135.227, and 91.527 prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, or control surfaces of an aircraft. This is commonly referred to as the *clean aircraft concept*. The degradation in aircraft performance and changes in flight characteristics when frozen contaminants are present are *wide ranging, unpredictable, and highly dependent upon individual aircraft design*. The magnitude of these effects can be significant. It is imperative that *takeoff not be attempted* unless the PIC has ascertained, as required by the FAR, that all critical components of the aircraft are free of ice, snow, or frost formations.

Flight safety following ground operations in conditions conducive to icing encompasses the clean aircraft concept. Understanding the need for a clean aircraft requires a knowledge of:

- Adverse effects of ice, snow, or frost on aircraft performance and flight characteristics, which are generally reflected in the form of decreased thrust, decreased lift, increased stall speed, trim changes, and altered stall characteristics and handling qualities;
- Various procedures available for aircraft ground deicing and anti-icing, including the use and effectiveness of FPD fluids;
- Capabilities and limitations of these procedures in various weather conditions;
- Critical areas of aircraft such as the wings and tail; and
- Recognition that *final ensurance of a safe takeoff rests in confirmation of a clean aircraft*.

Frozen Contaminants

Frozen contaminants in the form of ice, snow, or frost can accumulate on exterior surfaces of an aircraft on the ground. The type of accumulation on the aircraft surface is a key factor in determining the type of deicing/anti-icing procedure that should be used.

Ice, snow, and frost should be removed before takeoff. Dry, powdery snow can be removed by blowing cold air or nitrogen gas across the aircraft surface. Heavy, wet snow or ice can be removed by using solutions of heated FPD fluids and water or by mechanical means such as brooms and squeegees.

Frozen contaminants can also be removed from the surface of an aircraft by using FPD fluids. There are a number of FPD's available for use on commercial large transport category aircraft. The FPD's used most often are glycol-based fluids produced by a number of North American, European, and Russian chemical manufacturers.

Deicing and Anti-icing Fluids

Common practice, developed by the North American and European aviation communities over many years of experience, is to deice and anti-ice an aircraft before takeoff. Various techniques of ground deicing and anti-icing have been developed. The most common of these techniques is to use FPD fluids in the ground deicing process and to anti-ice with a protective film of FPD fluid to delay the reforming of ice, snow, or frost. Commercially available FPD fluids used for aircraft deicing are ethylene glycol or propylene glycol based. Today's FPD fluids have characteristics that are best defined by a phase diagram or freeze chart as shown in Figure 1. The general characteristics of these fluids are described in Table 1.

Note: Generally, the freeze characteristics of commercially available FPD fluids are based on the "neat" (undiluted premix) solution as furnished by the fluid manufacturer.

The basic philosophy of using FPD fluids for aircraft deicing is to decrease the freezing point of water in either the liquid or crystal (ice) phase. FPD fluids are highly soluble in water; however, ice is slow to absorb FPD or to melt when in contact with it. If frost, ice, or snow is adhering to an aircraft surface, the formation may be melted by repeated application of proper quantities of FPD fluid. This process can be significantly accelerated by thermal energy from heated fluids. As the ice melts, the FPD mixes with the water thereby diluting the FPD. As dilution occurs, the resulting mixture may begin to run off. If all the ice is not melted, additional applications of FPD become necessary until the fluid penetrates to the aircraft surface. When all ice has melted, the remaining liquid residue is a mixture of water and FPD. The resulting film could freeze (begin to crystallize) with only a slight temperature decrease.

Traditional North American Fluids

As shown in Table 1, there are various types of FPD's available. These fluids are produced by chemical manufacturers in North America and Europe. The FPD's used to deice aircraft in North America are usually composed of ethylene or propylene glycol combined with water and other ingredients. Users can purchase this deicing fluid in a concentrated form (80 percent–90 percent glycol) or in a solution that is approximately 50 percent glycol with 50 percent water by volume.

ISO Commercial Fluids

These fluids were originally known as AEA Type I and Type II. Specifications for these two types of FPD's are provided in the ISO guidelines as ISO #11075, "Aircraft deicing/anti-icing Newtonian fluids ISO Type I" and ISO #11078, "Aircraft deicing/anti-icing non-Newtonian fluids ISO Type II."

SAE Commercial Fluids. SAE Type I and Type II fluids are very similar in all respects to ISO Type I and Type II fluids. The minor differences will not be presented in this AC. These FPD's, specified by the SAE and ISO as Type I and Type II, are distinguished by material requirement, freezing point, rheological properties (viscosity and plasticity), and anti-icing performance.

SAE and ISO Type I Fluids. These fluids in the concentrated form contain a minimum of 80 percent glycols and are considered "unthickened" because of their relatively low viscosity. These fluids are used for deicing or anti-icing, but provide very limited anti-icing protection.

SAE and ISO Type II Fluids. These fluids contain a minimum of 50 percent glycols and are considered "thickened" because of added thickening agents that enable the fluid to be deposited in a thicker film and to remain on the aircraft surfaces until the time of takeoff. These fluids are used for deicing and anti-icing, and provide greater protection than do Type I fluids against ice, frost, or snow formation in conditions conducive to aircraft icing on the ground.

SAE and ISO Type II fluids are designed for use on aircraft with V_R *greater than 85 knots*. As with any deicing or anti-icing fluid, SAE and ISO Type II fluids should not be applied unless the aircraft manufacturer has approved their use regardless of rotation speed. SAE and ISO Type II fluids are effective anti-icers because of their high viscosity and pseudoplastic behavior. They are designed to remain on the wings of an aircraft during ground operations or short term storage, thereby providing some anti-icing protection, but to readily flow off the wings during takeoff. When these fluids are subjected to shear stress, such as that experienced during a takeoff run, their viscosity decreases drastically, allowing the fluids to flow off the wings and causing little adverse effect on the aircraft's aerodynamic performance.

The anti-icing effectiveness of SAE and ISO Type II fluids is dependent upon the pseudoplastic behavior which can be altered by improper deicing/anti-icing equipment or handling. Some of the North American airlines have updated deicing and anti-icing equipment, fluid storage facilities, deicing and anti-icing procedures, quality control procedures, and training programs to accommodate the distinct characteristics of SAE and ISO Type II fluids. Testing indicates that SAE and ISO Type II fluids, if applied with improper equipment, may lose 20 percent to 60 percent of anti-icing performance.

SAE and ISO Type II fluids have been in the process of introduction in North America since 1985. Widespread use of SAE and ISO Type II fluids began to occur in 1990. Similar fluids, but with slight differences in characteristics, have been developed, introduced, and used in Canada.

U.S. Military Aircraft Deicing Fluids

The U.S. Department of Defense has issued military specifications, "Anti-icing and Deicing-Defrosting Fluids." These documents specify the following types of FPD's:

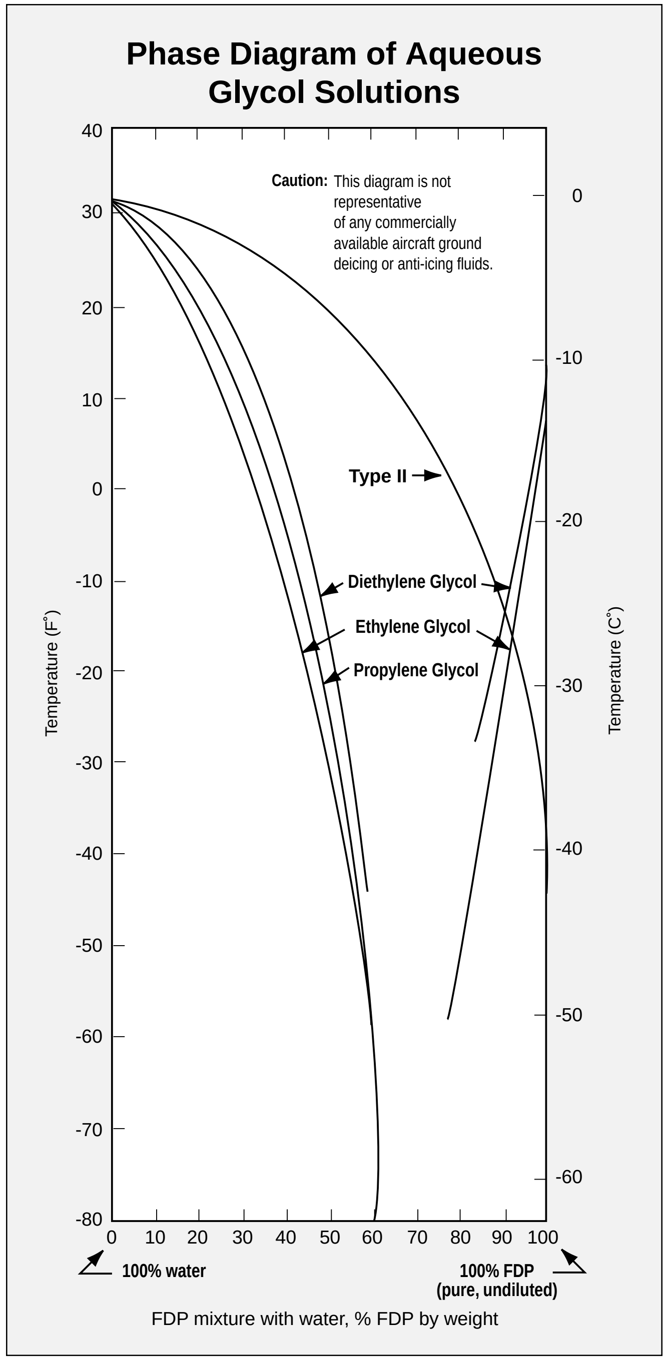

Figure 1

- MIL-A-4823C Type I–standard
- MIL-A-4823C Type II–standard with inhibitor
- MIL-A-4823D Type I (propylene glycol base)
- MIL-A-4823D Type II (ethylene and propylene glycol mix)

Military Types I and II fluids are essentially the same, except that Military Type II fluids contain a fire inhibitor. *Military Types I and II fluids are unrelated to SAE and ISO Types I and II fluids* (see Table 1).

Characteristics of FPD Fluids

Chemical Composition of FPD Fluids. Commercially available FPD fluids are of the ethylene glycol or propylene glycol family. The exact formulas of various manufacturers' fluids are proprietary. It is important to understand that some commercially available FPD fluids contain either ethylene glycol or derivatives of ethylene glycol, such as diethylene glycol, with small quantities of additives and water. Various FPD manufacturers, upon request, will premix aqueous solutions of FPD for specific customer reasons. Before using a solution of FPD, it is imperative that the ingredients be checked by close examination of the stock number and by a quality control examination to ascertain that the fluid supply conforms to the customer need. FPD fluid manufacturers can supply methodology and suggest equipment needed for quality control examinations. It is desirable that the pilot understand the criticality of effective quality control.

Freezing Characteristics of FPD Fluids. Before a fluid is used on an aircraft, it is crucial that the user knows and understands its freezing characteristics. These characteristics can be determined through understanding of the fluid procurement specifications and tolerances and through quality control inspections. FPD fluids are either premixed (diluted with water) by the manufacturer or mixed by the user from bulk supplies. To ensure known freezing characteristics, samples of the final mixture should be analyzed before use.

FPD Fluid Strength When Applied. Fluid strength or the ratio of FPD ingredients, such as glycol, to water should be known if proper precautions, such as those outlined above, are taken before application. It is crucial to realize that fluid strength is a significant factor in deicing properties, as is the time that the FPD fluid may remain effective (holdover time). …

Do not use pure (100 percent) ethylene glycol or pure propylene glycol fluids in nonprecipitation conditions. The reasons for this caution are explained below.

- The freezing point of pure ethylene glycol is much higher than that diluted with water. Slight temperature decreases can be induced by factors such as cold-soaked fuel in wing tanks, reduction of solar radiation by clouds obscuring the sun, ambient temperature cooling, wind effects, and lowered temperature during development of wing lift. If the freezing point of the remaining film is found to be insufficient, the deicing/anti-icing procedure should be repeated before the aircraft is released for flight.

- Full strength (undiluted) propylene glycol, having a strength of about 88 percent glycol at temperatures less than -10°C (+14°F), is quite viscous. In this form, propylene glycol based fluids have been found to produce lift reductions of about 20 percent. Propylene glycol FPD fluids are not intended to be used in the undiluted state unless specifically recommended by the aircraft manufacturer.

Temperature Buffer

American Practice. The practice developed and accepted by the North American air carrier industry using traditional North American fluids is to ensure that the remaining film has a freeze point of at least 20°F below ambient temperature.

European and Canadian Practice. The practice developed by the European air carrier industry has been to ensure that the freezing point of residual SAE and ISO Type I fluids is at least 10°C (18°F) below ambient temperature. This is similar to the North American practice, except for metric conversion differences. For SAE and ISO Type II fluids, the freeze temperature should be at least 7°C (13°F) below ambient temperature. This temperature difference between SAE and ISO Type I and SAE and ISO Type II FPD fluids is primarily to accommodate differences in fluid dilution rates which occur in freezing precipitation. Type II fluids, which are thicker, will not dilute to the same extent in a given period of time.

Current FAA Recommendations

Generally the holdover time is increased with an expansion of the temperature buffer. Therefore, if the choice is available, use the maximum buffers. Greater buffers require the use of more glycol, which is more costly and which increases the burden for collection and processing of FPD spillage and runoff. FPD fluid mixtures and their attendant buffers should be determined after consideration of the following factors in the listed order of priority.

- Safety
- Environmental impact
- Cost

Table 1
General Characteristics of Commercially Available FPD's

Common Name	Primary Active Ingredients	Viscosity	Primary Use	Notes (see AC 20-117 for more complete information)
North American	Ethylene glycol propylene glycol	Low	Deicing	Includes AMS 1425, AMS 1427, and Mil-A-8243 fluids. May not meet SAE nor ISO Type I specs.
SAE Type I ISO Type I	Propylene/diethylene ethylene glycol	Low	Deicing	Propylene glycol based fluids not to be used undiluted at OAT < 14°F (-10°C). Aircraft performance changes may result. AMS 1424 included. SAE, ISO specs similar.
SAE Type II ISO Type II	Propylene/diethylene glycol with polymer thickener	High to Low	Deicing and anti-icing	For use on aircraft with V_R > 85 knots; lower viscosity than AEA Type II produced before 1988. AMS 1428 included. SAE, ISO specs similar.
Mil-A-8243D Type I	Propylene glycol	Medium	Deicing	Less toxic to animals. *Not to be used undiluted.* Not similar to Mil-A-8243C Type I or II.
Mil-A-8243D Type II	3 parts ethylene glycol, 1 part propylene glycol	Low	Deicing	Similar to Mil-A-8243C Type I and II. Not approved as SAE or ISO Type II.
Arktika (Russia)	Ethylene glycol with thickener	High	Deicing and anti-icing	Not approved as SAE or ISO Type II. Considered thickened Type I. Effects on aerodynamics unknown to date.

AMS = Aerospace Materials Specification
AEA = Association of European Airlines

For traditional North American and Type I SAE and ISO Fluids, the freeze point buffer of the anti-icing fluid should be as great as possible but not less than 10°C (18°F).

For SAE and ISO Type II Fluids, the freeze point buffer should not be less than those recommended by the SAE and ISO which is currently 7°C (13°F) at ambient temperatures below -7°C (19°F) and 3°C (5°F) at ambient temperatures above -7°C (19°F).

AC 20-117 Recommendation. The FAA's recommendation, published in AC 20-117 in December 1982 and reissued in 1988, is to ensure that the fluid freeze point is at least 20°F (11°C) below the colder of the ambient or aircraft surface (skin) temperature. The reasons for this differential are to delay refreezing of the anti-icing fluid and to take into consideration such factors as:

- *Temperature reduction* during climb or in the production of aerodynamic forces, and the possibility that residual fluids (on surfaces, in balance bays, etc.) will freeze at altitude;

- *Freezing potential* in conditions conducive to icing. As freezing precipitation or moisture from any source contacts and is absorbed by the residual anti-icing fluid, the freeze point is increased. A greater temperature buffer provides a longer holdover time due to this effect; and

- *Quality control* margin for error.

Variables That Can Influence Holdover Time

This section provides a listing of some of the major variables that can influence the effectiveness of FPD fluids, especially when the fluids are being diluted by precipitation. The influence of these variables on the FPD fluids' time of effectiveness is described in detail in appendix 3 of AC 20-117. These major variables include:

- Aircraft component inclination angle, contour, and surface roughness;

- Ambient temperature;

- Aircraft surface (skin) temperature;

- FPD fluid application procedure;

- FPD fluid aqueous solution (strength);
- FPD fluid film thickness;
- FPD fluid temperature;
- FPD fluid type;
- Operation in close proximity to other aircraft, equipment, and structures;
- Operation on snow, slush, or wet ramps, taxiways, and runways;
- Precipitation type and rate;
- Presence of FPD fluid;
- Radiational cooling;
- Residual moisture on the aircraft surface;
- Relative humidity;
- Solar radiation; and
- Wind velocity and direction.

Health Effects

Pilots must be aware of the potential health effects of deicing and anti-icing fluids in order to ensure that proper precautions are taken during the deicing and anti-icing process and to better ensure the well-being of passengers and flightcrew. Passengers and crew should be shielded from all FPD fluid vapors by turning off all cabin air intakes during the deicing and anti-icing process. Exposure to vapors or aerosols of any FPD fluid may cause transitory irritation of the eyes. Exposure to ethylene glycol vapors in a poorly ventilated area may cause nose and throat irritations, headaches, nausea, vomiting, and dizziness.

All glycols cause some irritation upon contact with the eyes or the skin. Although the irritation is described as “negligible,” chemical manufacturers recommend avoiding skin contact with FPD and wearing protective clothing when performing normal deicing operations.

Ethylene and diethylene glycol are moderately toxic for humans. Swallowing small amounts of ethylene or diethylene glycol may cause abdominal discomfort and pain, dizziness, and effects on the central nervous system and kidneys. Because the glycol contained in FPD fluids is considerably diluted with water and other additives, it is highly unlikely that deicing personnel would ingest anything close to a lethal amount (3 to 4 ounces of pure glycol). Detailed information on health effects and proper safety precautions for any commercial FPD fluid is contained in the material safety data sheet for that fluid which is available from the fluid manufacturer and should be on file with the operator providing the deicing or anti-icing service.

Deicing and Anti-icing Procedures

Depending on the type of accumulation on the surface of the aircraft and the type of aircraft, operational procedures employed in aircraft ground deicing and anti-icing vary. The general procedures used by aircraft operators are similar and are based on the procedures recommended by the aircraft manufacturer, which, in turn, may be based upon procedures recommended by the fluid manufacturer, engine manufacturer, the SAE and ISO. ...

Pilot training can be accomplished through the use of manuals, films, and, to a limited extent, onsite observation. It is essential that the PIC fully understand effective deicing and anti-icing procedures. An annual review of these procedures by all pilots is required to maintain current knowledge of deicing and anti-icing methods, since the *PIC is responsible* for ensuring that critical aircraft surfaces are free from ice, snow, or frost formations before takeoff. An aircraft may be deiced by any suitable manual method, using water, FPD fluids, or solutions of FPD fluids and water. Heating these fluids increases their deicing effectiveness; however, in the anti-icing process, unheated fluids are more effective. SAE and ISO Type II fluids are more effective for providing anti-icing protection than are traditional North American fluids and SAE and ISO Type I fluids.

Deicing and anti-icing may be performed as a one-step or two-step process, depending on predetermined practices, prevailing weather conditions, concentration of FPD used, and available deicing equipment and facilities.

The *one-step procedure* is accomplished using a heated or, in some cases, 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 deicing process. A technique used commonly in the past is to spray on a final coat of deicing fluid using a very fine mist, applied in an arched trajectory so as to cool the fluid before contact. This produces a thicker fluid film which will have slightly enhanced anti-icing effectiveness. *Exercise caution when using this technique to ensure that freezing has not occurred within the fluid previously applied*.

The *two-step procedure* involves both deicing and anti-icing. Deicing is accomplished with hot water or a hot mixture of FPD and water. The ambient weather conditions and the type of accumulation to be removed from the aircraft must be considered when determining which deicing fluid to use.

The second (anti-icing) step involves applying a mixture of SAE or ISO Type II and water to the critical surfaces of the aircraft.

When heated water alone is used in the deicing process, the second step must be performed before refreezing occurs — generally within 3 minutes after the beginning of the deicing step. If necessary, the process is conducted area-by-area. As with any deicing or anti-icing fluid, SAE and ISO Type II fluid should not be used unless the aircraft manufacturer has approved its use. SAE and ISO Type II fluids are designed for use on aircraft with V_R in excess of 85 knots. This is to ensure sufficient flowoff of the fluid during the takeoff. ...

Under no circumstances should SAE and ISO Type II fluids, in the concentrated (neat) form, be applied to the following areas of an aircraft:

- Pitot heads and angle-of-attack sensors;
- Control surface cavities;
- Cockpit windows and nose of fuselage;
- Lower side of radome underneath nose;
- Static ports;
- Air inlets; and
- Engines.

... FPD freezing points can be determined by using a refractometer or other similar techniques.

Recommended Use of Deicing/ Anti-icing Codes

Following ground deicing, anti-icing, and inspection by qualified personnel, information supplied to the flightcrew should include the type of final fluid coating applied, the mixture of fluid (percent by volume), and time of application. This may be transmitted to the pilot by a four element code, such as the following.

Element A	specifies Type I or Type II fluid;
Element B	specifies the percentage of fluid within the fluid/water mixture (e.g., 75/25 = 75 percent fluid and 25 percent water);
Element C	specifies the local time of the beginning of the final deicing/anti-icing step (e.g., 1330); and
Element D	specifies date (day, written month, year) (e.g., 20 April 1992).

These elements are recommended for use in recordkeeping, and are optional for flightcrew notification.

Examples of the Deicing/Anti-icing Information Format are as follows:

Type II	100/0	1100h	16 Mar 1991
Type II	75/25	1330h	20 Apr 1992
Type I	70/30	0942h	17 Feb 1992

Deicing of Aircraft Surfaces

An aircraft must be systematically deiced and anti-iced in weather conditions conducive to icing (Figure 2). Each aircraft surface requires a specific technique to achieve a clean aircraft.

The wings are the main lifting surfaces of the aircraft and must be free of contaminants to operate efficiently. An accumulation of upperwing frost, snow, or ice changes the airflow characteristics over the wing, reducing its lifting capabilities, increasing drag, increasing stall speed, and changing pitching moments. The weight increase is slight, and its effects are secondary to those caused by surface roughness.

On most aircraft, deicing of the wing should begin at the leading-edge wing tip, sweeping in the aft and inboard direction. This process avoids increasing the snowload on outboard wing sections, which under some very heavy snow conditions could produce excessive wing stresses. This method also reduces the possibility of flushing ice or snow deposits into the balance bays and cavities.

If ice accumulation is present in areas such as flap tracks and control cavities, it may be necessary to spray from the trailing edge forward. Also, under some weather or ramp conditions, it is necessary to spray from the trailing edge.

The extendable surfaces of the wing (i.e., leading-edge slats and trailing-edge flaps) should be retracted to avoid accumulating frost, snow, or ice during time at the gate or in overnight storage. A surface that is extended in weather conditions requiring deicing and anti-icing should be visually inspected to ensure that the surface, tracks, hinges, seals, and actuators are free of any contaminants before retraction. Flaps and slats retracted during anti-icing will not receive a protective film of FPD fluid and may freeze in precipitation or frost conditions. Consult the aircraft manufacturer to ascertain the most appropriate slat and flap management procedures.

The tail surfaces require the same caution afforded the wing during the deicing procedure. The balance bay area between moveable and stationary tail surfaces should be closely inspected. For some aircraft, positioning the horizontal stabilizer in the leading-edge-down position allows the FPD fluid and contaminants to run off rather than into balance bays.

For some aircraft, the horizontal stabilizer must be in the leading-edge-up position during deicing.

Balance bays, control cavities, and gap seals should be inspected to ensure cleanliness and proper drainage. When contaminants do collect in the surface juncture, they must be removed to prevent the seals from freezing and impeding the movement of the control surface.

The fuselage should be deiced and anti-iced from the top down. Clearing the top of the fuselage manually instead of by spraying requires that personnel use caution not to damage protruding equipment (e.g., antennas) while deicing. Spraying the upper section with heated FPD fluid first allows the fluid to flow down, warming the sides of the fuselage and removing accumulations. This is also effective when deicing the windows and windshield of the aircraft, since direct spraying of the surfaces can cause thermal shock resulting in cracking or crazing of the windows. The FPD fluid must be removed from the crew's windows to maintain optimal visibility.

Deicing the top of the fuselage is especially important on aircraft with aft-mounted centerline and fuselage mounted engines. The ingestion of ice or snow into an engine may result in compressor stalls or damage to the engine.

The radome or nose of the aircraft should be deiced to eliminate snow or ice accumulations from being projected into the crew's field of vision during takeoff. This area also contains navigation and guidance equipment; therefore, it must be cleared of accumulations to ensure proper operation of these sensors.

Also, special precautions are necessary to ensure that residual fluids do not enter sensitive instrumentation or flow over the cockpit windows during taxi or takeoff.

The cargo and passenger doors must also be deiced and anti-iced in order to ensure proper operation. All hinges and tracks should be inspected to ensure that they are free of accumulation. Although accumulation may not impair operation on the ground, it may freeze at flight altitude and prevent normal operation at the aircraft's destination. Frozen accumulation may also cause damage and leakage on cargo and passenger door hatches.

Sensor orifices and probes along the fuselage require caution during the application of FPD fluid. Direct spraying into these openings and resulting fluid residue can result in faulty instrument readings. Also, when protective covers used during applications are not removed, faulty instrument readings can result.

Deicing the Engine Area

Minimal amounts of FPD fluid should be used to deice the engine area and APU. FPD fluids ingested in the APU can cause smoke and vapors to enter the cabin. Engine intake areas should be inspected for the presence of ice immediately after shutdown. Any accumulation should be removed while the engine is cooling and before installation of plugs and covers. Any accumulation of water must be removed to prevent the compressor from freezing. A light coating of deicing fluid applied to the plug may prevent the plugs from freezing to the nacelle.

Fluid residue on engine fan or compressor blades can reduce engine performance or cause stall or surge. In addition, this could increase the possibility of, or the quantity of, glycol

Systematic Deicing of Aircraft in Conditions Conducive to Icing

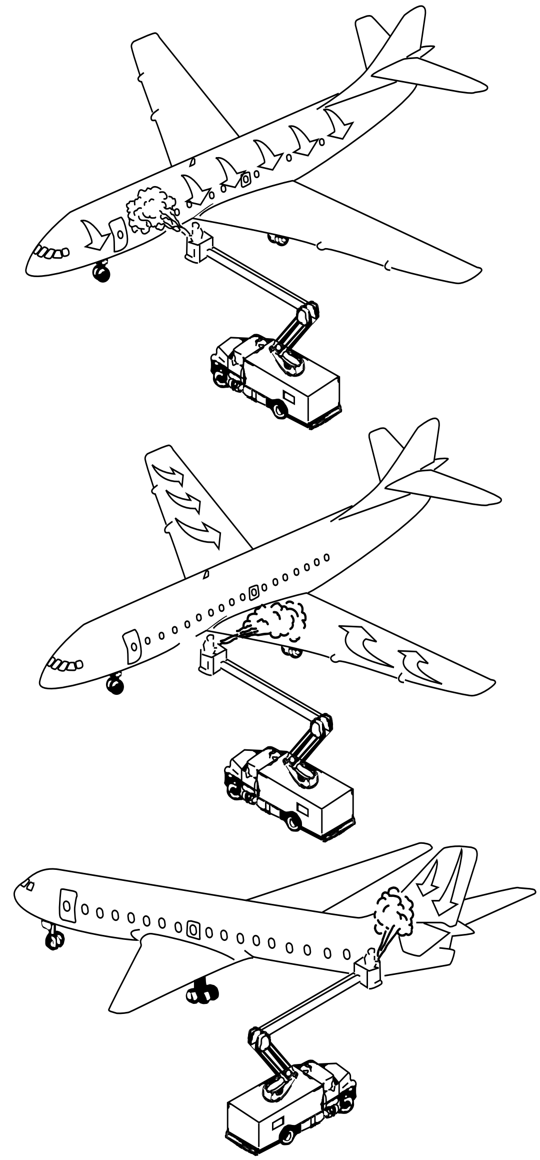

Figure 2

vapors entering the aircraft through the engine bleed air system.

Most turbojet and turboprop engine manufacturers recommend, and some AFM's require, that thrust levers be periodically advanced to an N1 rpm of 70 percent to 80 percent during ground operations. This practice prevents ice buildup that can result in reduced thrust, dynamic imbalance of the fan or compressor, or excessive induction of shed ice. The pilot must be aware of these operating procedures and should comply with procedures established for the aircraft.

Clear Ice Phenomena

Some aircraft have experienced formations of clear ice on the upper surfaces of wings in the vicinity of integral fuel tanks. Such ice is difficult to see and *in many instances cannot be detected other than by touch* with the bare hand or by means of special purpose ice detector. These phenomena typically occur on aircraft that have flown high altitude missions for a sufficient time to cold soak the fuel in tanks, and the fuel remaining in wing tanks at the destination is sufficient to contact upper wing skins when rain or high humidity is present. Upperwing frost can also occur under conditions of high relative humidity.

In either case, ice or frost formation on upper wing surfaces must be removed prior to takeoff. Skin temperature should be increased to preclude formation of ice prior to takeoff. This is often possible by refueling with warm fuel.

Clear ice formations of this type can cause aircraft performance changes and can break loose at rotation or during flight, causing engine damage on some aircraft types, primarily those with rear mounted engines.

Central and Remote Deicing

Deicing and anti-icing near the departure end of the runway has obvious advantages. This practice:

- Reduces the time between deicing/anti-icing and takeoff;
- Facilitates the recycling of FPD in the deicing mixture;
- Reduces the potential environmental impact; and
- Facilitates the application of correct ratio FPD/water for existing environmental conditions at departure.

This practice is encouraged where adequate facilities exist and if performed by qualified personnel. It should not be substituted for a pretakeoff check unless performed just prior to takeoff.

Techniques for Implementing the Clean Aircraft Concept

- Establish training programs to continually update pilots on the hazards of winter operations, adverse effects of ice formations on aircraft performance and flight characteristics, proper use of ice protection equipment, ground deicing and anti-icing procedures, deicing and pretakeoff procedures following ground deicing or anti-icing, and operations in conditions conducive to aircraft icing.
- Establish training programs for maintenance or other personnel who perform aircraft deicing to ensure thorough knowledge of the adverse effects of ice formations on aircraft performance and flight characteristics, critical components, specific ground deicing and anti-icing procedures for each aircraft type, and the use of ground deicing and anti-icing equipment including detection of abnormal operational conditions.
- Establish quality assurance programs to ensure that FPD fluids being purchased and used are of the proper characteristics, that proper ground deicing and anti-icing procedures are utilized, that all critical areas are inspected, and that all critical components of the aircraft are clean prior to departure.
- Perform thorough planning of ground deicing activities to ensure that proper supplies and equipment are available for forecast weather conditions and that responsibilities are specifically assigned and understood. This is to include maintenance service contracts.
- Monitor weather conditions very closely to ensure that planning information remains valid during the ground deicing or anti-icing process and subsequent aircraft operations. Type or concentration of FPD fluids, deicing or anti-icing procedures, and departure plans should be altered accordingly.
- Deice or anti-ice areas that are visible from the cockpit first so that during pretakeoff check the pilot may have assurance that other areas of the aircraft are clean. Areas deiced or anti-iced first will generally freeze first.
- Use the two-stage deicing process where ice deposits are first removed, and secondly all critical components of the aircraft are coated with an appropriate mixture of FPD fluid to prolong the effectiveness of the anti-icing.
- Ensure thorough coordination of the ground deicing and anti-icing process so that final treatments are provided just prior to takeoff.

- When feasible, provide and use remote sites near the takeoff position for deicing, anti-icing, final inspection, and to reduce the time between deicing and takeoff.

- Use multiple aircraft deicing or anti-icing units for faster and more uniform treatment during precipitation.

- Use FPD fluids that are approved for use by the aircraft manufacturer. Some fluids may not be compatible with aircraft materials and finishes, and some may have characteristics that impair aircraft performance and flight characteristics or cause control surface instabilities.

- Do not use substances that are approved for use on pneumatic boots (to improve deicing performance) for other purposes unless such uses are approved by the aircraft manufacturer.

- Use FPD fluid types and concentrations that will delay ice formations for as long as possible under the prevailing conditions.♦

Appendix 1
Application Guidelines Tables

FSF editorial note: Holdover time tables have been omitted in this report because the tables are no longer current. See current holdover time tables based on data from the Society of Automotive Engineers (SAE), the International Standards Organization (ISO), the Association of European Airlines (AEA), the relevant flight operations manual and/or the appropriate civil aviation authority.

Pilot Guide: Small Aircraft Ground Deicing

Advisory Circular (AC) 135-17
U.S. Federal Aviation Administration

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Preface

This advisory circular (AC) contains information and recommendations to assist pilots in conducting ground operations during weather conditions conducive to aircraft icing. It also contains information that can be used by other flight crewmembers, maintenance, servicing, and other aviation personnel responsible for ground deicing and aviation safety in general. Prudent operators will find that this information can further enhance safe operations and procedures.

This AC contains recent information and guidance regarding deicing and anti-icing fluids and procedures for their use. It provides information and guidance on how to comply with the clean aircraft concept, which requires the aircraft critical surfaces be free of contamination prior to beginning takeoff.

… The guidelines and procedures included in this AC are advisory. This AC does not change, or authorize any deviations from the Federal Aviation Regulations (FAR).

William J. White
Deputy Director, Flight Standards Service

Introduction

FAR §§ 121.629, 125.221, 135.227, and 91.527 prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, or control surfaces of an aircraft. This is commonly referred to as the clean aircraft concept. The degradation in aircraft performance and changes in flight characteristics when frozen contaminants are present are wide ranging, unpredictable, and highly dependent upon individual aircraft design. The magnitude of these effects can be significant. It is imperative that takeoff not be attempted unless the PIC has made certain, as required by the FAR, that all critical areas of the aircraft are free of ice, snow, and frost formations.

The clean aircraft concept is essential to safe flight operations. The PIC has the ultimate responsibility to determine if the aircraft is clean and that the aircraft is in a condition for safe flight. This requirement may be met if the PIC obtains verification from properly trained and qualified ground personnel that the aircraft is ready for flight. The general consensus of the aviation community is that a critical ingredient in ensuring a safe takeoff in conditions conducive to aircraft icing is visual and/or physical inspection of critical aircraft surfaces and components shortly before takeoff.

Understanding the need for a clean aircraft requires knowledge of:

- Adverse effects of ice, snow, or frost on aircraft performance and flight characteristics, including: decreased thrust, decreased lift, increased stall speed, trim changes, and altered stall characteristics and handling qualities;

- Various procedures available for aircraft ground deicing and anti-icing, including the use and effectiveness of freezing point depressant (FPD) fluids;

- Capabilities and limitations of these procedures in various weather conditions;

- Critical areas of aircraft such as the wings, propellers, control surfaces, airspeed, altimeter, rate of climb, and flight attitude instrument systems; and

To achieve compliance with the *clean aircraft concept*, it is imperative that takeoff not be attempted in any aircraft unless the pilot-in-command (PIC) is certain that critical components of the aircraft are free of frozen contaminants. The revised rules in Parts 121, 125, and 135 of the FAR are intended to achieve implementation of the clean aircraft concept. The new regulations require that the operator develop specific procedures for the PIC. Those procedures may require having, in place, specific procedures, qualified personnel, and adequate equipment, and supplies.

FAA AC 20-117 provides general information for the basic understanding of aircraft ground deicing issues and philosophy, including the definition of frozen contaminants and how they can affect aircraft performance and flight characteristics. The information contained herein is intended for basic understanding purposes and as a quick-reference guide for pilots of small aircraft (commuter, air taxi, and general aviation). For aircraft type specific procedures, pilots should refer to the aircraft flight manuals or other manufacturer documents developed for that particular type aircraft.

Practices for Pilots to Achieve A Clean Aircraft

- The *ultimate responsibility* for the safety of the flight rests with the *pilot in command* of the aircraft.

- For FAR Parts 135 and 125 operations a pretakeoff contamination check must be completed within 5 minutes prior to beginning takeoff.

- The fact that FAR's require that pretakeoff contamination checks be completed at least 5 minutes prior to beginning takeoff *does not mean* that the aircraft will always be safe for takeoff for a 5 minute period, or any other specific period of time. Under some weather or operational conditions (as described later), the time of effectiveness of FPD fluids may be less than 1 minute. Under those conditions, it is recommended that takeoff be delayed until the weather conditions abate and then additional checks should be conducted just prior to initiating takeoff roll to achieve compliance with the clean aircraft concept.

- Be knowledgeable of the adverse effects of surface roughness on aircraft performance and flight characteristics.

- Be knowledgeable of ground deicing and anti-icing practices and procedures being used on your aircraft, whether this service is being performed by your company, a service contractor, a fixed-base operator, or others.

- Do not allow deicing and anti-icing activities until you are familiar with the ground deicing practices and quality control procedures of the service organization.

- Be knowledgeable of critical areas of your aircraft and ensure that these areas are properly deiced and anti-iced.

- Ensure that proper precautions are taken during the deicing process to avoid damage to aircraft components, surfaces, and instrumentation sensors.

- Ensure that a thorough post-deicing/anti-icing check is performed as part of the deicing/anti-icing process.
- Be knowledgeable of the function, capabilities, limitations, and operations of the ice protection systems installed on your aircraft.
- Be aware that the time of effectiveness of FPD deicing or anti-icing treatments can only be estimated because of the many variables that influence this time (holdover time).
- The holdover times of deicing/anti-icing fluids should be used as guidelines and should not be relied upon as the sole basis for a decision to takeoff.
- Deicing and anti-icing should be performed at the latest possible time before taxi to the takeoff position.
- Accumulation of ice, frost, or snow on top of deicing or anti-icing fluids must be considered as adhering to the aircraft. Takeoff should *not* be attempted.
- Do not start engines until it has been ascertained that all ice deposits have been removed. Ice particles shed from rotating components (such as propellers) may damage the aircraft or injure ground personnel.
- Be aware that certain operations may produce recirculation of ice crystals, snow, or moisture.
- Be aware that operations in close proximity to other aircraft can induce snow, other ice particles, or moisture to be blown onto critical aircraft components, or can cause dry snow to melt and refreeze.
- It is not advisable to take off if snow or slush is observed splashing onto critical areas of the aircraft, such as wing leading edges, or trailing edge flaps during taxi.
- FPD fluids used during ground deicing are not intended for, and do not provide, ice protection during flight.

Frozen Contaminants and Their Causes

Frozen contaminants in the form of ice, snow, or frost can form and accumulate on exterior surfaces of an aircraft on the ground. These contaminates may be caused by weather and or operational conditions conducive of icing, generally described as follows:

Aircraft on the ground or in flight are susceptible to accumulation of ice formations (**Frozen Contaminants**) under various atmospheric and operational conditions. *It is generally accepted that icing conditions (during flight or ground operations) can occur and ice protection systems or procedures should be activated when OAT is below 50°F (10°C) and visible moisture in any form is present or when there is standing water, ice, or snow on the runway and/or taxiways*.

Aircraft In-Flight can encounter a variety of atmospheric conditions that will individually or in combination produce ice formations on various components of the aircraft. These conditions include:

- **Supercooled Clouds**. Clouds containing water droplets (at ambient temperatures below 32°F) that have remained in the liquid state. Supercooled water droplets are very small (generally in the range of 5 to 100 micrometers) and will freeze upon impact with another object. Water droplets can remain in the liquid state at ambient temperatures as low as -40°F. The rate of ice accretion and shape of ice formed on an aircraft component are dependent upon many factors such as cloud liquid water content, ambient temperature, droplet size, and component size, shape, and velocity.

  Note: One micrometer (micron) is one millionth of one meter or 0.00003937 inches.

- **Ice Crystal Clouds**. Clouds existing usually at very cold temperatures where moisture has frozen to the solid or crystal state.
- **Mixed Conditions**. Clouds at ambient temperatures below 32°F containing a mixture of ice crystals and supercooled water droplets.
- **Freezing Rain and Drizzle**. Precipitation existing within clouds or below clouds at ambient temperatures below 32°F where rain droplets remain in the supercooled liquid state. Freezing rain is generally differentiated from freezing drizzle as a function of droplet size where rain droplets range from 500 to 2000 microns and freezing drizzle droplets range less than 500 microns.

Aircraft on the Ground, when parked or during ground operations, are susceptible to many of the conditions that can be encountered in flight in addition to conditions peculiar to ground operations. These include:

- **Frozen precipitation such as snow, sleet, or hail**.
- **Residual ice from a previous flight**. Such contaminants may exist on leading edges of wings, empennage, trailing edge flaps, and other surfaces.
- **Operation on ramps, taxiways, and runways containing moisture, slush, or snow**. Residual ice or slush accumulated on airframe components during

landing and taxi operations on contaminated runways, taxiways and ramps, can remain in place if low temperatures and other weather conditions exist unless identified and removed. Contaminants of this type are commonly found in wheel wells, on landing gear components, trailing edge flaps, undersurfaces of wings and horizontal stabilizers, and other components.

- **Supercooled ground fog and ice fog**. Similar to supercooled clouds found at altitude but caused by advection or night time cooling and existing near ground level.

- **Blowing snow**. Snow blown by ambient winds, other aircraft or ground support equipment from snow drifts, other aircraft, buildings, or other ground structures.

- **Recirculated snow**. Snow made airborne by engine, propeller, or rotor wash. Operation of jet engines in reverse thrust, reverse pitch propellers, and helicopter rotor blades are common causes of snow recirculation.

- **High relative humidity**. Conditions that may produce frost formations on aircraft surfaces having a temperature at or below the dew or frost point. Frost accumulations are common during overnight ground storage and after landing where aircraft surface temperatures remain cold following descent from higher altitudes. This is a common occurrence on lower wing surfaces in the vicinity of fuel cells. Frost and other ice formations can also occur on upper wing surfaces in contact with cold fuel. On some aircraft clear ice formations can occur that are difficult to detect.

- **Frost**. Frost, including hoar frost, is a crystallized deposit, formed from water vapor on surfaces which are at or below 0°C (32°F).

- **Underwing Frost**. Operational experience as well as research experiments with several aircraft have indicated that underwing frost formations do not generally influence aircraft performance and flight characteristics as severely as leading edge and upper wing frost; however, *it must be understood that some aircraft designs may be more sensitive to underwing frost than others and particular aircraft could be unsafe with underwing frost*. It is required that underwing frost be removed unless the FAA Aircraft Certification Office accepts the aircraft manufacturer's data for such operations.

- **Polished Frost**. FAR 135 and other rules for small aircraft allow takeoff with frost formations on the wing surfaces if the frost is polished smooth, thereby reducing the amount of surface roughness. It is recommended that all wing frost be removed by means of conventional deicing process, however, if polishing of frost is desired, the aircraft manufacturers' recommended procedures should be followed.

- **Clear Ice Phenomena**. Some aircraft have experienced formations of clear ice on the upper surfaces of wings in the vicinity of integral fuel tanks. Such ice is difficult to see and in many instances can not be detected other than by touch with the bare hand or by means of a special purpose ice detector. These phenomena typically occur on aircraft that have flown high-altitude missions for a sufficient time to cold soak fuel in integral tanks, and the fuel remaining in these tanks, after landing, is sufficient to contact upper wing skins causing clear ice to form when rain, drizzle, wet snow, or high humidity is present (at, above, or below freezing ambient temperatures). Upperwing frost can also occur under conditions of high relative humidity.

Other Potential Locations of Frozen Contamination

- **Areas under leading edge slats and portions of trailing edge flaps** (e.g.; leading edges and upper surfaces of multi segment fowler flaps) might not be exposed to anti-icing fluids during the deicing/anti-icing process. Such unprotected areas may be exposed and susceptible to icing during precipitation or high relative humidity conditions, in taxi, takeoff queue, or takeoff configurations.

- **Leading edges of wings, empennage, slotted flaps, engine air inlets, etc.; of arriving aircraft** may contain residual ice formations from previous flights. If ambient conditions are not such that these formations would be dissipated by natural means, or removed by means of a deicing process, they will remain and can have significant effect upon aircraft performance and flight characteristics during subsequent operations.

- **Wing flap tracks, landing gear wheel wells, control bays, control seals, engine cowl inlets, etc**.

- **Ports, orifices, vents, air and fluid drains**.

- **Propellers and other rotating components** during ground operations are exposed to conditions similar to those of forward flight. Some aircraft require operation of inflight ice protection equipment while on the ground. Others may prohibit, or inhibit by design, operation of such equipment during ground operations.

The Effects of Contamination

Test data indicate that ice, snow, or frost formations having thickness and surface roughness similar to medium or course

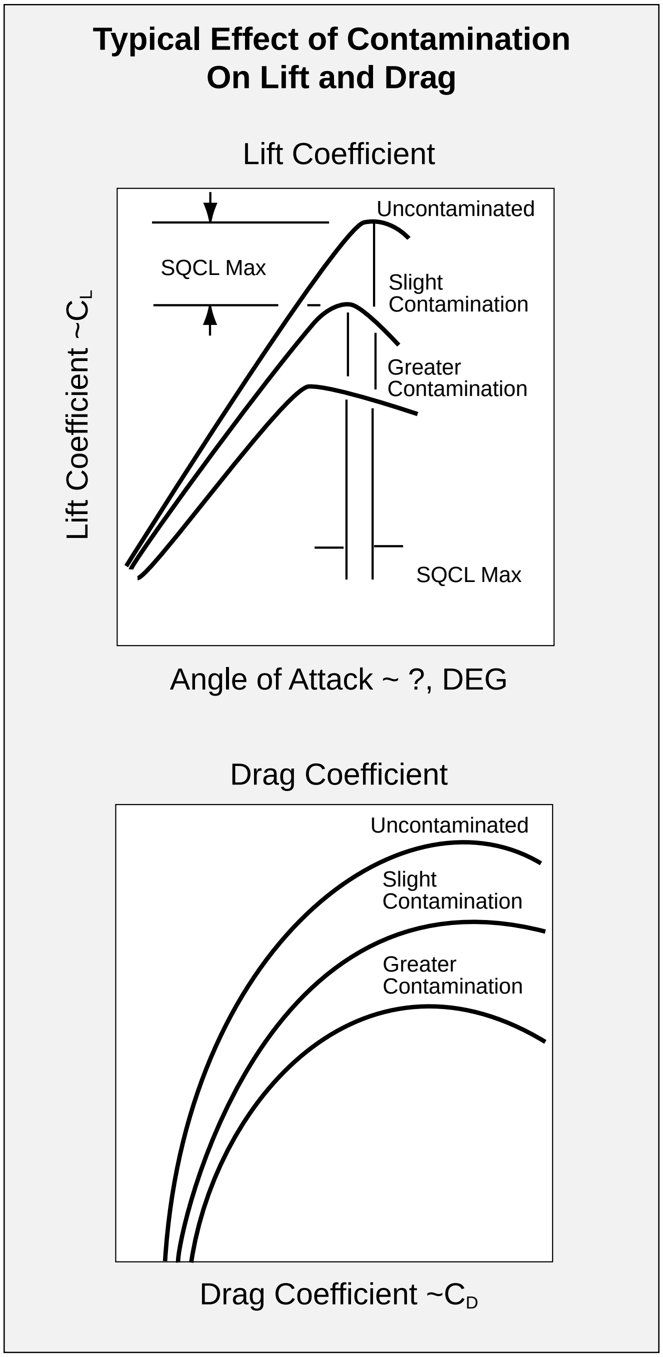

Figure 1

sandpaper on the leading edge and upper surfaces of a wing can reduce wing lift by as much as 30 percent and increase drag by 40 percent. See Figure 1. As illustrated in Figure 2, greater surface roughness can increase these values. Some aircraft are more susceptible to the effects of surface roughness than others.

Changes in lift and drag significantly increase stall speed, reduce controllability, and alter aircraft flight characteristics. Thicker or rougher frozen contaminants can have increasing adverse effects on lift, drag, stall speed, stability and control, and aircraft performance with the primary influence being surface roughness located on critical portions of an aerodynamic surface. These adverse effects on the aerodynamic properties of the airfoil may result in sudden departure from the commanded flight path and may not be preceded by any indications or aerodynamic warning to the pilot. Therefore, it is imperative that *takeoff not be attempted* unless the PIC has made certain that the critical surfaces and components of the aircraft are free of adhering ice, snow, or frost formations.

More than 30 factors have been identified that can influence whether ice, snow, or frost may accumulate and cause surface roughness on an aircraft and affect the anti-icing abilities of FPD fluids. These factors, among others, include: ambient temperature; aircraft surface (skin) temperature; deicing fluid type, temperature, and concentration; relative humidity; and wind velocity and direction.

Snow, frost, slush, and other ice formations on other components of the aircraft, can cause undesirable local air flow disturbances, or restriction of air and fluid vents. They can cause mechanical interference and restricted movement of flight controls, flap, slat, speed brake, landing gear retraction, and other mechanisms which are necessary for safe flight.

Ice formations on turbine engine and carburetor air intakes can cause a power loss, and if dislodged and ingested into the engine, can cause engine damage and/or failure.

Ice formations on external instrumentation sensors, such as pitot-static ports, and angle of attack sensors can cause improper indications or improper operation of certain systems and components that may be critical to safe flight.

Key Points

The following list provides key points regarding operations in ground icing conditions and aircraft deicing and anti-icing procedures for small aircraft.

- Most ground deicing-related accidents have occurred when the aircraft was not deiced before takeoff attempt.
- The deicing process is intended to restore the aircraft to a clean configuration so that neither degradation of aerodynamic characteristics nor mechanical interference from contaminants will occur.
- The decision of whether or not to deice an aircraft is an integral part of the deicing process.
- It is essential that the PIC have a thorough understanding of the deicing and anti-icing process and the approved procedures necessary to ensure that the aircraft is clean for takeoff.

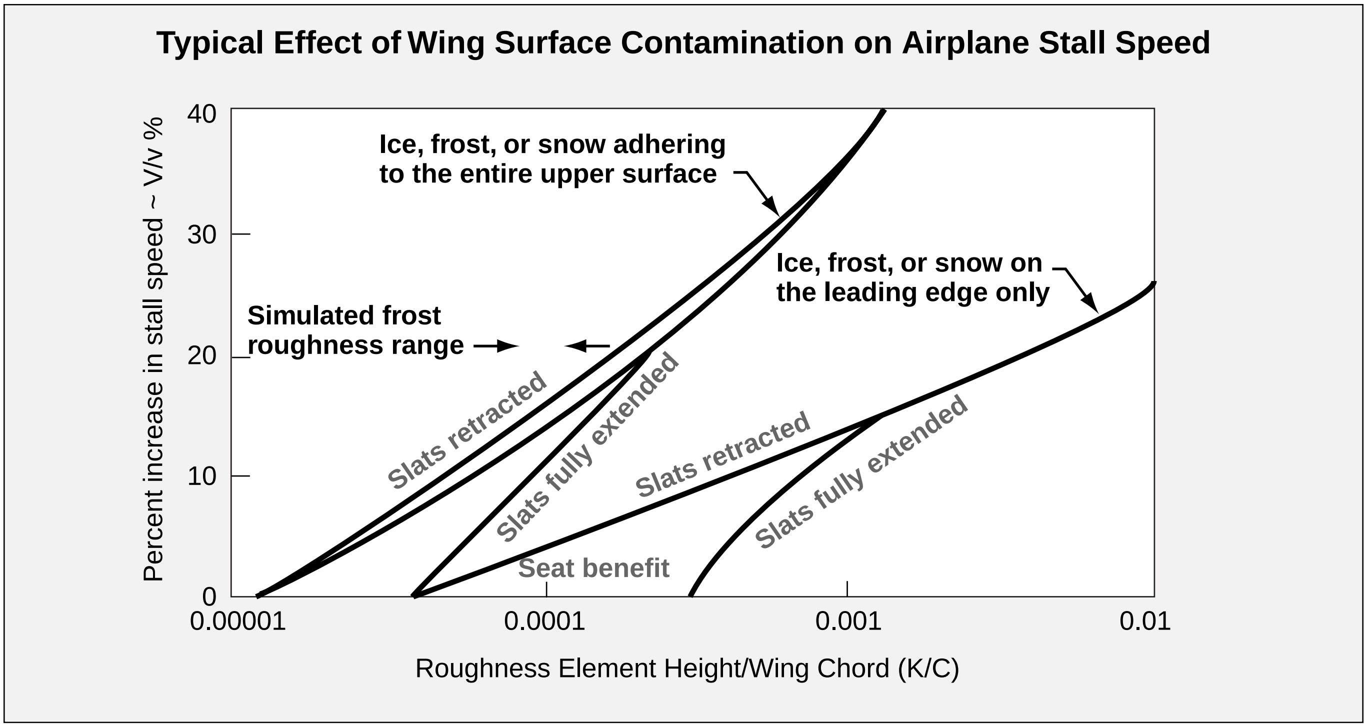

Figure 2

- Heated solutions of FPD, water, or both are more effective in the deicing process than unheated solutions because thermal energy is used to melt the ice, snow, or frost formations.

- Unheated FPD fluids or aqueous solutions, especially AEA, SAE and ISO Type II, are generally more effective in the anti-icing process because the final fluid film thickness is greater.

- Anti-icing should be performed as near to the takeoff time as possible to minimize the risk of exceeding the useful life or time of effectiveness of the anti-icing fluid.

- The freezing point of the final anti-icing coating should be as low as possible. The recommended minimum ambient temperature vs. freeze point buffers are shown below:

Fluid Type	OAT Range	Buffer
AEA, SAE and ISO Type I	All	18° F
AEA, SAE and ISO Type II	above 19° F	5° F
AEA, SAE and ISO Type II	below 19° F	13° F

OAT = Outside Air Temperature

Warning: *Some Deicing/Anti-Icing fluids may not be approved for use on certain aircraft. Your aircraft should not be deiced or anti-iced with fluids or procedures not approved for use on your aircraft type. AEA/SAE/ISO Type I fluids should not be used in the concentrate form. They shall be diluted with water before use in accordance with manufacturer's instructions.*

- Undiluted SAE and ISO Type II fluids contain no less than 50 percent glycols and have a freeze point of -32°C (-25.6°F) minimum. Diluted solutions have higher (warmer temperature) freeze points.

- SAE and ISO Type II fluids have a longer time of effectiveness than conventional North American or SAE and ISO Type I fluids.

- A post-deicing/anti-icing check should be performed during or immediately following the ground deicing and anti-icing process.

- Flight tests performed by manufacturers of large transport category aircraft have shown that most SAE and ISO Type II fluid flows off lifting surfaces by rotation speeds (V_R) on the order of 85 knots or greater. Most fluid remaining dissipates during 2nd segment climb. Some large aircraft experience performance degradation due to fluid residue and may require weight or other takeoff compensation. *Degradation of takeoff and climb performance, induced by Type II fluids, may be significant on smaller airplanes.*

- Flight tests with some small and large airplanes have indicated that the test pilot does not usually notice FPD fluid induced changes in performance (lift-off speed, lift-off deck angle, best angle of climb, best climb rate) and flight characteristics (stall margin, control margins, and stability margins) even though these changes have occurred and could be dangerous.

- Propwash from operating propellers can cause rapid degradation (blowoff) of FPD; e.g., SAE Type II fluids on wing and other surfaces within the slipstream.

- Some fluid residue may remain throughout the flight in aerodynamically quiet areas. The aircraft manufacturer should have determined that this residue (in aerodynamically quiet areas) will have no significant adverse effect on aircraft performance, handling qualities, or component operation. However, this residue should be cleaned periodically.

- Windshield wipers *may alone be a good indication* that the aircraft is clean. However, if windshield wipers are iced, it might indicate that other critical aircraft components are no longer clean and are also contaminated.

- Deicing procedures and equipment developed for large transport airplanes may not be appropriate for some smaller aircraft.

- Conditions that are conducive to aircraft icing during ground operations include:

  – Precipitation in the form of snow, freezing rain drizzle, sleet, and hail.

  – High relative humidity and low aircraft skin temperature.

  – Blowing or recirculated snow, other ice crystals or water droplets.

  – Splashing of water or slush.

- Certain conditions can cause ice to remain on the aircraft even though ground conditions, other than ambient temperature, are not conducive to ground icing. All residual frozen contamination must be removed prior to subsequent takeoff.

  – Residual ice formations may remain on leading edges of wings and other surfaces following flight operations in airborne icing conditions. The aircraft should always be inspected for residual ice formations and these ice formations must be removed (properly deiced) prior to departure.

  – Pneumatic boots, commonly used on small airplanes of the type used in many FAR 135 operations, may retain some residual ice on leading edge boots and aft of the boots during and following flight in icing conditions.

Cold Weather Preflight Inspection Procedures

- Pilot preflight inspection/cold weather preflight inspection procedures. This is the normal walk-around preflight inspection conducted by a pilot. This inspection should be used to note any aircraft surface contamination and initiate any required deicing/anti-icing operations.

- A thorough preflight inspection is more important in temperature extremes because those temperature extremes may affect the aircraft or its performance. At extremely low temperatures, the urge to hurry the preflight of the aircraft is natural, particularly when the aircraft is outside and adverse weather conditions exists, which make the preflight physically uncomfortable for the pilots. This is the very time to perform the most thorough preflight inspection.

- Aircraft areas that require special attention during a preflight during cold weather operations depend on the aircraft design and should be identified in the certificate holder's training program. The preflight should include, at a minimum, all items recommended by the aircraft manufacturer. A preflight should include items appropriate to the specific aircraft type. Generally, those items may include:

  – Wing leading edges, upper and lower surfaces.

  – Vertical and horizontal stabilizing devices, leading edges, upper surfaces, lower surfaces, and side panels.

  – Lift/drag devices such as trailing edge flaps.

  – Spoilers and speed brakes.

  – All control surfaces and control balance bays.

  – Propellers.

  – Engine inlets, particle separators, and screens.

  – Windshields and other windows necessary for visibility.

  – Antennas.

  – Fuselage.

  – Exposed instrumentation devices such as angle-of-attack vanes, pitot-static pressure probes, and static ports.

  – Fuel tank and fuel cap vents.

  – Cooling and auxiliary power unit (APU) air intakes, and exhausts.

  – Landing gear.

- Blowing Snow. If an aircraft is exposed to blowing snow, special attention should be given to openings in the aircraft where snow can enter, freeze, and obstruct normal operations. The following openings should be free of snow and ice before flight:

  – Pitot tubes and static system sensing ports.

  – Wheel wells.

  – Heater intakes.

  – Engine air intakes and carburetor intakes.

  – Elevator and rudder controls.

  – Fuel vents.

Post-deicing/Anti-icing Checks

Post-deicing/anti-icing checks should be performed as part of the deicing and anti-icing process. Generally, the following items should be checked, as applicable to the aircraft type and recommended by the manufacturer.

- Wing leading edges, upper surfaces, and lower surfaces;
- Vertical and horizontal stabilizing devices, leading edges, upper surfaces, lower surfaces, and side panels;
- High-lift devices such as leading-edge slats and leading or trailing-edge flaps;
- Propellers;
- Spoilers and speed brakes;
- All control surfaces and control balance bays;
- Engine inlets, particle separators, and screens;
- Windshields and other windows necessary for flight crew visibility;
- Antennas;
- Fuselage;
- Exposed instrumentation devices such as angle-of-attack vanes, pitot-static pressure probes, static ports, and temperature probes;
- Fuel tank and fuel cap vents;
- Cooling and auxiliary power unit (APU) air intakes, inlets, and exhausts; and
- Landing gear.

Pretakeoff Contamination Checks

FAR Parts 135 and 125 require that a pretakeoff contamination check be completed within 5 minutes prior to beginning takeoff.

A pretakeoff contamination check is a check to make sure the wings and control surfaces are free of frost, ice, or snow.

Procedures for conducting this aircraft type specific check must be approved by the certificate holder's principal operations inspector (POI) and referenced or described in the certificate holder's operations specifications.

Caution: *Under extreme weather or operational conditions contamination can occur in less than 5 minutes.*

The components that can be checked vary by aircraft type and design. In some aircraft, the entire wing and portions of the empennage are visible from the cockpit or the cabin. In other aircraft, these surfaces are positioned such that only portions of the upper surface or lower surface of the wings are in view. Undersurfaces of wings and the undercarriage are viewable only from high-wing-type aircraft. A practice in use by some operators is to perform a visual inspection or check of wing surfaces, leading edges, engine inlets, and other components of the aircraft that are in view from either the cockpit or cabin, whichever provides the maximum visibility. The PIC may require the assistance of trained and qualified ground personnel to conduct the pretakeoff contamination check.

If any aircraft surfaces have not been treated with FPD fluid, the PIC or another trained crewmember should look for, and examine any evidence of, melting snow and possible freezing. If the aircraft has been treated with FPD fluids, aircraft surfaces should appear glossy, smooth, and wet. If these checks indicate accumulations of ice, snow, or frost, or ice formation that may have been induced by taxi operations, the aircraft should be re-deiced/anti-iced.

Types of Deicing and Anti-icing Equipment and Facilities

General. Manual methods of deicing provide a capability, in clear weather, to clean an aircraft adequately to allow a safe takeoff and flight. In inclement, cold weather conditions, however, the only alternative is sometimes limited to placing the aircraft in a protected area such as a hangar to perform the cleaning process by available means. A common practice developed is to clean the aircraft in the hangar and provide a protective coating of FPD fluid (anti-icing) to protect the aircraft from ice or snow accumulation for a limited period of time prior to takeoff. Most modern airports have traffic conditions and limitations of hangar space that, for the most part, preclude indoor ground deicing. These airports usually have one or more fixed base operators who have the equipment, capability, and experience to clean the aircraft and provide brief protection to allow a safe takeoff to be performed. Many airlines have repositioned ground deicing equipment for ramp deicing at major airports where icing conditions are prevalent in the United States, Canada, and European countries. Some airports or operators have installed permanently stationed equipment at central locations where aircraft can be deiced and anti-iced. Discussions of these types of facilities are contained in AC 20-117 and AC 150/5300-14.

Warm Hangars. Early methods employed the use of hangars to avoid exposure to the elements or to provide a place for warming the aircraft and melting ice, frost, and snow formations prior to departure. This method generally requires that all moisture that could freeze is either removed or the aircraft is also treated with FPD fluid to preclude freezing upon removal of the aircraft from the warm hangar into below freezing ambient conditions. Some operators use warm hangars for the complete deicing and anti-icing process with fluids.

Wing and Other Covers. The use of wing covers and covers for other critical components such as windshields, engine air intakes, pitot probes, etc., are useful to lessen the extent of manual work or deicing fluid required to remove frost, snow, or other ice formations from the aircraft.

Mechanical Methods. Various devices such as brooms, brushes, ropes, squeegees, fire hoses, or other devices; have been used to remove dry snow accumulations, to remove the bulk of large wet snow deposits, or to polish frost to a smooth surface. These manual methods require that caution be exercised to preclude damage to aircraft skins and other critical components.

Deicing and Anti-icing Fluids. These fluids are used for quickly removing frost and to prevent or retard ice formation during overnight storage. In addition, they are used to assist in melting and removal of snow or other ice formations such as would develop as a result of freezing rain or drizzle, and for assisting in the removal of ice or frost formations accumulated during a previous flight.

Deicing/Anti-icing Equipment Commonly Used for Small Airplanes

Portable Spray Equipment and Dispensers. Various methods of applying FPD fluids have been utilized in the past, such as use of portable, pressurized containers with spray wands, mopping the fluid on the surface requiring treatment from a bucket, use of hand pumps attached to a supply tank and spreading the solution with a mop, brush or other suitable devices to, in time, melt the ice to the extent that it can be removed by manual means.

Mobile Deicing and Anti-icing Equipment. Several manufacturers of various types of aircraft ground deicing equipment exist today to meet the ground support equipment demands of the aviation community. These ground support equipments vary in types from simple trailers hauling a 55 gallon drum of FPD fluid with a wobble pump and mop to sophisticated equipment capable of heating and dispensing large quantities of water and deicing fluid and capable of elevating deicing personnel to heights necessary to have access to any area of the largest of today's aircraft. Some of this equipment may not be compatible for use on small airplanes because of the very high pressures and very high temperatures used in the deicing process for large airplanes.

Central and remote deicing. Deicing and anti-icing near the departure end of the runway has obvious advantages, some of which are highlighted as follows:

- Provides a place for conducting pretakeoff contamination checks.
- Reduces the time between deicing/anti-icing and takeoff.

This practice is encouraged where adequate facilities exist and if performed by trained and qualified personnel.

Deicing and Anti-icing Fluids

Common practice, developed by the North American and European aviation communities over many years of experience, is to deice and anti-ice an aircraft before takeoff. Various techniques of ground deicing and anti-icing have been developed. The most common of these techniques is to use FPD fluids in the ground deicing process and to anti-ice with a protective film of FPD fluid to delay the reforming of ice, snow, or frost. Commercially available FPD fluids used for aircraft deicing are ethylene glycol or propylene glycol based. The general characteristics of these fluids are described in Table 1.

The basic philosophy of using FPD fluids for aircraft deicing is to decrease the freezing point of water in either the liquid or crystal (ice) phase. FPD fluids are highly soluble in water; however, ice is slow to absorb FPD or to melt when in contact with it. If frost, ice, or snow is adhering to an aircraft surface, the formation may be melted by repeated application of proper quantities of FPD fluid. This process can be significantly accelerated by thermal energy from heated fluids. As the ice melts, the FPD mixes with the water thereby diluting the FPD. As dilution occurs, the resulting mixture may begin to run off. If all the ice is not melted, additional applications of FPD become necessary until the fluid penetrates to the aircraft surface. When all ice has melted, the remaining liquid residue is a mixture of water and FPD. The resulting film could freeze (begin to crystallize) with only a slight temperature decrease.

Traditional North American Fluids. As shown in Table 1, there are various types of FPD's available. These fluids are produced by chemical manufacturers in North America and Europe. The FPD's used to deice aircraft in North America are usually composed of ethylene or propylene glycol combined with water and other ingredients. Users can purchase this deicing fluid in a concentrated form (80 percent-90 percent glycol) or in a solution that is approximately 50 percent glycol with 50 percent water by volume.

ISO Commercial Fluids. These fluids were originally known as AEA Type I and Type II. Specifications for these two types of FPD's are provided in the ISO guidelines as ISO 11075, "Aircraft deicing/anti-icing Newtonian fluids ISO Type I" and ISO 11078, "Aircraft deicing/anti-icing non-Newtonian fluids ISO Type II."

SAE Commercial Fluids. SAE Type I and Type II fluids are very similar in all respects to ISO Type I and Type II fluids. The minor differences will not be presented in this AC. These FPD's, specified by the SAE and ISO as Type I and Type II, are distinguished by material requirement, freezing point, rheological properties (viscosity and plasticity), and anti-icing performance.

SAE and ISO Type I Fluids. These fluids in the concentrated form contain a minimum of 80 percent glycols and are considered "unthickened" because of their relatively low viscosity. These fluids are used heated and diluted for deicing or anti-icing, but provide very limited anti-icing protection.

Table 1
General Characteristics of Commercially Available FPD's

Common Name	Primary Active Ingredients	Viscosity	Primary Use	Notes
Traditional North American	Ethylene, propylene, diethylene glycols and/or isopropyl alcohol	Low	Deicing	Includes *SAE AMS1425, SAE AMS 1427, AF 3609, Mil-A-4823, other pre-1993 Mil-Spec fluids and other commercially available fluids.
AEA Type I SAE Type I (AMS 1424) ISO Type I	Propylene and/or diethylene glycol	Low	Deicing	Propylene glycol based fluids not to be used undiluted at OAT < 14° F (10°C). Aircraft performance changes may result.
AEA Type II SAE Type II (AMS 1424) ISO Type II	Propylene and/or diethylene glycol and polymer thickeners	Low High	Deicing and anti-icing	For use on aircraft with V_R > 85 knots. Lower viscosity than AEA Type II produced before 1988.
Old Mil Type I New Mill Type I	Ethylene, propylene glycol Propylene glycol base	Low Medium	Deicing	No fire inhibitor. May not conform to SAE Type I Spec. See AC 20-117 for more detail.
Old Mil Type II New Mil Type II	Ethylene and propylene glycol	Low	Deicing	With fire inhibitor. Does not conform to SAE Type I Spec. See AC 20-117 for more detail.
Arktika Arktika 2000	Ethylene glycol and thickeners	Low High	Deicing Anti-icing	Not currently approved as AEA, SAE or ISO Type I or Type II. Effects on aerodynamics unknown. Prevalent in Russia.

* Beginning with the 1993–1994 winter season, North American manufacturers intend to no longer produce AMS 1425 and AMS 1427 in favor of the new AMS 1424.

SAE and ISO Type II Fluids. These fluids contain a minimum of 50 percent glycols and are considered "thickened" because of added thickening agents that enable the fluid to be deposited in a thicker film and to remain on the aircraft surfaces until the time of takeoff. These fluids are used for deicing and anti-icing, and provide greater protection than do Type I fluids against ice, frost, or snow formation in conditions conducive to aircraft icing on the ground.

SAE and ISO Type II fluids are designed for use on aircraft with V_R *greater than 85 knots*. As with any deicing or anti-icing fluid, SAE and ISO Type II fluids should not be applied unless the aircraft manufacturer has approved their use regardless of rotation speed. SAE and ISO Type II fluids are effective anti-icers because of their high viscosity and pseudoplastic behavior. They are designed to remain on the wings of an aircraft during ground operations or short term storage, thereby providing some anti-icing protection, but to readily flow off the wings during takeoff. When these fluids are subjected to shear stress, such as that experienced during a takeoff run, their viscosity decreases drastically, allowing the fluids to flow off the wings and causing little adverse effect on the aircraft's aerodynamic performance.

The anti-icing effectiveness of SAE and ISO Type II fluids is dependent upon the pseudoplastic behavior which can be altered by improper deicing/anti-icing equipment or handling. Some of the North American airlines have updated deicing and anti-icing equipment, fluid storage facilities, deicing and anti-icing procedures, quality control procedures, and training programs to accommodate the distinct characteristics of SAE and ISO Type II fluids. Testing indicates that SAE and ISO Type II fluids, if applied with improper equipment, may lose 20 percent to 60 percent of anti-icing performance.

SAE and ISO Type II fluids have been in the process of introduction in North America since 1985. Widespread use of SAE and ISO Type II fluids began to occur in 1990. Similar fluids, but with slight differences in characteristics, have been developed, introduced, and used in Canada.

Military Deicing Fluids. The U.S. Department of Defense has issued military specifications, "Anti-icing and Deicing-Defrosting Fluids." These documents specify the following types of FPD's:

- MIL-A-4823C Type I — standard
- MIL-A-4823C Type II — standard with inhibitor
- MIL-A-4823D Type I — (propylene glycol base)
- MIL-A-4823D Type II — (ethylene and propylene glycol mix)

Military Types I and II fluids are essentially the same, except that Military Type II fluids contain a fire inhibitor. *Military Types I and II fluids are unrelated to SAE and ISO Types I and II fluids*.

SAE Type III Fluids. Specifications for fluids for use on small aircraft which would last longer but yet would have minimal aerodynamic effect, are being developed. These fluids are referred to as Type III fluids. Fluids of this type have been developed and used to a limited extent, in large airplane operations, and have generally been referred to as Type I 1/ 2 fluids as they possess characteristics in between Type I and Type II; i.e., last longer than Type I with less aerodynamic effect than Type II.

Use of Antifreeze and Unapproved Fluids. Use FPD fluids that are approved for use by the aircraft manufacturer. Some fluids may not be compatible with aircraft materials and finishes and some may have characteristics that impair aircraft performance and flight characteristics or cause control surface instabilities. Use of automotive anti-freeze is NOT approved. Its time of effectiveness (holdover time) and its effects on aircraft aerodynamic performance is generally unknown.

Characteristics of FPD Fluids

Chemical Composition of FPD Fluids. Commercially available FPD fluids are of the ethylene glycol, diethylene glycol, or propylene glycol family. The exact formulas of various manufacturers' fluids are proprietary. It is important to understand that some commercially available FPD fluids contain one or more of these glycols plus small quantities of additives and water. Various FPD manufacturers, upon request, will premix aqueous solutions of FPD for specific customer reasons. Before using a solution of FPD, it is imperative that the ingredients be checked by close examination of the stock number and by a quality control examination to ascertain that the fluid supply conforms to the user need. FPD fluid manufacturers can supply methodology and suggest equipment needed for quality control examinations. It is desirable that the pilot understand the criticality of effective quality control.

Freezing Characteristics of FPD Fluids. Before a fluid is used on an aircraft, it is crucial that the user knows and understands its freezing characteristics. These characteristics can be determined through understanding of the fluid procurement specifications and tolerances and through quality control inspections. FPD fluids are either premixed (diluted with water) by the manufacturer or mixed by the user from bulk supplies. To ensure known freezing characteristics, samples of the final mixture should be analyzed before use.

FPD Fluid Strength When Applied. Fluid strength or the ratio of FPD ingredients, such as glycol, to water should be known if proper precautions, such as those outlined above, are taken before application. It is crucial to realize that fluid strength is a significant factor in deicing and anti-icing properties. Fluid strength affects the time that the FPD fluid may remain effective (holdover time). …

Do not use pure (100 percent) ethylene glycol or pure propylene glycol fluids in nonprecipitation conditions. The reasons for this caution are explained below.

- The freezing point of pure ethylene glycol is much higher than when diluted with water. Slight temperature decreases can be induced by factors such as cold-soaked fuel in integral tanks, reduction of solar radiation by clouds obscuring the sun, ambient temperature cooling, wind effects, and lowered temperature during development of wing lift. If the freezing point of the remaining film is found to be insufficient, the deicing/anti-icing procedure should be repeated before the aircraft is released for flight.

- Full strength (undiluted) propylene glycol, having a strength of about 88 percent glycol at temperatures less than -10°C (+14°F), is quite viscous. In this form, propylene glycol based fluids have been found to produce lift reductions of about 20 percent. Propylene glycol FPD fluids are not intended to be used in the undiluted state.

Temperature Buffer

American Practice. The practice developed and accepted by the North American air carrier industry using traditional North American fluids is to ensure that the remaining film has a freeze point of at least 20°F below (lower than) ambient temperature.

European and Canadian Practice. The practice developed by the European air carrier industry has been to ensure that the freezing point of residual SAE and ISO Type I fluids is at least 10°C (18°F) below ambient temperature. This is similar to the North American practice, except for metric conversion differences. For SAE and ISO Type II fluids, the freeze temperature should be at least 7°C (13°F) below ambient temperature. This temperature difference between SAE and ISO Type I and SAE and ISO Type II FPD fluids is primarily to accommodate differences in fluid dilution rates which occur in freezing precipitation. Type II fluids, which are thicker, will not dilute to the same extent in a given period of time.

Current FAA Recommendations. Generally the holdover time is increased with an expansion of the temperature buffer. Therefore, if the choice is available, use the maximum buffers. Greater buffers require the use of more glycol, which is more costly and which increases the burden for collection and processing of FPD spillage and runoff. FPD fluid mixtures and their attendant buffers should be determined after consideration of the following factors in the listed order of priority.

- Safety

- Availability

- Environmental impact

- Cost

For traditional North American and AEA, SAE and ISO Type I Fluids, the freeze point buffer of the anti-icing fluid should be as great as possible but not less than 10°C (18°F).

For AEA, SAE and ISO Type II Fluids, the freeze point buffer should not be less than those recommended by the SAE and ISO which is currently 7°C (13°F) at ambient temperatures below -7°C (19°F) and 3°C (5°F) at ambient temperatures above -7°C (19°F).

AC 20-117 Recommendation

The FAA's recommendation, published in AC 20-117 is to ensure that the fluid freeze point is at least 20°F (11°C) below the colder of the ambient or aircraft surface (skin) temperature. The reasons for this differential are to delay refreezing of the anti-icing fluid and to take into consideration such factors as:

- *Temperature reduction* during climb or in the production of aerodynamic forces, and the possibility that residual fluids (on surfaces, in balance bays, etc.) will freeze at altitude;

- *Freezing potential* in conditions conducive to icing. As freezing precipitation or moisture from any source contacts and is absorbed by the residual anti-icing fluid, the freeze point is increased. A greater temperature buffer provides a longer holdover time due to this effect; and

- *Quality control* margin for error.

Holdover Times

Holdover Time. For Part 135 operators that do not have an approved deicing/anti-icing program (under Section 135.227(b)(3)), which complies with Section 121.629(c), the use of holdover timetables is for use in departure planning only. The use of holdover times for these Part 135 operators does not relieve the pilot from conducting a pretakeoff contamination check. For Part 135 operators that have an approved deicing/anti-icing program (under Section 135.227(b)(3)), they must follow the appropriate Part 121 procedures.

Holdover time is the estimated time deicing/anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the protected surfaces of an aircraft.

Holdover time begins when the final application of deicing/anti-icing fluid commences and expires when the deicing/anti-icing fluid applied to the aircraft loses its effectiveness.

Holdover time tables are based on fluid type, fluid concentration, outside air temperature (OAT) and various weather conditions, e.g., frost, freezing fog, snow, freezing rain. SAE/ISO holdover tables and how they are used are explained in Appendix A.

Many other variables may affect holdover times, some of these include:

- Aircraft surface (skin) temperature;
- Operation in close proximity to other aircraft, equipment, and structures;
- Operation on snow, slush, or wet ramps, taxiways, and runways;
- Precipitation rate;
- Relative humidity;
- Wind velocity and direction.

Deicing and Anti-icing Procedures

Depending on the type of accumulation on the surfaces and components of the aircraft and the type of aircraft, operational procedures employed in aircraft ground deicing and anti-icing vary.

Ground deicing and anti-icing procedures vary depending primarily on aircraft type, type of ice accumulations on the aircraft, and FPD fluid type. *All pilots should become familiar with the procedures recommended by the aircraft manufacturer* in the Aircraft Flight Manual (AFM) or the maintenance manual and, where appropriate, the aircraft service manual.

The general procedures used by aircraft operators are similar and are based on the procedures recommended by the aircraft manufacturer, which, in turn, may be based upon procedures recommended by the fluid manufacturer, engine manufacturer, the SAE, ISO, AEA, and other standardization organizations.

Caution: *If improperly used, some deicing/anti-icing fluids can cause undesirable and potentially dangerous changes in aircraft performance, stability, and control. In addition, the fluid may not remain effective for the expected time*.

Ice, snow, frost, and slush should be removed before takeoff. Any frozen contamination may be removed by placing the aircraft in a heated hangar or by other normal deicing procedures.

Frost, including underwing frost in the vicinity of integral fuel tanks should be removed before takeoff. On some small aircraft frost formations may be polished smooth. Underwing frost may be allowed on some aircraft if the aircraft manufacturer has underwing data accepted by the FAA Aircraft Certification Office showing that the aircraft can be operated safely under such conditions.

Dry, powdery snow can be removed by sweeping with an appropriate brush or broom or by blowing *cold* air or nitrogen gas or other inert gasses across the aircraft surface. Heavy, wet snow can be removed by mechanical means such as squeegees and brooms, by using heated water, solutions of heated water and deicing/anti-icing fluids, or a combination of these techniques.

Any frozen contamination may be removed by placing the aircraft in a heated hangar or by other normal deicing procedures.

Deicing and Anti-icing Aircraft with Fluids

An aircraft must be systematically deiced and anti-iced in weather conditions conducive to icing. The specific deicing method and procedure used depends upon the aircraft type, available equipment, and the deicing/anti-icing fluids available. Aircraft operating under FAR 135 and other small airplanes may not be permitted to use or have available some of the modern deicing/anti-icing fluids. Each aircraft surface requires a specific technique to achieve a clean aircraft.

The wings are the main lifting surfaces of the aircraft and must be free of contaminants to operate efficiently. An accumulation of upperwing frost, snow, or ice changes the airflow characteristics over the wing, reduces its lifting capabilities, increases drag, increases stall speed, and changes pitching moments. The weight increase is slight, and weight effects are secondary to the effects of surface roughness.

On most aircraft, deicing of the wing should begin at the leading edge wing tip, sweeping in the aft and inboard direction. This process avoids increasing the snowload on outboard wing sections, which under some very heavy snow conditions could produce excessive wing stresses. This method also (for most aircraft) reduces the possibility of flushing ice or snow deposits into conventional balance bays and cavities.

If ice accumulation is present in areas such as flap tracks and control cavities, it may be necessary to spray from the trailing edge forward. Also, under some weather (wind) or ramp conditions, it may be necessary to spray from the trailing edge.

Propellers should be thoroughly deiced in the static mode assuring that all blades are uniformly clean.

The extendible surfaces of the wing (i.e., leading-edge flaps or slats and trailing-edge flaps) should be retracted to avoid accumulating frost, snow, or ice during time at the gate or in overnight storage. A surface that is extended in weather conditions requiring deicing and anti-icing should be visually inspected to ensure that the surface, tracks, hinges, seals, and actuators are free of any contaminants before retraction. Flaps and slats retracted during anti-icing will not receive a protective film of FPD fluid and may freeze in precipitation or frost conditions. Consult the AFM, AOM, or Maintenance Manual for recommended procedures to determine the most appropriate slat and flap management procedures.

Tail surfaces require the same caution afforded the wing during the deicing procedure. The balance bay area between moveable and stationary tail surfaces and areas adjacent to balance horns should be closely inspected. For some aircraft, positioning the horizontal stabilizer in the leading-edge-down position allows the FPD fluid and contaminants to run off rather than into balance bays. For some aircraft, the horizontal stabilizer must be in the leading-edge-up position during deicing. Some aircraft, with fixed or movable horizontal stabilizer, may require the elevator to be in a preset position.

Balance bays, control cavities, and gap seals should be inspected to ensure cleanliness and proper drainage. When contaminants do collect in the surface juncture, they must be removed to prevent the seals from freezing and impeding the movement of the control surface.

The fuselage should be deiced and anti-iced from the top down. Clearing the top of the fuselage manually instead of by spraying also requires that personnel use caution not to damage protruding equipment (e.g., antennas) while deicing. Spraying the upper section with heated FPD fluid first allows the fluid to flow down, warming the sides of the fuselage and removing accumulations. This is also effective when deicing the windows and windshield of the aircraft, since direct spraying of the surfaces can cause thermal shock resulting in cracking or crazing of the windows. The FPD fluid must be removed from the flight crew’s windows to maintain optimal visibility.

Deicing the top of the fuselage is especially important on aircraft with aft-mounted centerline and aft-side fuselage mounted engines. The ingestion of ice or snow into a turbine engine may result in compressor stalls or damage to the engine.

The nose of the aircraft (radome area on some aircraft) should be deiced to eliminate snow or ice accumulations from being projected into the crew’s field of vision during takeoff. This area may also contain navigation and guidance equipment; and if so, it must be cleared of accumulations to ensure proper operation of these sensors.

Also, special precautions are necessary to ensure that residual fluids do not enter sensitive instrumentation or flow over the cockpit windows during taxi or takeoff.

Cargo and passenger doors must also be deiced and anti-iced in order to ensure proper operation. All hinges, tracks, and seals should be inspected to ensure that they are free of contamination. Frozen contamination may also cause damage and leakage on cargo and passenger door seals.

Sensor orifices and probes along the fuselage require caution during the application of FPD fluid. Direct spraying into these openings and resulting fluid residue can result in faulty instrument readings. Also, when protective covers used during applications are not removed, faulty instrument readings can result.

In the use of heated water alone, care must be taken to assure that water freezing does not reoccur or that water does not collect in pockets, such as control balance bays, control seals, etc. where refreezing might occur. Use of water alone for deicing is generally limited to temperatures above 27°F (-3°C) and where the water is heated (to facilitate deicing and evaporation) to about 140°F, followed by very close inspection to assure that refreezing does not occur.

A number of deicing/anti-icing fluids are available for use on commercial large transport category aircraft and some small aircraft, typically used in FAR 135 operations, if approved for use by the aircraft manufacturer. The FPD’s used most often in the past were glycol-based fluids produced by a number of North American, European, and Russian chemical manufacturers. Most common fluids in use today conform to SAE or ISO specifications. … In any case, the procedures for deicing and anti-icing your aircraft must conform to the procedures developed for your aircraft and contained in your operations manual and other documentation.

Heating of deicing/anti-icing fluids increases their deicing effectiveness; however, in the anti-icing process, unheated fluids are generally more effective. SAE and ISO Type II fluids are more effective (last longer) in providing anti-icing protection than traditional North American fluids and SAE and ISO Type I fluids. (See section entitled “Deicing and Anti-icing Fluids” for more complete description of fluid types.)

Deicing and anti-icing with fluids may be performed as a one-step or two-step process, depending on predetermined practices, prevailing weather conditions, concentration of FPD used, and available deicing equipment and facilities.

The one-step procedure is accomplished using a heated 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 deicing process. A technique used commonly in the past is to spray on a final coat of deicing fluid using a very fine mist, applied in an arched trajectory so as to cool the fluid before contact. With most fluids this produces a thicker fluid film which will have slightly enhanced anti-icing effectiveness. Using this procedure caution must be exercised to assure that the deicing fluid has not begun to crystallize before application of the final overspray.

The two-step procedure involves separate deicing and anti-icing steps. Deicing is accomplished with hot water or a hot mixture of FPD and water. The ambient weather conditions and the type of accumulation to be removed from the aircraft must be considered when determining which deicing fluid to use. …

Only fluids approved for use on your aircraft should be used.

The second (anti-icing) step involves applying SAE or ISO Type II (if approved for use) or a richer mixture (but never the full, undiluted concentrate) of the deicing fluid, preferably unheated, to the critical surfaces of the aircraft.

Caution: *Exercise caution when using the two-step technique to ensure that freezing has not occurred within the fluid previously applied*.

When heated water alone is used in the deicing process, the second step must be performed before refreezing occurs — generally within 3 minutes after the beginning of the first (deicing) step. If necessary, the process is conducted area-by-area.

Caution: *SAE and ISO Type II fluids are designed for use on aircraft with rotation speeds (VR) in excess of 85 knots and therefore may not be usable on many small aircraft operating under FAR 135 and other rules. As with any deicing or anti-icing fluid, AEA, SAE, or ISO Type II fluid should not be used unless the aircraft manufacturer has approved its use*.

Under no circumstances should AEA, SAE or ISO Type II fluids, in the concentrated (neat) form, be applied to the following areas of an aircraft:

- Pitot heads and angle-of-attack sensors;
- Control surface cavities;
- Cockpit windows and nose of fuselage;
- Lower portion of fuselage underneath nose (on radome of some aircraft);
- Static ports;
- Air inlets; and
- Engines.

Some of these areas can be deiced and anti-iced using a diluted traditional North American or SAE Type I fluid however care should always be exercised to assure that neither FPD fluid nor water enter pilot or static ports. Aircraft and engine manufacturer recommended procedures should be strictly followed when deicing/anti-icing these areas. Some aircraft manufacturers require that protective covers be used during the deicing process.

Caution: *Protective covers not removed following deicing have caused accidents in the past. Post deicing and pretakeoff inspections and checks must include checks to ensure that covers have been properly removed and stowed.*

… FPD freezing points can be determined by using a refractometer or similar devices and methods.

Deicing the Engine Area

Minimal amounts of FPD fluid should be used to deice the engine area and APU. FPD fluids ingested in the APU (if installed) can cause smoke and vapors to enter the cabin. Engine air intake areas should be inspected for the presence of ice immediately after shutdown. Any accumulation should be removed while the engine is cooling and before installation of plugs and covers. Any accumulation of water must be removed to prevent the compressor from freezing. A light coating of deicing fluid applied to the plug may prevent the plugs from freezing to the nacelle.

Fluid residue on engine fan or compressor blades can reduce engine performance or cause stall or surge. In addition, this could increase the possibility of, or the quantity of, glycol vapors entering the aircraft through the engine bleed air system.

Most turbojet and turboprop engine manufacturers recommend, and some AFM's require, that thrust levers be periodically advanced to an N1 rpm of 70 percent to 80 percent during ground operations. This practice is intended to prevent ice buildup that can result in reduced thrust, dynamic imbalance of the fan or compressor, or excessive induction of shed ice. The pilot must be aware of these operating procedures and should comply with procedures established for the aircraft.

Note: On turboprop aircraft approved for use of and using SAE Type II fluids specific procedures must be followed to prevent blowoff of FPD fluid during high engine operating speeds prior to takeoff. In most operations this can be done by operation with the propellers disking (flat pitch) for engine runups and by performing taxi operations with minimum thrust and acceleration. Use of reverse thrust is also discouraged since this may cause contamination of the FPD fluid.

Health Effects

Pilots must be aware of the potential health effects of deicing and anti-icing fluids in order to ensure that proper precautions are taken during the deicing and anti-icing process and to better ensure the well-being of passengers and flightcrew. Passengers and crew should be shielded from all FPD fluid vapors by turning off all cabin air intakes during the deicing and anti-icing process. Exposure to vapors or aerosols of any FPD fluid may cause transitory irritation of the eyes. Exposure to ethylene glycol vapors in a poorly ventilated area may cause nose and throat irritations, headaches, nausea, vomiting, and dizziness.

All glycols cause some irritation upon contact with the eyes or the skin. Although the irritation is described as "negligible," chemical manufacturers recommend avoiding skin contact with FPD and wearing protective clothing when performing normal deicing operations.

Ethylene and diethylene glycol are moderately toxic for humans. Swallowing small amounts of ethylene or diethylene glycol may cause abdominal discomfort and pain, dizziness, and effects on the central nervous system and kidneys. Because the glycol contained in FPD fluids is considerably diluted with water and other additives, it is highly unlikely that deicing personnel would ingest anything close to a lethal amount (3 to 4 ounces of pure glycol). Detailed information on health effects and proper safety precautions for any commercial FPD fluid is contained in the material safety data sheet for that fluid which is available from the fluid manufacturer and should be on file with the operator providing the deicing or anti-icing service.♦

Appendix A
Application Guidelines Tables

FSF editorial note: Holdover time tables have been omitted in this report because the tables are no longer current. See current holdover time tables based on data from the Society of Automotive Engineers (SAE), the International Standards Organization (ISO), the Association of European Airlines (AEA), the relevant flight operations manual and/or the appropriate civil aviation authority.

Temporary Guidance Leaflet No. 4

Joint Aviation Authorities (JAA)

FSF editorial note: See current holdover time tables based on data from the Society of Automotive Engineers (SAE), the International Standards Organization (ISO), the Association of European Airlines (AEA), the relevant flight operations manual and/or the appropriate civil aviation authority.

The material contained in this leaflet has been issued in accordance with Chapter 10 of Administrative and Guidance Material, Section Four: Operations, Part Two: Procedures (Joint Aviation Requirements Operations [JAR OPS]). It was decided that the text (which reflects changes to the NPA-OPS-7 text by the Operational Procedures Study Group, following consideration of the Notice of Proposed Amendment [NPA] comments) should be published as a Temporary Guidance Leaflet (TGL) pending international agreement on certain fluid specifications and other matters.

The TGL is therefore authorized for use by the national authorities on a voluntary basis. When these issues have been resolved, the text may need to be revised and circulated as a further NPA before final publication in JAR OPS following any required NPA. This material will be added to JAR OPS in the form of an acceptable means of compliance (AMC). This document draft is reprinted here with its editorial changes.

To purchase the most up-to-date version of the JAA JAR OPS, contact:

Westward Digital Limited
37 Windsor Street
Cheltenham, Gloucestershire GL52 2DG
England
Telephone: +44 1242 235 151
Fax: +44 1242 584 139

Temporary Guidance Leaflet No. 4

Joint Aviation Authorities (JAA)

JAA – OC [Operations Committee] DRAFT
October 1, 1997

Proposed text to be published as a TGL OPS De-icing/Anti-icing. Text based upon the OC decision to contact the AEA de-icing/anti-icing group to bring the content up-to-date.

TGL OPS to JAR OPS 1.345(a)
Ice and other contaminants - Procedures
See JAR OPS 1.345(a).

1. General:

   a. Any deposit of ice, snow, frost or slush on the external surfaces of an aeroplane may drastically affect its performance due to reduced aerodynamic lift and increased drag resulting from both the disturbed airflow and the weight of the deposit. Furthermore, they may cause moving parts such as elevators, ailerons, flap actuating mechanism etc., to jam thus creating a potentially hazardous condition. Also, engine operation may be seriously affected by the ingestion of snow or ice into the engine, causing engine stall or compressor damage. The most critical ambient temperature range is between +30ºC and -10ºC. However, ice may form on the top and underside of fuel tanks containing large quantities of cold fuel at much higher ambient temperatures (possibly up to +l5ºC or higher).

   b. The procedures established by the operator for de-icing/anti-icing are intended to ensure that the airframe is clear of contamination so that neither degradation of aerodynamic characteristics nor mechanical interference will occur and, following anti-icing, to maintain the airframe in that condition for the appropriate holdover time. The de-icing/anti-icing procedures should therefore include aeroplane type specific requirements and cover:

      i. Contamination checks, including detection of clear ice and underwing frost (Limits on the thickness/area of contamination, if published in the AFM or other manufactures documentation should be followed):

      ii. De-icing/Anti-icing procedures (including procedures to be followed if de-icing/anti-icing is interrupted or unsuccessful);

iii. Pretake-off checks; and

iv. The recording of any incidents relating to de-icing/anti-icing

v. The responsibilities of all personnel involved in de-icing/anti-icing.

c. Material for establishing operational procedures can be found in:

- ICAO Doc 9640-AN/940 “Manual of aircraft ground de-icing/Anti-icing operations”.
- ISO 11075*) ISO Type I fluid;
- ISO 11076*) - Aircraft de-icing/anti-icing methods with fluids;
- ISO 11077*) - Self-propelled de-icing/anti-icing vehicles - Functional requirements.
- ISO 11078*) ISO Type II fluid
- AEA “Recommendations for De-icing/Anti-icing of aircraft on the ground”
- SAE ARP4737 Aircraft de-icing/anti-icing methods with fluids
- SAE AMS 1428 Dealing with anti-icing fluids
- SAE AMS 1424 Type I fluids

*) As the revision period of ISO documents in general is about 5 years, these documents may not reflect the latest industry standards.

2. Terminology:

Terms used in the context of this TGL have the following meanings:

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

b. Anti-icing fluid. Anti-icing fluid includes but is not limited to the following:

i. Type I fluid;

ii. Mixture of water and Type I fluid;

iii. Type II fluid;

iv. Mixture of water and Type II fluid;

v. Type IV fluid;

vi. Mixture of water and Type IV fluid.

NOTE: Anti-icing fluid is normally applied unheated on uncontaminated aeroplane surfaces.

c. Clear ice: A coating of ice, generally clear and smooth, but with some air pockets. It is formed and on exposed objects at temperatures below or slightly above the freezing temperature by freezing of supercooled drizzle, droplets or raindrops.

d. Conditions conducive to aeroplane icing on the ground: Freezing conditions, Freezing fog; Freezing precipitation, Frost/Hoar frost, rain or high humidity (on cold soaked wing), Sleet, Slush, and Snow.

e. De-icing. The procedure by which frost, ice, snow or slush is removed from an aeroplane in order to provide uncontaminated surfaces.

f. De-icing fluid: De-icing fluid includes but is not limited to the following:

i. Heated water;

ii. Type I fluid;

iii. Mixture of water and Type I fluid;

iv. Type II fluid;

v. Mixture of water and Type II fluid;

vi. Type IV fluid;

vii. Mixture of water and Type IV fluid.

NOTE: De-icing fluid is normally applied heated with a minimum temperature of 60ºC at the nozzle in order to assure maximum efficiency.

g. De-icing/anti-icing. De-icing/anti-icing is the combination in which the procedure described in subparagraph a. above and/or the procedure described in subparagraph e. above may be performed in one or two steps. One-step de-icing means, that de-icing and anti-icing are carried out at the same time using a mixture of anti-icing fluid and water. Two-step de-icing means that de-icing and anti-icing are carried out in two separate steps. The aeroplane is first de-iced using heated water only or a heated mixture of de-icers fluid and water. After completion of the de-icing operation a layer of a mixture of anti-icing fluid and water or of anti-icing fluid only is to be sprayed over the aeroplane surfaces. The 2nd step fluid must be applied, before the first step fluid freezes, typically within 3 minutes and, if necessary, area by area.

h. Freezing conditions.– Conditions in which the outside air temperature is below +3ºC (37,4ºF) 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.

i. Freezing drizzle. – Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0,02 in)] very close together which freezes upon impact with the ground or other exposed objects.

j. Freezing fog. A suspension of numerous minute water droplets which freezes 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).

k. Freezing Precipitation: Means Freezing rain or Freezing drizzle.

l. Frost/Hoar-Frost. Ice crystal that form from ice saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.

m. Holdover time. The estimated ***Period of*** time for which an anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the protected surfaces of an aeroplane on the ground. ~~before commencing the take-off roll, under weather conditions as specified in 6. below.~~

n. Light Freezing rain. Precipitation of liquid water particles which freezes upon impact with exposed objects, either in the form of drops of more than 0.5 mm (0.02 in) or smaller drops which, in contrast to drizzle, are widely separated. Measured intensity of liquid water particles are up to 2.5 mm/hr (0.10 in/hr) or 25 grams/dm^2/hour with a maximum of 2.5 mm (0.10 in) in 6 minutes.

o. Pre-takeoff check. – This check ensures that the representative surfaces of the aeroplane are free of ice, snow, slush or frost just prior to take-off. This check should be accomplished as close to the time of take-off as possible and is normally made from within the aeroplane by visually checking the wings or other critical surfaces, defined by the aeroplane manufacturer.

p. Rain or high humidity (on cold soaked wing). Water forming ice or frost on the wing surface, when the temperature of the aeroplane wing surface is at or below 0°C (32°F) *q.* Sleet. – Precipitation in the form of a mixture of rain and snow. For operation in light sleet treat as light freezing rain.

r. Slush. Snow or ice that has been reduced to a soft watery mixture by rain, warm temperature and/or chemical treatment.

s. Snow. Precipitation of ice crystals, most of which are branched, star-shaped or mixed with unbranched crystals. At temperatures higher than -5°C ((23°F), the crystals are generally agglomerated into snowflakes.

3. Anti-icing fluids:

a. Due to its properties, Type I fluid forms a thin, liquid-wetting film on surfaces to which it is applied which gives a rather limited holdover time depending on the prevailing weather conditions. With Type I fluids, increasing the concentration of fluid in the fluid/water mix <u>does not provide</u> any increase in holdover time.

b. Type II/IV fluid contains a thickener which enables the fluid to form a thicker liquid-wetting film on surfaces to which it is applied. Generally, this fluid provides a longer hold over time than Type I fluids in similar conditions. With this type of fluid, the holdover time can be increased by increasing the concentration of fluid in the fluid/water mix, up to the maximum hold over time available from undiluted fluid.

4. Anti-icing code

a. The operators procedures should include an anti-icing code which indicates the treatment the aeroplane has received. This code provides flight crew with the minimum details necessary to assess the holdover time and confirms that the aeroplane is clean.

b. The procedures for releasing the aeroplane after the treatment should therefore provide for the Commander to be informed of:

i. The anti-icing code; and

ii. The date/time that the final anti-icing step commenced.

c. Codes to be used (examples):

i. "Type I" at [Date/time] - To be used if de-icing/anti-icing has been performed with a Type I fluid.

ii. "Type II/100" at [Date/time] - To be used, if de-icing/anti-icing has been performed with undiluted Type II fluid.

iii. "Type II/75" at [Date/time]- To be used, if de-icing/anti-icing has been performed with a mixture of 75% Type II fluid and 25% water.

iv. "Type IV/50" at [Date/time] - To be used, if de-icing/anti-icing has been performed with a mixture of 50% Type IV fluid and 50% water.

~~*) required for record-keeping, optional for flight crew notification.~~

5. Holdover protection:

a. Holdover protection is achieved by a layer of anti-icing fluid remaining on and protecting aeroplane surfaces for a period of time. With a one step de-icing/anti-icing procedure, the holdover-time begins at the commencement of de-icing/anti-icing. With a two-step procedure, the holdover-time begins at the commencement of the second (anti-icing step). Holdover-time will have effectively run out:

(i) ***at the commencement of the take-off roll; or***

(ii) when frozen deposits start to form/accumulate aeroplane surfaces.

b. The duration of holdover protection may vary subject to the influence of factors other than those specified in Holdover-tables. These other factors may include:

i. Atmospheric conditions (e.g. the exact type and rate of precipitation, the wind velocity, the relative humidity and solar radiation); and

ii. The aeroplane and its surroundings (e.g. such as aeroplane component inclination angle, contour and surface roughness, operation in close proximity to other aeroplanes (jet or propeller blast) and ground equipment and structures).

c. Holdover times are not meant to imply that flight is safe in the prevailing conditions if the specified hold-over time has not been exceeded. Certain meteorological conditions, such as freezing drizzle or rain, may be beyond the certification envelope of the aeroplane.

d. The operator should publish Holdover-time tables to be used in the Operations Manual. However, it should be noted that holdover times should be used as guidelines only.

6. Procedures to be used:

a. Operator's procedures should ensure that;

i. When aeroplane surfaces are contaminated by ice, frost, slush or snow, they are de-iced prior to take-off;

ii. Account should be taken of the wing-skin temperature versus OAT, as this may affect:

(A) the need to carry-out aeroplane de-icing/anti-icing; and

(B) the performance of the de-icing/anti-icing fluids.

iii. When freezing precipitation exists or there is a risk of precipitation adhering to the surface at the time of take-off, aeroplane surfaces should be anti-iced. If both anti-icing and de-icing are required, the procedure may be performed in a one- or two-step process depending upon weather conditions, available equipment, available fluids and the holdover time to be achieved;

iv. When longer holdover times are needed/desired, use of unheated undiluted Type II fluid should be considered;

v. During conditions conducive to aeroplane icing on the ground or after de-icing/anti-icing, an aeroplane is not dispatched for departure unless it has been given a check/inspection by a trained and qualified person. This check should visually cover all critical parts of the aeroplane and be performed from points offering sufficient visibility of these parts (e.g. from the antiicing vehicle or gantry itself or another elevated piece of equipment). To ensure that there is no clear ice on suspect areas, it may be necessary to make a physically check (e.g. touch);

vi. The required entry is made in the technical log. (See AMC OPS 1.915, paragraph 2, Section 3.vi.);

vii. When severe freezing precipitation exists, a pre-take off check of the aeroplane's aerodynamic surfaces is carried out by a trained and qualified person, if requested by the commander. This check/inspection should be carried out immediately prior to the aeroplane entering the active runway, or commencing the take-off roll, in order to confirm that these surfaces are free of contamination;

viii. Where any doubt exists as to whether or not any deposit may adversely effect the aeroplane's performance and/or controllability, the Commander should not commence take-off.

7. Special Operational Considerations:

a. The operator should comply with any operational requirements such as an aeroplane mass decrease and/or a take-off speed increase when associated with a fluid application for certain types of aeroplanes.

b. The operator should take into account any flight handling procedures (rotation speed and rate, Take off speed, aeroplane attitude etc.) laid down by the manufacturers when associated with a fluid application.

c. The use of de-icing/anti-icing fluids has to be in accordance with the aeroplane manufacturer documentation. This is particularly true for thickened fluids to assure sufficient "flow off" during take-off.

8. Training requirements:

   a. An operator should establish an appropriate de-icing/anti-icing training programme including communication training for Flight Crew and those of his Ground Crew that are involved in de-icing/anti-icing.

   b. The de-icing /anti-icing training programme should include additional training if any of the following are introduced:

      i. A new procedure;

      ii. A new type of fluid and/or equipment; and

      iii. A new type(s) of aeroplane.

   c. The Operator should take all reasonable measures to ensure that if subcontracting the task of de-icing/anti-icing, the subcontractor is competent to execute the task.♦

Recommendations for De-Icing/Anti-Icing of Aircraft on the Ground

Association of European Airlines (AEA)

FSF editorial note: See current holdover time tables based on data from the Society of Automotive Engineers (SAE), the International Standards Organization (ISO), the Association of European Airlines (AEA), the relevant flight operations manual and/or the appropriate civil aviation authority.

To purchase the most up-to-date version of the document, contact AEA at:

Association of European Airlines (AEA)
350 Ave. Louise, Bte. 4
B-1050 Brussels, Belgium
Telephone: +32 2 6270600
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Table of Contents

Foreword

This document "Recommendations for De-Icing/Anti-Icing of Aircraft on the Ground" is the tenth edition of the report of the AEA Task Force on De-/Anti-Icing Aircraft on the ground. It replaces previous editions of the AEA's Recommendations.

This Task Force (composed of representatives from Air France, Austrian Airlines (since 1993), British Airways, Finnair (previous Chairman), KLM (Chairman), Lufthansa, Sabena, SAS (Vice-Chairman) and Swissair) was set up in 1982 to answer the requests of the Airworthiness Authorities following the problems of winter 1981/82. Since 1995, the Task Force cooperates with the Society of Automotive Engineers.

The purpose of this amendment is to introduce type IV fluid, a Quality Assurance Programme as well as an amendment of the methods for de-icing/anti-icing. Draft text to replace ISO 11076 has been developed.

The legal framework for this document is provided in JAR-OPS 1.345.

The document has been approved by the AEA Technical and Operations Committee at its 46th meeting on 27th September 1996 in Istanbul. The committee thereby encouraged aircraft operators to adopt as soon as possible the appropriate recommendations and procedures and to implement the Quality Assurance Programme.

These recommendations have been established by the AEA De-/Anti-Icing Task Force and are not legally binding.

Dr. Klaus Menninger
General Manager Technical Affairs

Sent to Delegates & Alternates of:

Technical and Operations Committee
TOC/Rules Sub-Committee
TOC/De-/Anti-Icing Task Force

Recommendations for De-Icing/Anti-Icing of Aircraft on the Ground

Association of European Airlines (AEA)

1. Introduction

This document completely replaces the Ninth Edition of De-Icing/Anti-Icing of Aircraft on the Ground.

An update of the recommendations has been developed to accommodate the latest "state-of-the-art" in de-/anti-icing technology. Fluid specifications have been updated as well as the methods of de-icing/anti-icing. A Quality Assurance Programme has been defined and added. Type IV fluids have been introduced, offering longer holdover times when used in concentrated form.

This set of AEA recommendations is based upon the standards ISO 11075 (type 1 fluid), ISO 11076 (methods), ISO 11077 (equipment) and ISO 11078 (type 2 fluid) from the International Standards Organization (ISO), it offers amendments and additional information where necessary.

The AEA de-icing/anti-icing Task Force and the US Society of Automotive Engineers (SAE) G-12 Committee on Aircraft Ground De-Icing cooperated to develop updates for these documents. The ISO documents will need update, which will not be ready before coming winter season 1996/97. SAE on their part, however, will incorporate those updates in the applicable SAE documents already before the start of coming winter season. For that reason reference to relevant SAE documents will be made so that access to the latest information is widely available.

As the methods document has changed significantly to address the latest development in fluid technology, the entire proposal to update the ISO 11076 document is incorporated in this tenth revision, so it can be used already in the upcoming winter period. The hold over time table for type IV fluid incorporated herein has been approved by the FAA and Transport Canada.

The proposed updates have already been presented to the ISO Technical Committee (T/C) 20, Sub-committee (S/C) 9 in their meeting in London, June 12, 1996. S/C 9 accepted the AEA/SAE proposals in following motions:

> "N 130: The TC 20/SC 9, 27th Plenary Meeting unanimously agrees that ISO/CD 11075, 11076 and 11078, incorporating the changes prepared by the AEA-SAE De-icing/Anti-icing Task Force, be balloted to SC 9 as soon as possible, with the minimum allowable response period. The object is to proceed to the DIS ballot process with a minimum of delay."

> "N 131: In the interest of making available the latest technical developments affecting flight safety as soon as possible, TC 20/SC 9 agrees to recognize the 1996 revisions of SAE AMS 1424, AMS 1428 and ARP 4737 as well as the AEA de-icing/anti-icing recommendations and encourage all parties concerned to use these documents, as early as the 1996/1997 winter, as interim references while awaiting completion of the

approval process of revisions to ISO 11075, 11076 and 11078."

Anywhere fluid types have been used in this document without the addition of "ISO" or "SAE", reference is made to ISO and SAE fluid types (for example, Type I fluid refers to ISO).

In locations where in this document, only ISO types are indicated, reference to the applicable SAE fluid types is included.

Copies of the SAE publications are available from:

SAE, 400 Common Wealth Drive,
Warrendale, PA 15096-0001, USA.
Fax.: +1-412-776-0243, Phone: +1-412-776-4841.

Copies of the ISO documents are available from:

International Organization for Standardization,
Case Postale 56, CH-1211,
Genève 20, Switzerland

2. ISO 11075, Aerospace — Aircraft De-Icing/ Anti-Icing Newtonian Fluids, ISO Type I

The document is not up-to-date, see 1. introduction. Reference: SAE AMS 1424 A for latest "state-of-the-art".

3. ISO 11076, Aerospace — Aircraft De-Icing/ Anti-Icing Methods With Fluids

The document is not up-to-date, see 1. Introduction. Reference: SAE ARP 4737 A.

Precaution On Type IV Fluids.

Type IV fluids, offering significant operational advantages in terms of hold over times, will be introduced during winter 1996/1997.

However, under certain low humidity conditions some of the fluids may, over a period of time, thicken and affect the aerodynamic performance of the fluid during the subsequent takeoff.

If gel residues of type IV fluids are found at departure, the surface must be cleaned and reprotected as necessary.

A sample of the gel residue should be shipped, with sufficient information, to the responsible department for further analysis/action.

The text of Section 3.1 thru 3.13 shall be used in replacement of ISO 11076

(This text is the latest "state of the art" and is intended to update ISO 11076.)

3.1 Scope

This document establishes the minimum requirements for ground-based aircraft de-icing/anti-icing with fluids to ensure the safe operation of transport aircraft during icing conditions (see also 3.8.3.2). All requirements specified herein are applicable only in conjunction with the referenced documents. This document does not specify requirements for particular airplane model types.

Note 1: Particular airline or aircraft manufacturers published manuals, procedures or methods supplement the information contained in this document.

Frost, ice or snow deposits, which can seriously affect the aerodynamic performance and/or controllability of an aircraft, are effectively removed by the application of the procedures specified in this document.

De-icing/anti-icing by mechanical means is not covered by this document.

3.2 References

The following documents contain provisions which, through reference in this text, constitute provisions of this document. All documents are subject to revision, use always the latest edition.

- ISO 11075:1993, Aerospace
  – Aircraft de-icing/anti-icing Newtonian fluids,
  ISO type 1.
- ISO 11077:1993, Aerospace
  – Self-propelled de-icing/anti-icing vehicles
  – Functional requirements.
- ISO 11078: 1993, Aerospace
  – Aircraft de-icing/anti-icing non-Newtonian fluids,
  ISO type II.
- SAE AMS 1424 A, De-icing/anti-icing fluid, aircraft, SAE type I.
- SAE AMS 1428 A, Fluid, aircraft de-icing/ anti-icing, non-Newtonian (pseudo-plastic), SAE types II/III/IV.
- SAE ARP 4737 A, Aircraft de-icing/anti-icing methods with fluids.
- SAE ARP 1971, Aircraft de-icing vehicle
  – self-propelled, large capacity.

3.3 Definitions

For the purposes of this document, the following definitions apply.

3.3.1 De-icing:

Procedure by which frost, ice, slush or snow is removed from an aircraft in order to provide clean surfaces.

3.3.2 De-icing fluid:

a) heated water;

b) ISO type I fluid in accordance with ISO 11075;

c) mixture of water and ISO type I fluid;

d) ISO type II, type III or type IV fluid in accordance with ISO 11078;

e) mixture of water and ISO type II, type III or type IV fluid.

Note 2: De-icing fluid is normally applied heated in order to assure maximum efficiency.

3.3.3 Anti-icing:

Precautionary procedure which provides protection against the formation of frost or ice and accumulation of snow or slush on treated surfaces of the aircraft for a limited period of time (hold overtime).

3.3.4 Anti-icing fluid:

a) ISO type I fluid in accordance with ISO 11075;

b) mixture of water and ISO type I fluid;

c) ISO type II, Type III or type IV fluid in accordance with ISO 11078;

d) mixture of water and ISO type II, type III or type IV fluid.

Note 3: Anti-icing fluid is normally applied cold on clean aircraft surfaces, but may be applied heated.

3.3.5 De-icing/anti-icing:

Combination of the procedures described in 3.3.1 and 3.3.3. It may be performed in one or two steps.

3.3.6 Holdover time:

Estimated time for which an anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the protected surfaces of an aircraft, under weather conditions as specified in section 3.13.

3.3.7 Freezing conditions:

Conditions in which the outside air temperature is below +3°C (37.4˚F) 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.

3.3.8 Frost/hoar frost:

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.

3.3.9 Freezing fog:

A suspension of numerous minute water droplets which freezes 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).

3.3.10 Snow:

Precipitation of ice crystals, most of which are branched, star-shaped or mixed with unbranched crystals. At temperatures higher than -5°C (23°F), the crystals are generally agglomerated into snowflakes.

3.3.11 Freezing drizzle:

Fairly uniform precipitation composed exclusively of fine drops (diameter less than 0.5 mm (0.02 in)) very close together which freezes upon impact with the ground or other exposed objects.

3.3.12 Light freezing rain:

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

3.3.13 Rain or high humidity (on cold soaked wing):

Water forming ice or frost on the wing surface, when the temperature of the aircraft wing surface is at or below 0°C (32°F).

3.3.14 Sleet:

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

3.3.15 Slush:

Snow or ice that has been reduced to a soft watery mixture by rain, warm temperatures and/or chemical treatment.

3.3.16 Check:

An examination of an item against a relevant standard by a trained and qualified person.

3.4 Abbreviations

OAT: outside air temperature, FP: freezing point

3.5 General

The various local rules concerning aircraft cold weather operations are very specific and shall be strictly adhered to.

A pilot shall not take off in an airplane that has:

a) frost, snow, slush or ice adhering to any propeller, windshield or power plant installation or to airspeed, altimeter, rate of climb or flight altitude instrument systems;

b) snow, slush or ice adhering to the wings or stabilizers or control surfaces or any frost adhering to the upper surfaces of wings or stabilizers or control surfaces.

3.6 Staff Training and Qualification

De-icing/anti-icing procedures must be carried out exclusively by trained and qualified personnel.

3.6.1 Training for crews

Both initial and annual recurrent training for flight crews and ground crews shall be conducted to ensure that all such crews obtain and retain a thorough knowledge of aircraft de-icing/anti-icing policies and procedures, including new procedures and lessons learned.

3.6.2 Training subjects shall include but are not limited to the following (when applicable):

a) Effects of frost, ice, snow, and slush on aircraft performance.

b) Basic characteristics of aircraft de-icing/anti-icing fluids.

c) General techniques for removing deposits of frost, ice, slush, and snow from aircraft surfaces and for anti-icing.

d) De-icing/anti-icing procedures in general and specific measures to be performed on different aircraft types.

e) Types of checks required.

f) De-icing/anti-icing equipment operating procedures including actual operation of equipment.

g) Safety precautions.

h) Emergency procedures.

i) Fluid application and limitations of holdover time tables.

j) De-icing/anti-icing codes and communication procedures.

k) Special provisions and procedures for contract de-icing/anti-icing (if applicable).

l) Environmental considerations, e.g. where to de-ice, spill reporting, hazardous waste control.

m) New procedures and development, lessons learned from previous winters.

3.6.3 Records

Records of personnel training and qualifications shall be maintained for proof of qualification.

3.7 Fluid Handling

De-icing/anti-icing fluid is a chemical product with environmental impact. During fluid handling, avoid any unnecessary spillage and comply with local environmental and health laws and the manufacturer’s safety data sheet.

Different Products Shall Not Be Mixed Without Additional Qualification Testing.

Note 4: Slippery conditions can exist on the ground or equipment following the de-icing/anti-icing procedure. Caution should be exercised, particularly under low humidity or non-precipitating weather conditions due to increased slipperiness.

3.7.1 Storage

- Tanks dedicated to the storage of de-icing/anti-icing fluids shall be used.
- Storage tanks shall be of a material of construction compatible with the deicing/anti-icing fluid, as specified by the fluid manufacturer.
- Tanks shall be conspicuously labeled to avoid contamination.

- Tanks shall be inspected annually for corrosion and/or contamination. If corrosion or contamination is evident, tanks shall be maintained to standard or replaced. To prevent corrosion at the liquid/vapor interface and in the vapor space, a high liquid level in the tanks is recommended.

- The storage temperature limits shall comply with the manufacturer's guidelines.

- The stored fluid shall be checked routinely to ensure that no degradation/contamination has occurred.

3.7.2 Pumping

De-icing/anti-icing fluids can show degradation caused by excessive mechanical shearing. Therefore only compatible pumps and spraying nozzles shall be used. The design of the pumping systems shall be in accordance with the fluid manufacturer's recommendations.

3.7.3 Transfer lines

Dedicated transfer lines shall be conspicuously labeled to prevent contamination and shall be compatible with the de-icing/anti-icing fluids to be transferred.

3.7.4 Heating

De-icing/anti-icing fluids shall be heated according to the fluid manufacturer's guidelines. The integrity of the fluid following heating shall be checked periodically.

3.7.5 Application

Application equipment shall be cleaned thoroughly before being initially filled with de-icing/anti-icing fluid in order to prevent fluid contamination.

De-icing/anti-icing fluid in trucks shall not be heated in confined or poorly ventilated areas such as hangars.

The integrity of the fluid at the spray nozzle shall be checked periodically.

3.8 Procedures

These procedures specify the recommended methods for de-icing and anti-icing of aircraft on the ground to provide an aerodynamically clean aircraft.

When aircraft surfaces are contaminated by frozen moisture, they shall be de-iced prior to dispatch. When freezing precipitation exists and there is a risk of precipitation adhering to the surface at the time of dispatch, aircraft surfaces shall be anti-iced. If both anti-icing and de-icing are required, the procedure may be performed in one or two steps (see 3.3.5). The selection of a one- or two-step process depends upon weather conditions, available equipment, available fluids and the holdover time to be achieved. If a one step procedure is used, then both 3.8.1 and 3.8.2 apply.

For guidance regarding fluid limitations, see 3.8.3.1.

Note 5: Where holdover time is critical, a two-step procedure using undiluted fluid for the second step, should always be considered.

3.8.1 De-icing

Ice, snow, slush or frost may be removed from aircraft surfaces by heated fluids or mechanical methods. The following procedures shall be used for their removal.

3.8.1.1 Requirements

Ice, snow, slush and frost shall be removed from aircraft surfaces prior to dispatch or prior to anti-icing.

3.8.1.2 General

For maximum effect, fluids shall be applied close to the surface of the skin to minimize heat loss.

Note 6: The heat in the fluid effectively melts any frost, as well as light deposits of snow, slush and ice. Heavier accumulations require the heat to break the bond between the frozen deposits and the structure; the hydraulic force of the fluid spray is then used to flush off the residue. The de-icing fluid will prevent refreezing for a period of time depending on aircraft skin and ambient temperature, the fluid used, the mixture strength and the weather.

3.8.1.3 Removal of frost and light ice

A nozzle setting giving a solid cone (coarse) spray should be used.

Note 7: This ensures the largest droplet pattern available, thus retaining the maximum heat in the fluid. Providing the hot fluid is applied close to the aircraft skin, a minimal amount of fluid will be required to melt the deposit.

3.8.1.4 Removal of snow

A nozzle setting sufficient to flush off deposits shall be used.

Note 8: The procedure adopted will depend on the equipment available and the depth and type of snow; i.e. light and dry or wet and heavy. In general, the heavier the deposits the heavier the fluid flow that will be required to remove it effectively and efficiently from the aircraft surfaces. For light deposits of both wet and dry snow, similar procedures as for frost removal may be adopted. Wet snow is more difficult to remove than dry snow and unless deposits are relatively light, selection of high fluid flow will be found to be more effective. Under certain conditions it will be possible to use the heat, combined with the hydraulic force of the fluid spray to melt and subsequently flush off frozen deposits. However, where snow has bonded to the aircraft skin, the procedures detailed in 3.8.1.5 should be utilized. Heavy accumulation of snow will always be difficult to remove from aircraft surfaces and vast quantities of fluid will invariably be consumed in the attempt. Under these conditions, serious consideration should be given to removing the worst of the snow manually before attempting a normal de-icing procedure.

3.8.1.5 Removal of ice

Heated fluid shall be used to break the ice bond. The method makes use of the high thermal conductivity of the metal skin.

A jet of hot fluid is directed at close range on to one spot, until the bare metal is just exposed. This bare metal will then transmit the heat laterally in all directions raising the temperature above the freezing point thereby breaking the adhesion of the frozen mass to the aircraft surface. By repeating this procedure a number of times, the adhesion of a large area of frozen snow or glazed ice can be broken. The deposits can then be flushed off with either a low or high flow, depending on the amount of the deposit.

3.8.1.6 General de-icing fluid application strategy

For effective removal of snow and ice, the following techniques shall be adopted. Certain aircraft can require unique procedures to accommodate design differences.

- Wings/tailplane. Spray from the tip inboard to the root from the highest point of the surface camber to the lowest. However, aircraft configurations and local conditions can dictate a different procedure.
- Vertical surfaces. Start at the top and work down.
- Fuselage. Spray along the top center-line and then outboard.
- Landing gear and wheel bays. The application of de-icing fluid in this area shall be kept to a minimum. De-icing fluid shall not be sprayed directly onto brakes and wheels.

Note 9: Accumulations such as blown snow can be removed mechanically. However, where deposits have bonded to surfaces, they can be removed by the application of hot air or by spraying with hot de-icing fluids.

- Engines. Deposits of snow should be removed mechanically from engine intakes prior to departure. Any frozen deposits that have bonded to either the lower surface of the intake or the fan blades may be removed by hot air or other means recommended by the engine manufacturer.
- De-icing location. De-icing/anti-icing near the beginning of the departure runway provides the minimum interval between de-icing/anti-icing and takeoff.

3.8.2 Anti-icing

Ice, snow, slush or frost will, for a period of time, be prevented from adhering to or accumulating on aircraft surfaces by the application of anti-icing fluids. The following procedures shall be adopted when using anti-icing fluids.

3.8.2.1 Required usage

Anti-icing fluid shall be applied to the aircraft surfaces when freezing rain, snow or other freezing precipitation may adhere to the aircraft at the time of aircraft dispatch.

3.8.2.2 Optional usage

Anti-icing fluid may be applied to aircraft surfaces at the time of arrival (preferably before unloading begins) on short turnarounds during freezing precipitation and on overnight parked aircraft.

Note 10: This will minimize ice accumulation prior to departure and often makes subsequent de-icing easier.

On receipt of a frost, snow, freezing drizzle, freezing rain or freezing fog warning from the local meteorological service, anti-icing fluid may be applied to clean aircraft surfaces prior to the start of freezing precipitation.

Note 11: This will minimize the possibility of snow and ice bonding or reduce the accumulation of frozen precipitation on aircraft surfaces and facilitate subsequent de-icing.

3.8.2.3 General

For effective anti-icing, an even film of fluid is required over the prescribed aircraft surfaces which are clean or which have been de-iced. For longer anti-icing protection, undiluted, unheated ISO type II, type III or type IV fluid should be used.

The high fluid pressures and flow rates normally associated with de-icing are not required for this operation and, where possible, pump speeds should be reduced accordingly. The nozzle of the spray gun should be adjusted to give a medium spray.

Note 12: ISO type I fluids have limited effectiveness when used for anti-icing purposes. Little benefit is gained from the minimal holdover time generated.

3.8.2.4 Anti-icing fluid application strategy

The process should be continuous and as short as possible. Anti-icing should be carried out as near to the departure time as operationally possible in order to utilize maximum holdover time. The anti-icing fluid shall be distributed uniformly over all surfaces to which it is applied. In order to control the uniformity, all horizontal aircraft surfaces shall be visually checked during application of the fluid. The correct amount is indicated by fluid just beginning to drop off the leading and trailing edges.

The most effective results are obtained by commencing on the highest part of the wing section and covering from there towards the leading and trailing edges. On vertical surfaces, start at the top and work down.

The following surfaces shall be protected:

a) wing upper surface and leading edges;

b) tailplane upper surface;

c) vertical stabilizer and rudder;

d) fuselage upper surfaces depending upon the amount and type of precipitation (especially important on center-line engined aircrafts).

CAUTION: It is possible that anti-icing fluids may not flow evenly over wing leading edges, horizontal and vertical stabilizers. These surfaces should be checked to ensure that they are properly coated with fluid.

3.8.2.5 De-icing/anti-icing near the beginning of the departure runway provides the minimum interval between de-icing/anti-icing and takeoff.

3.8.3 Limits and precautions

3.8.3.1 Fluid related limits

3.8.3.1.1 Temperature limits

When performing two-step de-icing/anti-icing, the freezing point of the fluid used for the first step shall not be more than 3°C (5.4°F) above ambient temperature. (See also table 1 and table 2.)

- ISO type I fluids

The freezing point of the ISO type I fluid mixture used for either one-step de-icing/anti-icing or as a second step in the two-step operation shall be at least 10°C (18°F) below the ambient temperature.

Undiluted ISO type I fluids shall meet aerodynamic and freezing point requirements.

- ISO type II/III/IV fluids

ISO type II/III/IV fluids used as de-icing/anti-icing agents have a lower temperature application limit of -25°C (-13°F). The application limit may be lower, provided a 7°C (12.6°F) buffer is maintained between the freezing point of the neat fluid and outside air temperature. In no case shall this temperature be lower than the lowest operational use temperature as defined by the aerodynamic acceptance test.

CAUTION: Some type IV fluids may, over a period of time under certain low humidity conditions, thicken and affect the aerodynamic performance of the fluid during subsequent takeoff. If gel residues of type IV fluids are found at departure, the surface must be cleaned and reprotected as necessary.

3.8.3.1.2 Application limits

An aircraft that has been anti-iced with undiluted ISO type II, type III or type IV fluid shall not receive a further coating of anti-icing fluid directly on top of the contaminated fluid under any circumstances. If it is necessary for an aircraft to be reprotected prior to the next flight, the external surfaces shall first be de-iced with a hot fluid mix before a further application of anti-icing fluid is made. (See also tables 3, 4 and 5.)

3.8.3.2 Aircraft related limits

The application of de-icing/anti-icing fluid shall be in accordance with the guidelines of the airframe/engine manufacturers.

3.8.3.3 Procedure precautions

3.8.3.3.1 One-step de-icing/anti-icing is performed with an anti-icing fluid (refer to 3.3.4). The fluid used to de-ice the aircraft remains on aircraft surfaces to provide limited anti-ice capability. The correct fluid concentration shall be chosen with regard to desired holdover time and is dictated by outside air temperature and weather conditions. See tables 1 and 2.

CAUTION: Wingskin temperature may differ and in some cases may be lower than OAT. A stronger mix can be used under the latter conditions.

3.8.3.3.2 Two-step de-icing/anti-icing: the first step is performed with de-icing fluid (refer to 3.3.2). The correct fluid shall be chosen with regard to ambient temperature. After de-icing, a separate overspray of anti-icing fluid (refer to 3.3.4) shall be applied to protect the relevant surfaces thus providing maximum possible anti-ice capability. The second step is performed with anti-icing fluid. The correct fluid concentration shall be chosen with regard to desired holdover time and is dictated by outside air temperature and weather conditions. See tables 1 and 2.

CAUTION: Wingskin temperature may differ and in some cases may be lower than OAT.

A stronger mix can be used under the latter conditions.

The second step shall be performed before first step fluid freezes (typically within 3 min), if necessary area by area. If freezing has occurred on the critical areas of the aircraft, the first step shall be repeated.

CAUTION: When a fluid conforming to ISO 11078 (Type II/III/IV fluid) is used to perform step two in a two-step de-icing/anti-icing operation, and the fluid used in step one is a Type I fluid conforming to ISO 11075, a test shall be made to confirm that the combination of these fluids does not significantly reduce the anti-icing performance of the ISO 11078 fluid.

3.8.3.3.3 With regard to holdover time provided by the applied fluid, the objective is that it be equal to or greater than the estimated time from start of anti-icing to start of take-off based on existing weather conditions.

3.8.3.3.4 Aircraft shall be treated symmetrically, that is, left-hand and right-hand side shall receive the same and complete treatment.

Note 13: Aerodynamic problems could result if this requirement is not met.

3.8.3.3.5 During anti-icing and de-icing, the moveable surfaces shall be in a position as specified by the aircraft manufacturer.

3.8.3.3.6 Engines are normally shut down but may remain running at idle during deicing/anti-icing operations. Air-conditioning and/or APU air shall be selected OFF, or as recommended by the airframe and engine manufacturer.

3.8.3.3.7 De-icing/anti-icing fluids shall not be sprayed directly onto brakes, wheels, exhausts or thrust reversers.

3.8.3.3.8 De-icing/anti-icing fluid shall not be directed into the orifices of pitot heads, static vents or directly onto airstream direction detectors probes/angle of attack airflow sensors.

3.8.3.3.9 All reasonable precautions shall be taken to minimize fluid entry into engines, other intakes/outlets and control surface cavities.

3.8.3.3.10 Fluids shall not be directed onto flight deck or cabin windows as this can cause cracking of acrylics or penetration of the window sealing.

3.8.3.3.11 All doors and windows should be closed to prevent:

a) galley floor areas being contaminated with slippery de-icing fluids;

b) upholstery becoming soiled.

3.8.3.3.12 During the application of de-icing/anti-icing fluids, doors shall not be closed until all ice or snow has been removed from the surrounding area.

3.8.3.3.13 Any forward area from which fluid can blow back onto windscreens during taxi or subsequent take-off shall be free of fluid residues prior to departure.

3.8.3.3.14 If ISO type II, type III or type IV fluids are used, all traces of the fluid on flight deck windows should be removed prior to departure, particular attention being paid to windows fitted with wipers.

De-icing/anti-icing fluid may be removed by rinsing with an approved cleaner and a soft cloth.

3.8.3.3.15 Landing gear and wheel bays shall be kept free from build-up of slush, ice or accumulations of blown snow.

3.8.3.3.16 When removing ice, snow, slush or frost from aircraft surfaces care shall be taken to prevent it entering and accumulating in auxiliary intakes or control surface hinge areas, i.e. remove snow from wings and stabilizer surfaces forward towards the leading edge and remove from ailerons and elevators back towards the trailing edge.

3.8.3.3.17 Ice can build up on aircraft surfaces when descending through dense clouds or precipitation during an approach. When ground temperatures at the destination are low, it is possible for flaps to be retracted and for accumulations of ice to remain undetected between stationary and moveable surfaces. It is therefore important that these areas are checked prior to departure and any frozen deposits are removed.

3.8.3.3.18 Under freezing fog conditions, the rear side of the fan blades shall be checked for ice build-up prior to start-up. Any deposits discovered shall be removed by directing air from a low flow hot air source, such as a cabin heater, onto the affected areas.

3.8.3.3.19 A flight control check should be considered according to aircraft type (see relevant manuals). This check should be performed after de-icing/anti-icing.

3.8.3.4 Clear ice precautions

3.8.3.4.1 Clear ice can form on aircraft surfaces, below a layer of snow or slush. It is therefore important that surfaces are closely inspected following each de-icing operation, in order to ensure that all deposits have been removed.

3.8.3.4.2 Significant deposits of clear ice can form, in the vicinity of the fuel tanks, on wing upper surfaces as well as underwing. Aircraft are most vulnerable to this type of build-up when:

a) wing temperatures remain well below 0°C (32°F) during the turn around/transit;

b) ambient temperatures between -2°C and +15°C (28°F and 59°F) are experienced;

Note 14: Clear ice can form at other temperatures if conditions a), c) and d) exist.

c) precipitation occurs while the aircraft is on the ground;

d) frost or ice is present on lower surface of either wing.

This type of ice formation is extremely difficult to detect. Therefore when the above conditions prevail, or when there is otherwise any doubt whether clear ice has formed, a close examination shall be made immediately prior to departure, in order to ensure that all frozen deposits have in fact been removed.

Note 15: This type of build-up normally occurs at low wing temperatures and when large quantities of cold fuel remain in wing tanks during the turnaround/transit and any subsequent refueling is insufficient to cause a significant increase in fuel temperature.

3.9 General Aircraft Requirements After De-Icing/Anti-Icing

Following the de-icing/anti-icing procedures and prior to take-off, the critical aircraft surfaces shall be clean of all frost, ice, slush, and snow accumulations in accordance with the following requirements.

3.9.1 Wings, tail and control surfaces

Wings, tail and control surfaces shall be free of ice, snow, slush, and frost except that a coating of frost may be present on wing lower surfaces in areas cold soaked by fuel between forward and aft spars in accordance with the aircraft manufacturer's published manuals.

3.9.2 Pitot heads and static ports

Pitot heads and static ports shall be clear of ice, frost, snow and fluid residues.

3.9.3 Engine inlets

Engine inlets shall be clear of internal ice and snow and fan shall be free to rotate.

3.9.4 Air conditioning inlets and exits

Air conditioning inlets and exits shall be clear of ice, frost and snow. Outflow valves shall be clear and unobstructed.

3.9.5 Landing gear and landing gear doors

Landing gear and landing gear doors shall be unobstructed and clear of ice, frost and snow.

3.9.6 Fuel tank vents

Fuel tank vents shall be clear of ice, frost and snow.

3.9.7 Fuselage

Fuselage shall be clear of ice and snow. Adhering frost may be present in accordance with the aircraft manufacturer's manuals.

3.9.8 Flight control check

A functional flight control check using an external observer may be required after de-icing/anti-icing depending upon aircraft type (see relevant manuals). This is particularly important in the case of an aircraft that has been subjected to an extreme ice or snow covering.

3.10 Final Check Before Aircraft Dispatch

An aircraft shall not be dispatched for departure under icing conditions or after a de-icing/anti-icing operation until the aircraft has received a final check by a responsible authorized person.

The check shall visually cover all critical parts of the aircraft and be performed from points offering sufficient visibility of these parts (e.g. from the de-icer itself or another elevated piece of equipment).

The authorized person shall indicate the check results in accordance with section 3.9 by documentation, if applicable, according to airline or local airworthiness authority requirements.

3.11 Pre Take-off Check

When freezing precipitation exists, aerodynamic surfaces shall be checked just prior to the aircraft taking the active runway or initiating the take-off roll in order to confirm that they are free of all forms of frost, ice, snow and slush. This is particularly important when severe conditions are experienced or the published hold overtimes have either been exceeded or are about to run out. When deposits are in evidence, the de-icing operation shall be repeated.

If aircraft surfaces cannot adequately be checked from inside the aircraft, it is desirable to provide a means of assisting the flight crew in determining the condition of the aircraft. This check should be conducted as near as practical to the beginning of the departure runway.

3.12 Flight Crew Information

3.12.1 De-icing/anti-icing operation

An aircraft shall not be dispatched for departure after a de-icing/anti-icing operation until the flight crew has been notified of the type of de-icing/anti-icing operation performed.

The standardized notification performed by qualified personnel indicates that the aircraft critical parts are checked free of ice, frost, snow, and slush, and in addition includes the necessary de-icing/anti-icing code as specified in 3.12.2 to allow the flight crew to estimate the hold overtime to be expected under the prevailing weather conditions with reference to section 3.13.

3.12.2 De-icing/anti-icing codes

The following information shall be recorded and be communicated to the flight crew by referring to the last step of the procedure and in the sequence provided below:

a) the ISO fluid type; i.e. Type I for ISO type I, Type II for ISO type II, Type III for ISO type III and Type IV for ISO type IV

b) the concentration of fluid within the fluid/water mixture, expressed as a percentage by volume;

Note 16: no requirement for ISO Type I fluid

c) the local time (hours/minutes) at the beginning of the final de-icing/anti-icing step,

d) the date (written: day, month, year).

Note 17: required for record keeping, optional for crew notification.

Transmission of elements a), b), and c) to the flight crew confirm that a post de-icing/anti-icing check was completed and that the aircraft is clean.

Example:

A de-icing/anti-icing procedure whose last step is the use of a mixture of 75% of ISO type II fluid and 25% water, commencing at 13:35 local time on 20 April 1992, is recorded as follows:

Type II/75 13:35 (20 April 1992)

3.13 Holdover Time

Holdover time is obtained by anti-icing fluids remaining on the aircraft surfaces.

In a one-step de-icing/anti-icing operation the hold overtime begins at the start of the operation, in a two-step operation at the start of the final (anti-icing) step. Holdover time will have effectively run out when frozen deposits start to form/accumulate on treated aircraft surfaces.

Due to their properties, ISO Type I fluids form a thin liquid wetting film, which provides limited holdover time, especially in conditions of freezing precipitation.

With Type I fluid no additional holdover time would be provided by increasing the concentration of fluid in the fluid/water mix.

ISO Type II/IV fluid contain a pseudo plastic thickening agent which enables the fluid to form a thicker liquid wetting film on external aircraft surfaces. This film provides for 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 the fluid in the fluid/water mix, with maximum holdover time available from undiluted fluid.

Tables 3, 4, and 5 give an indication as to the time frame of protection that could reasonably be expected under conditions of precipitation. However, due to the many variables that can influence holdover time, these times should not be considered as minimum or maximum as 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 moderate precipitation and the upper limit indicates the estimated time of protection during light precipitation.

CAUTION: 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 also be reduced when aircraft skin temperature is lower than OAT. Therefore, the indicated times should be used only in conjunction with a pre-takeoff check.

The Responsibility for the Application of these Data Remains with the User.

Table 1
Guidelines for the Application of ISO Type I Fluid/Water Mixtures (Minimum Concentrations) as a Function of Outside Air Temperature (OAT)

	One Step Procedure	Two Step Procedure	
OAT	**De-icing/Anti-icing**	**First Step: De-icing**	**Second Step: Anti-icing[1)]**
-3˚C (27˚F) and above below -3˚C (27˚F)	FP of heated fluid mixture[2)] 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 mix of fluid and water FP of heated fluid mixture shall not be more than 3˚C (5˚F) above actual OAT	FP of fluid mixture shall be at least 10˚C (18˚F) below actual OAT

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 fluid and aircraft manufacturers recommendations.

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

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

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

Table 2
Guidelines for the Application of ISO Type II and Type IV Fluid/Water Mixtures (Minimum Concentrations) as a Function of Outside Air Temperature (OAT)

	One Step Procedure	Two Step Procedure	
OAT	**De-icing/Anti-icing**	**First Step: De-icing**	**Second Step: Anti-icing[1)]**
-3˚C (27˚F) and above	50/50 heated[2)] Type II or IV	Water heated to 60˚C (140˚F) minimum at the nozzle or a heated mix of Type I, II, or IV with water	50/50 Type II or IV
below -3˚C (27˚F) to -14˚C (7˚F)	75/25 heated[2)] Type II or IV	Heated 50/50 Type II or IV or suitable mix of Type I with Freezing Point (FP) not more than 3˚C (5˚F) above actual OAT	75/25 Type II or IV
below -14˚C (7˚F) to -25˚C (13˚F)	100/0 heated[2)] Type II or IV	Heated 75/25 Type II or IV or suitable mix of Type I with FP not more than 3˚C (5˚F) above actual OAT	100/0 Type II or IV
below -25˚C (-13˚F)	ISO Type II/Type 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 ISO Type I when Type II or IV fluid cannot be used (see Table 1).		

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 fluid and aircraft manufacturers recommendations.

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

Caution: An insufficient amount of anti-icing fluid, especially in the second step of a two step procedure, may cause a substantial loss of holdover time. This is particularly true when using a Type I fluid mixture for the first step (de-icing).

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

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

Table 3
Guideline for Holdover Times Anticipated for ISO Type I Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature (OAT)

OAT °C (°F)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
	Frost*)	Freezing Fog	Snow	Freezing Drizzle***)	Light Freezing Rain	Rain on Cold Soaked Wing
above 0° (32°F)	0:45	0:12–0:30	0:06–0:15	0:05–0:08	0:02–0:05	0:02–0:05
0° to -10° (32°F to 14°F)	0:45	0:06–0:15	0:06–0:15	0:05–0:08	0:02–0:05	
below -10° (14°F)	0:45	0:06–0:15	0:06–0:15			

ISO Type I Fluid/Water Mixture is selected so that the Freezing Point (FP) of the mixture is at least 10°C (18°F) below actual OAT.

Table 4
Guideline for Holdover Times Anticipated for ISO Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature (OAT)

OAT	ISO Type II Fluid Concentration Neat-Fluid/Water (Vol%/Vol%)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
		Frost*)	Freezing Fog	Snow	Freezing Drizzle***)	Light Freezing Rain	Rain on Cold Soaked Wing
above 0° (32°F)	100/0	12:00	1:15-3:00	0:20–1:00	0:30–1:00	0:15–0:30	0:20–0:40
	75/25	6:00	0:50–2:00	0:15–0:45	0:20–0:45	0:10–0:30	0:10–0:25
	50/50	4:00	0:35–1:30	0:05–0:15	0:15–0:25	0:05–0:15	
0° to -3°C (32° to 27°F)	100/0	8:00	0:35–1:30	0:20–0:45	0:30–1:00	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	0:15–0:45	0:05–0:15	0:15–0:25	0:05–0:15	
below -3° to -14°C (<27 to 7°F)	100/0	8:00	0:35–1:30	0:20–0:45	0:30–1:00**)	0:10–0:30**)	
	75/25	5:00	0:25–1:00	0:15–0:30	0:20–0:45**)	0:10–0:25**)	
below -14° to -25°C (<7 to -13°F)	100/0	8:00	0:35–1:30	0:20–0:45			
below -25°C (below -13°F)	100/0	ISO Type II fluid may be used below -25°C (-13°F) provided that the freezing point of the fluid is at least 7°C (13°F) below the actual OAT and the aerodynamic acceptance criteria are met. Consider the use of ISO Type I when ISO Type II fluid cannot be used. (see Table 3)					

Table 5
Guideline for Holdover Times Anticipated for ISO Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature (OAT)

		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
OAT	Type IV Fluid Concentration Neat-Fluid/Water (Vol%/Vol%)	Frost*)	Freezing Fog	Snow	Freezing Drizzle***)	Light Freezing Rain	Rain on Cold Soaked Wing
above 0˚C (>32˚F)	100/0	18:00	2:00–3:00	0:55–1:40	0:45–1:50	0:30–1:00	0:20–0:40
	75/25	6:00	0:40–2:00	0:20–1:00	0:20–1:00	0:15–0:30	0:10–0:25
	50/50	4:00	0:15–0:45	0:05–0:25	0:07–0:15	0:05–0:10	
0˚ to -3˚C (32˚ to 27˚F)	100/0	12:00	2:00–3:00	0:45–1:40	0:45–1:50	0:30–1:00	
	75/25	5:00	0:40–2:00	0:15–1:00	0:20–1:00	0:15–0:30	
	50/50	3:00	0:15–0:45	0:05–0:20	0:07–0:15	0:05–0:10	
below -3˚ to -14˚C (<27 to 7˚F)	100/0	12:00	2:00–3:00	0:35–1:15	0:45–1:50**)	0:30–0:55**)	
	75/25	5:00	0:40–2:00	0:15–1:00	0:20–1:00**)	0:10–0:25**)	
below -14˚ to -25˚C (<7 to -13˚F)	100/0	12:00	1:00–2:00	0:30–1:10			
below -25˚C (below -13˚F)	100/0	ISO Type IV fluid may be used below -25˚C (-13˚F) provided that the freezing point of the fluid is at least 7˚C (13˚F) below the actual OAT and the aerodynamic acceptance criteria are met. Consider the use of ISO Type I when ISO Type IV fluid cannot be used.					

Explanations to Table 3, Table 4, and Table 5

*) During conditions that apply to aircraft protections for **Active Frost**.
**) The lowest use temperature is limited to -10˚C (14˚F).
***) Use **Light Freezing Rain** holdover times if positive identification of **Freezing Drizzle** is not possible.

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 also be reduced when the aircraft skin temperature is lower than OAT. Therefore, the indicated times should be used only in conjunction with a pre-takeoff check.

4. ISO 11077, Aerospace — De-Icing/ Anti-Icing Self Propelled Vehicles — Functional Requirements

Reference: SAE ARP 1971, Aircraft deicing vehicle — self-propelled, large capacity. (No amendments are required at this time.)

5. ISO 11078, Aerospace — Aircraft De-Icing/ Anti-Icing Non-Newtonian Fluids, ISO Type II

The document is not up-to-date, see 1. introduction. Reference: SAE AMS 1428 A for latest "state-of-the-art", including type IV fluid.

6. Quality Assurance Programme

6.1 Station Quality Assurance Programme for Aircraft De-icing/Anti-Icing Operations

6.1.1 Introduction

This Programme, that ensures compliance with the relevant sections of JAR OPS 1.345, shall be introduced at all on-line stations where aircraft de-icing/anti-icing is either normally carried out, or where local conditions may periodically lead to a requirement for aircraft to be de-iced/anti-iced. Deficiencies, with regard to a station's local de-/anti-icing procedures, will be identified and subsequently actioned through this Programme, thereby ensuring that the required safety standards are maintained.

It is the responsibility of *] to ensure;

1. compliance with this programme,
2. that any outstanding deficiencies (negative responses) identified, are resolved as a matter of urgency,
3. that an effective audit programme is maintained. *] Official nominated by Operator)

6.1.2 Inspection requirements

Prior to the start of each winter period complete a 'Station Inspection Checklist', then, using this information, compile a 'Station Inspection Report'. Distribute copies of both documents to the addressees listed at the end of the checklist. Ensure that all negative responses are actioned, within the time scale annotated on the inspection report, then complete and distribute updated copies of both the appropriate pages from the 'Station Inspection Checklist' and the 'Station Inspection Report'.

When a new Station is to be opened up, an initial inspection must be carried out, before the start of operations. Firstly, complete a 'Station Inspection Checklist', then, using this information, compile a 'Station Inspection Report'. Distribute copies of both documents to the addressees listed at the end of the checklist. Immediately prior to the start of operations carry out a follow up inspection, ensuring that all negative responses have been actioned, then complete and distribute updated copies of both the appropriate pages from the 'Station Inspection Checklist' and the 'Station Inspection Report'.

6.1.3 Responsibilities

Responsibilities for the delegation, regulation and control of aircraft ground deicing/anti-icing operations are defined in Company procedure

The following responsibilities apply in regard to aircraft operating under snow and ice conditions:

6.1.3.1 *] shall be responsible for ensuring that the necessary infrastructure is in place at the Stations under their control, in order to maintain safe operations during ground icing conditions. *] Official nominated by Operator)

6.1.3.2 The Handling Agent/Airline responsible for the de-icing/anti-icing operation shall maintain vehicles/ equipment, fluids, training and procedures, in accordance with the relevant ISO specification (ISO 11075 thru 11078).

6.1.3.3 Personnel carrying out the de-icing/anti-icing operation are responsible for ensuring that the task is performed in accordance with the requirements detailed in ISO 11076 and the Aircraft Maintenance Manual.

6.1.3.4 The person responsible for final release/dispatch of the aircraft is responsible for ensuring that the aircraft has been de-iced/anti-iced in accordance with the requirements detailed in ISO 11076 and the aircraft Maintenance Manual and/or that relevant surfaces are free of frost, ice, slush and snow at the time of dispatch.

6.1.3.5 After receiving the Anti-icing Code, the pilot in command (PIC) is responsible for ensuring that the relevant surfaces remain free of frost, ice, slush and snow until takeoff.

6.1.4 Station inspection report

Complete a Station Inspection Checklist (see section 6.1.5), then use it to answer the following questions. A positive response will be required to each of the questions, in order to ensure compliance with JAR OPS 1.345.

6.1.4.1 Have personnel carrying out the de-icing/anti-icing operations and those responsible for supervising them, been trained to ISO standards, understand their responsibilities and are authorized/approved?

( ) Yes ( ) No (end date*])

6.1.4.2 Do personnel responsible for final release/dispatch of the aircraft before flight, have received training in 'Cold Weather Operations' (as specified in ISO 11076) and do understand their responsibilities?

( ) Yes ( ) No (end date*])

6.1.4.3 Have training records been maintained for the personnel detailed in items 6.1.4.1. and 6.1.4.2?

( ) Yes ( ) No (end date*])

6.1.4.4 Copies of ISO 11076 are available to and have been understood by, appropriate handling agency and airline staff?

( ) Yes ( ) No (end date*])

6.1.4.5 De-icing/anti-icing fluids have been approved, correctly stored/ maintained and release documents retained by the consignee?

( ) Yes ( ) No (end date*])

6.1.4.6 De-icing/anti-icing vehicles and equipment have been maintained to an approved maintenance schedule and can dispense Type II, III or IV fluid without degrading it beyond the required limits?

( ) Yes ( ) No (end date*])

6.1.4.7 Records of mixture strength and viscosity checks (viscosity checks only applicable to Type II, III and IV fluids) carried out on local de-icing/anti-icing fluids have been maintained and are available for inspection?

( ) Yes ( ) No (end date*])

6.1.4.8 Local responsibilities, as detailed on the previous page, have been clearly defined and understood by the appropriate personnel?

( ) Yes ( ) No (end date*])

Where a negative response is given to any of the questions, remedial action shall be initiated as a matter of urgency.

For each negative response specify an end date by which the deficiency will have been rectified.

On completion, distribute copies of the 'Station Inspection Checklist' (or updated pages from the checklist) and the 'Station Inspection Report', to the addressees listed at the end of the checklist.

*] Negative response only

6.1.5 Station inspection checklist

6.1.5.1 General information

Station:

Date of Inspection:

Type of Inspection:

( ) Initial

( ) Follow-up

( ) Annual

6.1.5.2 Provision of de-icing/anti-icing services

Company providing service:

Person in overall responsibility:

Day to day contact person:

Telephone number(s):

Telefax number:

SITA code:

Type of company:

( ) Airline

( ) Airport Authority

( ) Ground service company

( ) Military

( ) Other

Valid contract signed:

( ) Yes ( ) No

Detail companies that may be called on to provide ad-hoc de-icing/anti-icing operations and complete separate audit survey for each:

6.1.5.3 Operational responsibilities

Who performs the initial check? (check for the need to de-ice)

( ) Duty Engineer

( ) Flying Engineer

( ) Pilot-in-Command

( ) Handling Agent

( ) Other*]

Comments:

Who requests de-icing/anti-icing?

( ) Duty Engineer

( ) Flying Engineer

( ) Pilot-in-Command

( ) Handling Agent

( ) Other*]

Comments:

Who checks the quality of the de-icing/anti-icing operation?

( ) Duty Engineer

( ) Flying Engineer

( ) Pilot-in-Command

( ) Handling Agent

( ) Other*]

Comments:

Who checks that the appropriate surfaces are free of frozen deposits during final release/dispatch?

( ) Duty Engineer

( ) Flying Engineer

( ) Pilot-in-Command

( ) Handling Agent

( ) Other*]

Comments:

*] Specify detail

6.1.5.4 De-icing/anti-icing fluids

Specify all de-icing/anti-icing fluids likely to be used on company aircraft by the previously named company providing de-icing/anti-icing services:

Fluid A

Manufacturer:

Brand name/type:

Specification fluid released to:

( ) ISO 11075

( ) ISO 11078

( ) AMS 1424

( ) AMS 1428

( ) Other (specify)

Has the fluid been approved?

( ) Yes ( ) No

Fluid B

Manufacturer:

Brand name/type:

Specification fluid released to:

( ) ISO 11075

( ) ISO 11078

( ) AMS1424

( ) AMS 1428

( ) Other (specify)

Has the fluid been approved?

( ) Yes ( ) No

(Copy this sheet and re-identify to include any additional fluids provided by this company)

Have fluid release documents (Certificate of Conformity) been received from the fluid manufacturer for each fluid delivery/ batch and retained by the consignee for inspection, as necessary?

( ) Yes ( ) No

Have records of refractive index checks, carried out on fluids sprayed from each operational piece of de-icing/anti-icing equipment, been maintained and is the information available to the operators?

(Where vehicles are equipped with a proportional mix system, a representative range of samples, taken from the nozzle at typical operational settings, shall be checked.)

( ) Yes ( ) No

Have records of viscosity checks, carried out on samples of Type II, III and IV fluids sprayed from the nozzle of each appropriate piece of de-icing/anti-icing equipment at typical operational settings, been maintained and is the information available to operators?

( ) Yes ( ) No

Note: Where no such viscosity checks are carried out, it will be necessary that representative samples (minimum 1 liter) of both diluted and concentrated Type II, III, IV fluids, will be taken annually from each operational piece of de-icing equipment and be forwarded for analysis to *]. Samples shall be sprayed from the nozzle at a typical operational setting.

*] Nominated by Operator

6.1.5.5 Training

Do the personnel who perform the check for the need to de-icing receive training in cold weather operations?

( ) Yes ( ) No

What standard are they trained to:

( ) ISO 11076

( ) SAE ARP 4737

( ) Co. Procedure (specify)

( ) Other (specify)

Do they receive annual refresher training?

( ) Yes ( ) No

Have training records been maintained?

( ) Yes ( ) No

How is the success of the training evaluated:

( ) Theoretical Test

( ) Practical Test

( ) Theoretical and Practical Test

( ) No Test

Do the personnel carrying out the de-icing/anti-icing operation receive training in cold weather operations?

( ) Yes ( ) No

What standard are they trained to:

( ) ISO 11076

( ) SAE ARP 4737

( ) Company procedure (specify)

( ) Other (specify)

Do they receive annual refresher training?

( ) Yes ( ) No

Are training records maintained?

( ) Yes ( ) No

How is the success of the training evaluated?

( ) Theoretical Test

( ) Practical Test

( ) Theoretical and Practical Test

( ) No Test

Do the personnel who carry out the pre-departure/transit check receive training in cold weather operations?

( ) Yes ( ) No

What standard are they trained to:

( ) ISO 11076

( ) SAE ARP 4737

( ) Company Procedure (specify)

( ) Other (specify)

Do they receive annual refresher training?

( ) Yes ( ) No

Are training records maintained?

( ) Yes ( ) No

How is the success of the training evaluated:

( ) Theoretical Test

( ) Practical Test

( ) Theoretical and Practical Test

( ) No Test

Where required, Cold Weather Operations training for either company or agency personnel can be arranged through *]

*] Nominated by Operator

6.1.5.6 De-icing/anti-icing equipment (specify vehicle of each separate type/modification state)

Manufacturer/Model:

Number in Fleet:

Tank 1 Fluid *]:

Tank 2 Fluid *]:

Tank 3 Fluid *]:

Have vehicle tanks been labeled for fluid Type/Mix?

( ) Yes ( ) No

Fluid mixed:

( ) In Bulk Unit

( ) Manually in Vehicle

( ) By Vehicle Proportional Mix System

What temperature is the de-icing fluid applied at?

(Temp. at nozzle):

Can a hot mix of Type II, III or IV fluid with water be sprayed without degrading the fluid beyond required limits?

( ) Yes ( ) No

Can cold concentrate Type II, III or IV fluid be sprayed without degrading the fluid beyond required limits?

( ) Yes ( ) No

Can the de-icing fluid spray reach all appropriate parts of the aircraft?

( ) Yes ( ) No

Is the vehicle maintained to an approved Maintenance Schedule?

( ) Yes ( ) No

Manufacturer/Model:

Number in Fleet:

Tank 1 Fluid *]:

Tank 2 Fluid *]:

Tank 3 Fluid *]:

Are vehicle tanks labeled for fluid Type/Mix?

( ) Yes ( ) No

Fluid mixed:

( ) In Bulk Unit

( ) Manually in Vehicle

( ) By Vehicle Proportional Mix System

What temperature is the de-icing fluid applied at?

(Temp. at nozzle):

Can a hot mix of Type II, III or IV fluid with water be sprayed without degrading the fluid beyond required limits?

( ) Yes ( ) No

Can cold concentrate Type II, III or IV fluid be sprayed without degrading the fluid beyond required limits?

( ) Yes ( ) No

Can the de-icing fluid spray reach all appropriate parts of the aircraft?

( ) Yes ( ) No

Is the vehicle maintained to an approved Maintenance Schedule?

( ) Yes ( ) No

**] Type/concentration of fluid (Copy this sheet as required to include additional vehicle types)*

6.1.5.7 De-icing/anti-icing facilities

Where are de-icing/anti-icing operations carried out?

( ) Gate

( ) After pushback *)

( ) Remote/Centralized Position*

( ) End of Runway*

( ) Other (specify)

*) Is local NOTAM/lnstruction (AIP) available from the Airport Authority?

( ) Yes ( ) No

Is location negotiable?

( ) Yes ( ) No

Where de-icing/anti-icing is carried out at an area away from the gate, who certifies that the aircraft has been correctly de-iced/anti-iced and that appropriate surfaces are free of all forms of frost, ice, slush and snow?

Is fluid heated in a bulk unit?

( ) Yes ( ) No

If heated in bulk unit, what method of heating is employed and to what temperature?

How is fluid stored:

( ) Barrels

( ) Mobile Tank(s)

( ) Fixed Tanks

Are all storage tanks labeled for fluid type/mix?

( ) Yes ( ) No

Are all storage tanks checked in accordance with ISO 11076?

( ) Yes ( ) No

6.1.5.8 Accountability

Compiled by:

Position:

Signature:

Date:

6.1.5.9 Distribution

Copies to: *]

*] *Nominated by Operator)*

6.2. Fluid Sampling Procedure for Type II, Type III or Type IV Fluids

6.2.1 Introduction

To ensure that the necessary safety margins are maintained between the start of the de-icing/anti-icing operation and takeoff, the fluid used to both de-ice and anti-ice aircraft surfaces, must be in an "ex-fluid manufacturers" condition and at the correct concentration. Due to the possible effect of vehicle/ equipment heating and/or delivery system components on fluid condition, it is necessary for the sampling method to simulate typical aircraft application.

This section therefore describes the approved methods for collecting samples of Type II, III and IV fluids, sprayed from operational aircraft de-icing/anti-icing vehicles/equipment, prior to the necessary quality control checks (see section 6.3) being carried out.

6.2.2 Method

The application is made onto a clean polythene sheet (approx. 2m x 2m) laid directly on the ground, or onto an aluminum plate with associated recovery system. Depending on wind speed/direction at the time of sampling the polythene sheet may require to be weighted down at the edges, to prevent movement.

The distance between the spray nozzle and the surface shall be approximately 3 m. and the fluid shall be sprayed perpendicular to the surface.

Where different spray patterns and flow rates are used during routine de-icing/ anti-icing operations, samples shall be taken at typical nozzle settings (e.g. fine, medium or coarse) and flow rates.

6.2.3 Procedure

Select the required flow rate/spray pattern for the fluid to be sampled.

Spray the fluid to purge the lines and check the concentration of a sample, taken from the gun/nozzle after purging.

Should the refractive index indicate that the lines have not been adequately purged, repeat previous item until the concentration is correct for the fluid to be sampled.

(On certain vehicles it may be necessary to spray more than 50 l of fluid, before the lines have been completely purged).

Direct the fluid onto the sampling surface and spray an adequate amount of fluid to allow for a 1 liter sample to be taken.

Where a polythene sheet is used for sampling purposes, carefully lift the corners of the sheet and collect 1 liter of the fluid in a clean and dry bottle.

6.2.4 Reference fluid

For reference purposes, take a 1 liter sample of the base fluid from the storage facility and a 1 liter sample from the fluid tank of the de-icing/anti-icing equipment/vehicle being sampled.

6.2.5 Identification of samples

Attach a label to each sample, providing the following data:

- Brand name and type of the fluid (e.g. Kilfrost ABC-3/ Type II, Hoechst MPII/Type II, other).
- Identification of de-icing/anti-icing equipment/ vehicle (e.g. Elephant Beta DT04, Fixed Rig R001, other).
- Indicate flow rate and spray pattern.
- Detail the place where the sample was taken from (e.g. nozzle, storage tank or equipment/vehicle tank).
- Mixture concentration (e.g. 100/0, 75/25, other)
- Station (e.g. BAK, other)
- Calendar date sample was taken.

6.3 Test Procedure For Aircraft De-Icing/ Anti-Icing Fluids

6.3.1 Introduction

This test procedure for aircraft de-icing/anti-icing fluids is in compliance with the AEA station quality assurance programme for aircraft de-icing/anti-icing operations and with the relevant sections of JAR OPS 1.345. The procedure ensures that the required safety standards concerning the de-icing/ anti-icing fluids quality will be maintained. When discrepancies will be determined, further investigation has to be conducted prior to use of the fluid.

6.3.2 Delivery check for fluids

Before filling the tank with the de-icing/anti-icing fluid, it shall be made sure that the brand name and the concentration of the product mentioned in the packing list correspond to the brand name and the concentration mentioned in the storage tank.

A sample of the delivered product shall be taken and checked from each batch before the storage tank/vehicle is filled.

Make the delivery check for fluids as follows:

Type I fluid:

- Make a visual contamination check according to 6.3.6.1,
- make a refractive index check according to 6.3.6.2,
- make a pH-value check according to 6.3.6.3.

Type II and type IV fluids:

- Make a visual contamination check according to 6.3.6.1,
- make a refractive index check according to 6.3.6.2,
- make a pH-value check according to 6.3.6.3,
- make a field viscosity check according to 6.3.6.4.

6.3.3 Operational check for fluids

The fluid or fluid/water mixture sample shall be taken from the de-icing/anti-icing vehicle nozzles. Operational settings for flow and pressure shall be used. Before taking the sample, the fluid shall be sprayed long enough that the fluid flow and concentration are stabilized (see also section 6.2.3). The sample shall also be protected against precipitation. Make the operational check for fluids as follows:

Type I, type II, type III and type IV fluids:

- Make a visual contamination check according to 6.3.6.1.
- Make a refractive index check according to 6.3.6.2.
- Repeat the procedure for other certified fluid mixtures according to 6.3.6.1 and 6.3.6.2 in order to guarantee the correct function of the vehicle.

Note: checks should be performed at a daily basis.

6.3.4 Laboratory check for fluids

The laboratory check for the stored fluids shall always be made before the de-icing/anti-icing season and periodically during the de-icing/anti-icing season and upon request. The samples shall be taken from the storage tank and from the de-icing/ anti-icing vehicle nozzle.

For thickened de-icing/anti-icing fluids take the sample as described in fluid sampling procedure for type II, type III and type IV fluids (see section 6.2).

Perform the laboratory check for fluids as follows:

Type I fluid:

- Make a visual contamination check according to 6.3.6.1.
- Make a refractive index check according to 6.3.6.2.
- Make a pH-value check according to 6.3.6.3.

Type II, type III and type IV fluids:

- Make a visual contamination check according to 6.3.6.1.
- Make a refractive index check according to 6.3.6.2.
- Make a pH-value check according to 6.3.6.3.
- Make a laboratory viscosity check according to 6.3.6.5.

6.3.5 Field check for fluids

Field check for fluids shall be made always when station inspection is made. The samples shall be taken from the storage tank and from the de-icing/anti-icing equipment nozzle.

For thickened de-icing/anti-icing fluids take the sample as described in fluid sampling procedure for type II, type III or type IV fluids (see section 6.2).

Make the field test for fluids as follows:

Type I fluid:

- Make a visual contamination check according to 6.3.6.1,

- make a refractive index check according to 6.3.6.2,
- make a pH-value check according to 6.3.6.3.

Type II, type III and type IV fluids:

- Make a visual contamination check according to 6.3.6.1,
- make a refractive index check according to 6.3.6.2,
- make a pH-value check according to 6.3.6.3,
- make a field viscosity check according to 6.3.6.4.

6.3.6 Fluid test methods

6.3.6.1 Visual contamination check

- Put fluid from the sample into a clean glass bottle or equivalent,
- check for any kind of contamination (e.g. rust particles, metallic debris, rubber parts, other),

Any other equivalent method is permitted.

6.3.6.2 Refractive index check

- Make sure the refractometer is calibrated and clean,
- put a fluid drop taken from the sample or from the nozzle onto the test screen of the refractometer and close the prism,
- read the value on internal scale and use the correction factor given by the manufacturer of the fluid in case the temperature of the refractometer is not 20° C,
- compare the value with the figures from the fluid manufacturer,
- clean the refractometer and return it into its protective cover,

Any other equivalent method is permitted.

6.3.6.3 pH-value check

- take a piece of pH paper and put it in the fluid so that the pH paper becomes wetted with the fluid,
- remove the pH paper from the fluid and compare its color with the color of the table provided with the pH paper and read the corresponding pH value,
- compare the pH value with the figures from the fluid manufacturer,

Any equivalent method is permitted.

6.3.6.4 Field viscosity check

This check shall be made with the falling ball method, where two reference liquids represent minimum and maximum permitted viscosity values which will be compared with that of the tested product.

- Put the sample into a clean sample tube, insert the steel ball into the glass, fill it up completely and close it, return the sample tube into the test tool, turn the tool into vertical position and let all steel balls reach the lower end of the test tubes.
- When all 3 balls have reached the bottom of the tubes, turn the tool by 180 degrees to the inverse vertical position.
- The balls will move downwards with different speeds.
- The speed of the steel ball in the sample tube shall be between the speed of the two other balls or be equal to the speed of one of them.

Any other equivalent method is permitted.

6.3.6.5 Laboratory viscosity check

Perform the viscosity check in accordance with ASTM D 2196.

The measurements shall be carried out at rotation speeds of 0.3 rpm, 6 rpm and 30 rpm.

- The temperatures at which the measurements are made and the spindle number shall be reported.
- Compare the viscosity values with figures from fluid manufacturer.

Any other equivalent method is permitted.

6.4 Communication

To be de determined.

7. Standardized Training

To be determined.

8. Remote/Centralized De-Icing/ Anti-Icing Operations

To be determined.♦

Editorial note: This article (pages 134–150) is reprinted from the December 1992, *Flight Safety Digest*. It does not necessarily reflect current practices of Finnair, whose ground deicing program is featured; in addition, other technical specifications or references in the article may have changed since the original publication date, but remain informative. Nevertheless, the editorial staff believes that the spirit and quality of Finnair's program deserve recognition as an example to emulate.

Small Airline Continues to Win Big Battle Against Aircraft Ground Icing

A series of recent fatal air transport accidents attributed to icing has brought regulatory changes and increased awareness of the danger of aircraft ground icing. One operator, Finnair, has had a highly successful deicing program in operation for several years.

FSF Editorial Staff

Editors Note: Flight Safety Foundation was invited by Finnair's chief pilot, Capt. Urpo Koskela, to observe the airline's ground deicing/anti-icing operations in Helsinki. He arranged for Roger Rozelle, FSF director of publications, to meet with Capt. Jorma Eloranta, director of special projects and DC-10 captain, and other Finnair employees involved in ground operations.

Eloranta remembers when ice damaged jet aircraft engines and aviation industry officials used to say "there are no icing problems." But that isn't true today. After years of research, trial-and-error and relentless advocacy spearheaded by Eloranta, Finnair has become a world leader in winning the battle against aircraft ground icing. And it has made believers out of the industry.

Capt. Jorma Eloranta

"Performance of Type I deicing fluids wasn't satisfactory," said Eloranta as he leaned across the table where he had piled several stacks of papers and reports on the subject of icing — ammunition to outline his description of the "icing problem."

"They were not giving the protection required for the airlines, especially from 1975 when traffic congestion in airports was growing, and taxi and hold times were increased," said Eloranta, who is known among colleagues for his outspoken and stubborn approach to problem-solving.

He told how many persons did not — and still do not — understand that spraying glycol is not deicing.

"It is the heated water that melts the ice," he explained. "The glycol is only there to prevent the water from refreezing. One of the most important things in deicing is the capability of the equipment to produce enough pressure to break into the ice and force the hot water under the ice to lift it from the wing."

He said that Finnair worked closely with Lufthansa German Airlines, Boeing and the Von Karman Institute in Belgium to test fluids in actual operating conditions. The Association of European Airlines also supported that project, which used a Boeing 737 airplane.

"Type II anti-icing fluids supposedly had thickening agents that kept the fluid in a solid layer on the wing until it lost adhesion — about rotation speed — caused by the airflow over the wing. But the fluids continued to stick to the wings after rotation, which caused serious drag, reduced lift and increased stall speed."

During the testing program, it was determined that wing contamination was the likely culprit in "plenty of incidents where there had been some loss of control after takeoff, especially with the DC-9s that were not equipped with leading edge wing slats, and early model Boeing 737s."

A car is equipped with a simulated aircraft aluminum fuel tank on its roof that has a Vibro-Meter electrical ice sensor built into the tank's upper surface. Various data, including wind speed, ambient temperature, fuel temperature and other information are recorded on a computer in the car. Several Finnair first officers conduct tests to determine optimum operating characteristics and standards for the sensor.

Eloranta said the fluids were designed originally under laboratory conditions and researchers were not using real-world conditions. Some fluids, he said, were made to flow off the wing when air temperatures were close to freezing, not at temperatures well below that — a problem exacerbated when the wings were often 20 degrees cooler than the surrounding air. "The skin temperature of the wing must determine the correct deicing and anti-icing procedures, not the outside air temperature," he asserted. "When the outside air temperature and the wing surfaces are well below freezing, unnecessary spraying should be avoided. After an aircraft is refueled, the situation should be reevaluated because the temperature of the wing may change significantly."

He readily admitted that today's deicing and anti-icing fluid mixtures are better than those of several years ago, but added that none of them are sure cures against aircraft ground icing. He also disagreed with U.S. reluctance to use Type II fluids.

"They have low toxicity," he claimed. "They are biodegradable. The pollution in the air is more harmful than using glycol in deicing. As for slipperiness, when there is already snow and ice on the ground, how much more slippery can it get? I do not believe it increases slipperiness, especially with the big aircraft."

During the 1970s and early 1980s, other problems were taking place that were not readily explained. In 1981, after a takeoff from Zürich, an engine was shut down. The DC-9 returned to the airport and landed safely. An examination revealed significant damage to one engine, and minor damage to the other, but no one was able to suggest a cause.

It was not until a passenger, who was on the aborted Zürich flight, wrote a letter to Finnair and reported that he had seen a piece of ice break away from the wing during takeoff that there seemed to be an answer to the puzzling cause behind the incident.

"It didn't ring all the bells," said Eloranta about the passenger's report. "It gave us a new perspective, but we didn't understand it. Since that was the only overnight stop, we decided that the climate was a factor."

Finnair Crews Battle Icy Morning in Helsinki

Icing conditions. I wanted to see firsthand the deicing process into which Capt. Jorma Eloranta had immersed himself with near-evangelistic fervor.

He considered sending me further north, to Lapland, where memories from my school books of long ago called up images of thick snowdrifts, fierce cold winds, invisible bodies cloaked in fur coats and great antlered reindeer. Firsthand experience grew less appealing.

Jorma explained that winter weather tended to move across Finland in a north-south line to the east. If there was inclement weather in the north, chances were that it was reflected in the south. The best that we could do was hope.

Finally, a forecast called for snow, beginning at midnight, with the heaviest snowfall expected about 0300 and not ending until noon. Above-freezing temperatures would follow the snow. Jorma suggested that I make my own way to the airport no later than 0630, when morning operations for departing flights began in earnest. A call to the maintenance supervisor, who would be alerted to my arrival, would confirm the status of the ground deicing operations.

The snow began to fall earlier than forecast — shortly after 1800. There was a possibility that warm temperatures would melt the snow and there would be no snow or ice to remove in the morning. Jorma shrugged his shoulders and said, "Wait and see."

Just before I crawled into bed at midnight, I saw that snow was no longer falling outside the window of my hotel room. And at 0430, when I awoke, there was little evidence of snow in the hotel courtyard, so I telephoned the airport.

"Yes, there will be deicing," said the voice of the maintenance supervisor on the telephone. "We have already started."

Several incidents in the early 1980s — most at Zürich during cold weather — involved damage to engine fan blades that was not indicative of traditional foreign object damage (FOD). Damage suggested soft FOD — several blades in a section were bent, but not sharply.

Eloranta said that during that period, fuel was expensive in Zürich, so the airline calculated that it saved money by tankering fuel in the wings on the inbound flight from Helsinki to Zürich. The aircraft would be parked overnight in Zürich and return the next day to Helsinki.

It was determined, finally, that the fuel carried in the wing tanks was supercooled during the long high-altitude flight to Zürich. After landing, if there was moisture in the air or precipitation, clear ice formed on the wing. The ice was nearly invisible. During takeoff, the wings flexed at rotation and broke the ice free, and it flowed aft into the engines.

Moreover, he discovered that even in moist air as much as 15 degrees above freezing, clear ice could still form on the wings as the result of supercooled fuel. "We determined that this is not just a winter problem, and seasonal transitions created dangerous times for icing," explained Eloranta. "So we required the check for ice all year. It was the only way to put it in the minds of the people all the time to guarantee safety. Still, it took a couple of years for everyone to get used to the procedure. And you can imagine that they really called me 'crazy Eloranta.'"

He said that Finnair warned its pilots of the problem, and they reacted positively. "But the maintenance personnel were not so positive," he said. "They were being given a new set of duties to perform, but we had no tools or equipment to give them to remove the ice. And they didn't want to perform a physical check of the wing. I probably didn't present it to the maintenance people as well as I should have."

He said that Finnair management, especially Tero Mustakallio, then-vice president of operations, recognized the problem and its broad scope, and they gave him a free hand — and a nearly open-ended budget — to organize a testing program to learn as much as possible about fluids and the problems of ice.

As the phenomenon began to be understood by Eloranta, the airline circulated information about how to recognize the conditions that would form ice and to develop methods to reduce the problem, such as avoiding tankering of fuel and refueling the aircraft with warm fuel when possible. Pilots were also cautioned to reduce fuel in wing tanks so that the fuel did not come in direct contact with the upper surfaces of the wings. Bulletins cautioned pilots to respect holdover times, to watch for signs of refrosting and, if in doubt, to check through cabin windows. They were reminded that these checks should be performed even during taxi, along with guidance that they should avoid taxiing too close behind other aircraft, which could blow snow onto their own aircraft.

"We sent out warnings internationally," he said. "They went to McDonnell Douglas, the FAA [U.S. Federal Aviation

"Will there be any operations left for me to photograph?" I asked in an anxious voice.

"Oh yes, I think so," he said, conveying a shred of doubt.

I told him I was leaving immediately.

I was quiet during the cab ride with a sleepy-looking driver. Snow was all but absent in the city. I grew uneasy that opportunities to capture deicing procedures on film were disappearing as fast as the snow.

As we moved away from the concrete buildings and closer to the airport, snow began to appear on the roadside. My spirits rose, amid a bit of guilt for hoping for the icy, freezing weather into which fellow aviators would have to launch their aircraft while I remained safely on the ground.

I was directed to the communications center where ground operations were coordinated and the deicing trucks were assigned to specific aircraft to remove snow and ice. There were three supervisors on duty; behind them, through a large window, there were parked aircraft and deicing trucks moving on the ramp. And most important, there was snow. Snow was on the ramp. Snow was on the aircraft. Snow was on the vehicles. Snow was falling in the air.

Ice forms more readily over the wing root, where the cold fuel settles and there is more metal structure, including the landing gear components, which can contribute to colder temperatures.

Administration], Pratt & Whitney and aircraft operators. We told them that there was a potential risk to air safety by clear ice — nearly invisible to the eye — that could accumulate on aircraft wings under certain conditions while the aircraft was parked, if the ice was not discovered and removed before flight."

He said that the reactions to his warning were negative. "It was a real experience to travel to the United States and have a 15-minute meeting with an aircraft manufacturer and be told 'there are no problems,'" he said. "No one believed me. Everyone was totally negative. 'Crazy Eloranta' they called me. But I always got a cup of coffee.

"I was frustrated, of course. But I decided that I wouldn't give up easily. And we tried to get the word out through different channels, such as talking directly to other operators."

Eloranta said he believed that if Finnair had been a major carrier, his warnings might have been heeded sooner. He said in those days it was sometimes difficult to be heard, even in safety matters, "but it isn't true today."

Then, in 1985, a Finnair DC-9 aborted a takeoff at Helsinki. When the aircraft was taken back to the hangar, large sheets of clear ice were found on the wings. During the ground roll on uneven pavement, the wings flexed and the ice broke free and damaged both engines.

"Everyone was supposed to have known by now about this problem," said Eloranta, shaking his head from side to side. "Human factors were at work. The mechanic checked and saw ice and ordered deicing. Then the mechanic and pilot checked and confirmed that there was glycol on the surface. But it was covering a solid sheet of clear ice that hadn't been removed during deicing."

The gentle bend in the blades is characteristic of soft foreign object damage.

He said that the incident emphasized the need for proper equipment to help confirm the presence of ice and then to remove it. Hard hand tools were being used to remove the ice, and when the tools were not available, he said that everyone just had to wait until the ice melted.

This led to Finnair taking a more active role in developing a specialized deicing truck [see "Finnair Crews Battle an Icy

Coveralls — in a size large enough, with high rubber boots too large — had been set aside for me. I struggled into them, and with my cap I resembled a Finnair lineman. Worried that snow, ice and deicing trucks would disappear before favorable light appeared, in spite of some assurances that would probably not be the case, I asked to be launched to the ramp, where snow would fall on me.

The tuft of parachute cord moved freely, but underneath the snow, clear ice had formed, and the cord's base was frozen solid.

For the next several hours, patient Finnair employees escorted me wherever I wanted to go on the ramp. Our activities were coordinated by two-way radio with a supervisor in the communications center, who advised us where the three deicing trucks on duty were located on the ramp, which was bustling with activity. Aircraft were taxied to and from the gates, and deicing trucks, along with baggage trucks and catering trucks, were moving from aircraft to aircraft. And everywhere there were mechanics and flight crews scurrying in the waning darkness of dawn.

I discovered that the occupants of deicing truck No. 7 were friendly and spoke English. Veijo Lappalainen, 27, and Tomas Cannelin, 22, had been working as a team since they met each other during training when they joined Finnair "two winters earlier." [Many Finns seemed to measure time in winters rather than years.]

They had both completed three-year vocational training, and they were classified as "aircraft fitters." They hoped to move up the ranks to become mechanics. Both men had previous experience driving trucks, so they had no problems adjusting to driving a fully loaded

Morning in Helsinki"] to meet the rugged influences of Finland's weather on aircraft ground icing.

Eloranta also began to consider mechanical and electrical methods that could be used to detect ice on the wing "and again everybody just called me 'crazy Eloranta.'" He developed a small tab with alternating horizontal color bands that could be used to judge the depth of accumulated snow and ice on the wing. When clear ice was present, refracted light would distort the color bands. Triangles painted on the wings served a similar purpose.

A mechanic holds a sheet of ice taken from the wing of the Finnair DC-9 that aborted a takeoff at Helsinki-Vantaa Airport in 1985 after flexing wings on the uneven runway broke the ice free, and it was ingested into the engines.

He also used small tufts of parachute cord as indicators of clear ice on the wing; if the tufts didn't move, they were buried in clear ice. "But you have to be careful," he cautioned. "Sometimes the ice freezes only the base of a tuft and the remainder of the tuft is free. So this is not a foolproof device."

In the meantime, he said that he was able to convince Finnair to allow him to install an electrical ice sensor in the upper surface of the wing of a DC-9. That meant electrical wiring would have to be run inside the fuel tank. He said that it helped that he was then the DC-9 fleet captain.

"The manufacturer wasn't against the idea, but it wasn't positive either," Eloranta said, with a smile. "In Finnair, people said 'if it succeeds, it's our idea. If it goes wrong, it's crazy Eloranta's idea.'"

By 1987, Eloranta said that the installation was completed (after waiting two years, he said, to get permission to install it from the aircraft's manufacturer) in the coldest area of one wing where it was most likely to collect ice that would break off and be ingested into the engine.

"I felt challenged," he said. "I just had to convince people that this was the way to go. It was easier for me by then, because I had a good record for what I had done so far."

It was a comprehensive program that Eloranta described. The aircraft was flown on the line (the pilots supported the program) in actual operating conditions. Equipment was installed to monitor temperatures of outside air, wing surface and fuel. Pilots made notes on daily flight reports about how the ice detector system was working. McDonnell Douglas became an active participant in the program, and two companies that were involved in development of ice-detector sensors also worked closely with him.

"Finally, the industry recognized that many soft FOD incidents had to have been caused by clear ice," said Eloranta. "The industry was asking for my help, putting on seminars about the problem, publishing information on clear ice; and they weren't calling me 'crazy Eloranta' anymore. It was satisfying."

Hot water under pressure in a tight stream was required to break ice free from an aircraft wing.

deicing truck that weighed 27,000 kilograms (60,000 pounds), which included 6,500 liters (1,690 U.S. gallons) of water, 2,500 liters (650 U.S. gallons) of glycol Type I and 1,400 liters (360 U.S. gallons) of glycol Type II.

"We usually refill the truck at least once during our shift," said Veijo. "But when things are busy, we may fill up three or four times. Two or three times a year we get so much snow that there are not enough trucks and there are delays."

Water in the truck was heated, and the water temperature was maintained at about 90 degrees C (194 degrees F — 20 degrees F below boiling). It was mixed with a Type I glycol that was colored red to make it easier to see treated areas during the deicing process. The mix-ratio can be varied, but the men reported that usually equal quantities of water and glycol were maintained. The fluid that left the nozzle was probably about 60 degrees C (140 degrees F). A computer system in the truck cab kept track of the details of each deicing operation, such as the amount of each fluid that was used. This information enabled the crew to know when liquids had to be replenished and simplified Finnair's billing for the services the men performed.

The men were rarely idle, and even then it was only for a few minutes. I joined them as they moved from aircraft to aircraft and deiced each one. The driver did his best to position the truck for optimum spraying, while considering the direction of the wind and the physical location of the aircraft. The men had regularly alternated the cab-basket

He said that the idea behind the electrical sensor is his and that he has been working for the past seven years toward the goal of it becoming an integral part of production aircraft.

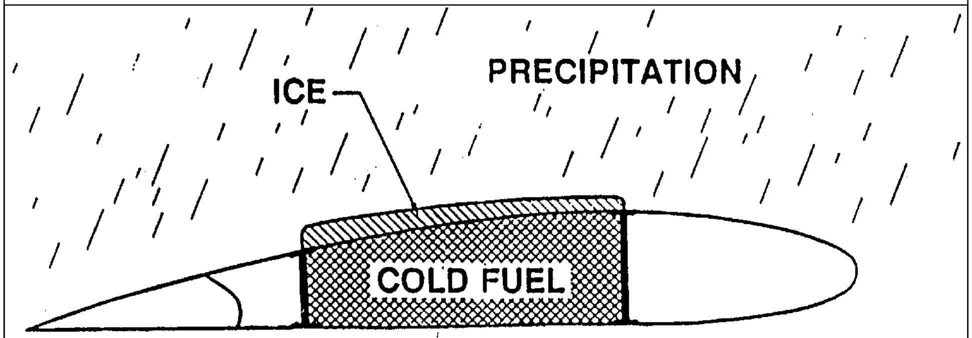
"My final goal has been that the status of the wing has to be determined in the cockpit with a backup advisory device that can provide go/no-go information just before takeoff," said Eloranta. "I'm convinced that this type of system works properly."

He expressed some ambivalence that Finnair would not share in the profits of commercial marketing of the product, an opportunity that he believes the company missed by not being more profit-oriented and not capitalizing on its knowledge. "Finnair has nothing," he said with a shrug of his shoulders, a frown on his face. "But it's not important. Really."

Finnair has continued an ongoing program to develop deicing and anti-icing procedures, including training of ground personnel and efforts to inform the aviation industry of its findings.

But he said that he was frustrated that the information was still not reaching the industry.

Typical Pattern of Fully Developed Ice from Cold Soaked Fuel Above Wing Fuel Tank. Air Temperature Outside the Fuel Tank Is Above Freezing



Not Necessarily a Cold Weather Phenomenon

Source: Finnair

"I felt so sorry about the SAS accident [Scandinavian Airlines System MD-80 made an off-airport landing on Dec. 27, 1991, after ice was ingested into both engines during takeoff], because it should have never happened," he said, with emotion between gritted teeth. "A hand check of the top surface of the wing was required, but it was not performed correctly so the ice was not discovered. At least the pilot was skilled and he was able to control the off-airport landing. No one was killed.

"Ground icing can happen to all aircraft. This is not an aircraft-type problem. The information about clear ice has been available for some time, but it is obviously not getting to everyone. As an industry, we cannot be proud of our performance in this matter." ♦

positions, so they each had a great deal of experience and an appreciation of all the factors that had to be considered in accomplishing the job.

Before any spraying was done, the truck crew confirmed that all doors and windows were closed to prevent the fluids from contaminating the floors with slippery liquids and soiling upholstery. They also made sure that control surfaces were in the proper position — usually neutral.

One man remained in the truck cab, which was equipped with controls that adjusted the mixture being sprayed. Tomas and I stepped into a basket that was lifted hydraulically with a system built into the truck, which promptly lifted us into the air — if necessary, more than 12 meters (40 feet) above the ground.

The wind was blowing at 16 knots from the southeast, and the air temperature was hovering around 0 degrees C to 2 degrees C (32 degrees F to 35 degrees F), and from our bird-like perch in the basket, we were well-exposed to the biting cold, made worse by a windchill temperature

Frost formed readily under the wings in the fuel tank area.

Icing Degrades Aircraft Performance; Fluids Provide Best Defense Against Ice on the Ground

Winter operations expose aircraft to weather conditions on the ground that can have a severe influence on aircraft performance, stability, control and how ailerons, rudders, sensors, flaps and landing gear mechanisms function. Most large aircraft with conventional airfoils and leading edge, high lift devices are considered less sensitive to contamination problems. Some aircraft without high lift devices appear to be more sensitive to wing contamination. Contamination of wing surfaces can result in pitching moment changes during takeoff rotation that could cause the airplane to act as if it were mistrimmed in the nose-up direction. After liftoff, degraded lateral stability calls for more and more control wheel input to keep the airplane from rolling, possibly followed by premature stall at lower than normal angles of attack.

A series of takeoff accidents attributable to wing ice accretion while the aircraft is on the ground, improper or inadequate deicing or anti-icing procedures and lack of aircrew awareness of the problems have focused attention on aircraft design and pilot training.

Regardless of the number of entities that may be involved in aircraft deicing and anti-icing, U.S. Federal Aviation Regulations (FAR) 121.629, *Icing Conditions*, and Joint Airworthiness Requirements (JAR) 91.527, *Operating in Icing Conditions*, place the ultimate responsibility on the pilot-in-command of the aircraft to ensure that the aircraft's wing and horizontal stabilizer are free of contamination and that the aircraft meets the airworthiness requirements for takeoff. Unfortunately, pilots in the cockpit cannot always see snow and ice on the wing or adequately judge the degree of contamination on aircraft that are not usually equipped with sensors that reveal the presence of contamination.

Specific Weather Conditions Cause Aircraft Icing on the Ground

There are several weather conditions that can cause icing problems.

- Freezing precipitation such as snow, sleet, freezing rain or drizzle can adhere to the aircraft's surfaces.
- Frost (including hoar frost) is formed from water vapor on surfaces that are at or below 0 degrees C (32 degrees F) and results in a crystallized deposit.
- Freezing fog creates clouds of supercooled water droplets that can form an ice deposit.
- Snow is precipitation in the form of small ice crystals or flakes that can accumulate.

The small brightly colored horizontal tab was buried in snow and clear ice, and provided a visual indication of contamination. It has no influence on the flight characteristics of the wing.

near -13 degrees C (9 degrees F). The extra layer of heavy waterproof clothing with a hood, eye goggles, hearing protector and gloves gave me the feeling of being well-equipped for my experience.

I stood in the basket with Tomas as he directed the fire-hose-like nozzle that sprayed the fluid onto the aircraft. I quickly recognized the rigors of this team's job. Billowing fog engulfed us. And in moments, the entire aircraft nearly disappeared below us into a grayish cloud.

Tomas communicated via a headset-intercom with Veijo, who slowly drove the truck to different locations around the aircraft that was being deiced to allow the basket operator to spray all the appropriate surfaces.

I took the thick gloves off my hands so I could operate my cameras, which were hung over my shoulders from straps and enclosed in clear plastic bags; the eyepieces and lenses protruded from holes I cut in the bags. Of course, moisture now covered all the lens surfaces. It didn't matter though, because I couldn't see through the goggles that were supposed to protect my eyes. Precipitation, which alternated between light rain and snow, was dripping on the outside of the goggles, and they were fogged on the inside. I removed the goggles, and while I groped to reach a clean handkerchief (to wipe lenses and goggles) through three layers of clothing — all requiring various stages of being

- Freezing rain is water condensed from atmospheric vapor that falls to the earth in supercooled drops and then forms ice.
- When the temperature of the aircraft wing surface is at or below freezing, rain or high humidity can form ice or frost.

Deicing and Anti-icing Defined

Deicing is the method by which frost, ice or snow is removed from the aircraft to clean the surface. Deicing fluid is usually applied heated at about 82 degrees C (180 degrees F) and sprayed under high pressure for maximum efficiency. The heat in the fluid melts frost as well as deposits of snow and ice. In heavier accumulations, the heat breaks the bond between the frozen deposits and the airplane structure, while the hydraulic force of the spray breaks the ice and flushes it off the aircraft. The deicing fluid may prevent refreezing for a short period of time, dependent on the temperature of the aircraft skin, ambient air temperature, the fluid used and the mixture's strength.

Anti-icing is considered a precautionary procedure to provide protection against the formation of frost or ice and accumulation of snow or slush on a clean surface for a limited period of time. Anti-icing fluid is usually applied cold to a clean aircraft surface.

Deicing/anti-icing is a combination of the two procedures just described and can be done either in one or two steps. When used for anti-icing, the fluid must be applied to a clean surface to provide a barrier against the buildup of frozen deposits.

One-step deicing/anti-icing is usually done with an anti-icing fluid that stays on the surface to provide a better anti-ice capability.

In a two-step procedure, deicing is followed by an application of anti-icing. The separate overspray of anti-icing fluid protects the clean surfaces and provides the greatest anti-ice capability.

Holdover time is the estimated time anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow or slush on the protected surfaces of an aircraft under average weather conditions. Many variables can affect holdover time, making it inadvisable to consider table times as absolute minimums or maximums because the actual time of protection can be affected by existing weather conditions. In heavy weather conditions, holdover time can be shortened. High winds or jet blast may degrade the protective film, and the

The mechanic gave a "thumbs-up" acknowledgment to the deicing truck crew that the wing surface was clean and there was no ice on it.

unzipped, unvelcroed and unbuttoned — I wiped a glycol-laden sleeve across my forehead. Some of the fluid made its way into my eyes and I was left with the minor stinging sensation that I had been warned about by the aircraft fitters.

Through all of this, Tomas continued spraying, but said: "This weather isn't bad at all. When it's really bad weather, it's tough working outside."

He sprayed the wings, starting forward of the leading edges and sweeping aft from each wing outboard, then inboard to the wing root. He said this procedure prevented the snow, which can be very heavy when wet, from putting too much strain on the outboard section of the wing. The tail surfaces were treated much the same as the wings.

Great care had to be taken not to direct the high-pressure stream into the cavities between the control surfaces and the airframe, Tomas said. He said there was a possibility that water could freeze in the cavities and jam the controls, and noted that slush being swept off the aircraft could create the same problem. This was one reason why it was important for the pilot to exercise the controls and confirm that they moved freely before takeoff. Anytime the deicing crew suspected such a condition, a rich mixture of anti-icing fluid and water was sprayed at a low-pressure rate into the area, he said.

Tomas explained that the nozzle was adjusted normally to concentrate the Type I spray in a high-pressure stream. When ice was on the aircraft, he said that he directed the hot fluid onto a particular section of the aircraft until it holdover time may be shortened considerably. Therefore, deicing experts recommend that indicated holdover times should be used only in conjunction with a pretakeoff inspection conducted by well-trained personnel.

Type I and Type II Fluids Vary

The Association of European Airlines (AEA), has designated fluids as either Type I or Type II to distinguish between plain deicers and anti-icers. Fluids have also been described as "Newtonian" or "non-Newtonian," which the Society of Automotive Engineers (SAE) defines as follows:

- Newtonian fluids are fluids whose viscosities are shear independent and time independent. The shear rate of a Newtonian fluid is directly proportional to the shear stress. The fluid will begin to move immediately upon application of a stress. It has no yield stress that must be achieved before flow begins. Type I fluids are considered Newtonian-type fluids.

- Non-Newtonian fluids are fluids whose viscosities are shear and time dependent and whose shear rate is not directly proportional to its shear stress. The fluid will not begin to move immediately upon application of a stress. It has a yield stress that must be achieved before flow begins. Type II fluids containing thickeners demonstrate a pseudoplastic behavior, which is defined as a decrease in viscosity with an increase in shear rate. Air must move faster across the wing surface before the thickened fluids will blow away.

Freezing Point Lowered in Type I Fluids

Type I fluids are generally considered deicing fluids and are effective because water has been heated to remove ice and snow. They have a lowered freezing point because glycol has been mixed with them. Such fluids work relatively quickly and do not cause damage to the aircraft surface. Type I mixtures contain at least 80 percent glycol that can be either monoethylene glycol, diethylene glycol, propylene glycol or a mixture of these glycols. The balance is made up of water, inhibitors and wetting agents. Inhibitors prevent corrosion, increase the flash point or comply with materials compatibility and handling requirements. Wetting agents, if used, allow the fluid to form a uniform film over the aircraft surfaces.

Glycols can be diluted with water. The freezing point of a water/glycol mixture varies with the content of water. Type I

melted the ice and heated the metal surface of the aircraft. He said that as the heat spread in the metal, the ice lost adhesion, and it became easier to remove it from the aircraft surface with the nozzle's high-pressure stream.

Spraying distance was less than 10 meters (33 feet), the maximum distance considered effective in maintaining thermal energy and a forceful flow. Spraying closer than 3 meters (10 feet) was avoided to prevent deformation of skin panels.

The fuselage was also sprayed from the top down, which allowed the fluid to drain down the sides of the fuselage. They reported that this reduced the likelihood of damaging the windows, which might be crazed or cracked by the sudden shock of warm fluid being sprayed directly on them, and it exposed gaskets and seals to less deterioration. They also acknowledged that cleaning the fuselage was particularly important with center-line mounted engines to prevent snow or ice from being ingested into the engine.

When they deiced beneath the wings to remove frost, they were especially cautious not to spray the fluid onto the wheels and brake assemblies, especially when they were hot. They said that they were careful not to spray into external probes, such as pitot heads and static vents, as well as exhausts and thrust reversers.

After an aircraft was deiced, a ground mechanic or his foreman was called to inspect the aircraft's surfaces. Sometimes a mechanic carried a ladder to the aircraft so he could climb onto the wing surface. Others drove a truck equipped with a built-in walkway that extended beyond the front end of the truck and could be located over a wing. Once on the wing, the mechanic removed a glove and put his bare hand onto the wing surface, usually near the wing root, to confirm that there was no ice on the wing. He also

Fog formed from the hot water used in deicing, but the Type I fluid did not seem to add any slipperiness to the snow-covered ramp.

fluids are usually diluted with water of the same volume. In a 50/50 mixture of water and glycol, the mixture has a lower freezing point than the concentrated fluid and, because of its lower viscosity, it flows off the wing more easily. It is generally agreed that the fluid does not present a hazard (i.e, increasing slipperiness) to runway operations.

Viscosity, or the measure of the resistance to flow caused by a fluid's internal friction, is dependent on temperature. Type I fluids show a relatively low viscosity that changes with temperature. The type of glycol used will also influence viscosity. Propylene-based fluids show higher viscosities than monoethylene-based fluids.

Type I fluids provide minimal holdover time, so they have little benefit in situations that require substantive anti-icing protection.

Type II Fluids Provide Best Anti-icing Protection

Type II fluids are considered anti-icing. They contain at least 50 percent per volume diethylene glycol or propylene glycol, different inhibitors, wetting agents and a polymer that acts as thickening agent to give the fluids a high viscosity, similar to that of molasses. About 45 percent to 48 percent of the mixture is water.

The viscosity of the fluid and the wetting agents allow fluid sprayed on the clean aircraft to adhere to the surface and act as a protective cover. If the wing already has snow or ice on it, the surface must be cleaned, usually with a Type I fluid before the Type II fluid can be applied.

During takeoff roll, the fluid flows off the airfoil and onto the runway to leave a clean surface. Preliminary tests show no evidence that small amounts of Type II fluid affect the runway condition to any appreciable extent. However, an aircraft design working group has noted that when a gel-like Type II anti-icing fluid is applied to an aircraft, not all of the fluid flows smoothly from the wings on takeoff. The Boeing Co. has advised that residue "generally results in measurable lift losses and drag increases" during takeoff.

Type II fluids have been used extensively in Europe for more than 20 years, while only a few major airlines have used Type II in the United States during the past few years. Some industry observers say some U.S. reluctance to accept Type II fluids has been because the products are proprietary to European airlines and the cost for Type II fluids can be double that of Type I fluids.

notified the aircraft's pilot that deicing had been performed and a hand check had confirmed that the wing was clear of ice.

"If he doesn't do a hand check for ice, he goes back to work in the hangar and loses his certificate for a year," said Veijo. Precipitation and temperatures hovering around freezing required that anti-icing fluids be applied, so a Type II solution was sprayed immediately onto the aircraft's clean surfaces.

The men said that the Type II fluid contained at least 50 percent glycol and a thickening agent; no coloring was added, so the fluid was clear [it appeared white to me] when it was applied. They said that it had to be handled properly, from storage to application, to prevent degradation of fluid performance. It was kept at about 20 degrees C (68 degrees F), which was much cooler than Type I.

To apply the Type II fluid, the nozzle's spray pattern was widened and the flow pressure was reduced. The fluid was applied until it was beginning to drip off the leading and trailing edges of the aircraft. After the anti-icing was completed, the driver advised the pilot that Type II fluid had been applied and in what percentage it had been mixed with water. He also reported the time that holdover had begun (the time started from when Type II was first applied to the aircraft).

The information provided to the pilot about deicing and fluids is mandatory and it is the final clearance for airworthiness; the mechanic's report is required by the cockpit checklist in Finnair's aircraft.

Moreover, as long as the aircraft remains at the gate, the ground mechanic is responsible for the airworthiness of the aircraft, and he must ensure that the aircraft remains free of ice. If, for example, there is a gate hold and the holdover time is exceeded, the mechanic must make sure that if any additional deicing or anti-icing is required, it will be performed. Even if there is no ice, conditions such as worsening weather and a continued gate hold may still require that the aircraft be deiced and, if required, anti-iced.

The deicing truck crew said that such situations do not occur very often because when the airport is busy, their supervisors go into the control tower and work closely with the controllers to coordinate the deicing procedures in concert with air traffic control arrivals and departures.

Comprehensive Deicing Procedures New to U.S. Airlines, And Questions Linger about Type II Fluids

While European airlines rely on AEA handbooks and holdover tables, both of which have proved to be highly reliable in standardizing their deicing/anti-icing operations, the U.S. has had no similar standards.

A Society of Automotive Engineers (SAE) committee, composed of representatives from aircraft manufacturers, makers of deicing equipment and fluids, the airlines, the Air Line Pilots Association (U.S.), the FAA and European experts, has been developing U.S. specifications for fluids, procedures and ground equipment used in deicing with both types of fluids. SAE also has been conducting various tests that include measuring how fast contamination accumulates on test strips of metal at airports and on wing surfaces. By working with airplane manufacturers, SAE anticipates publication of flight training materials to educate pilots.

Deicing experts are not in agreement that Type II fluids are the answer for all icing problems. Type I fluid performs well if used on the aircraft shortly before takeoff, or when freezing precipitation is not a factor. However, only a few U.S. airports allow for remote deicing near the departure end of the active runway. Taxiing long distances for takeoff from a deicing facility or waiting in line for takeoff limits the benefits of Type I deicing because of its short holdover time.

Local governments or airport authorities can impose restrictions that prevent U.S. carriers from using Type II fluids based on their concerns about liabilities, cost and damage to the environment from the runoff of the glycol. ♦

Sometimes Tomas and Veijo operated their truck together with another crew's truck to spray a large aircraft or to expedite a departure. When conditions are "bad" and an aircraft such as a DC-9 or MD-80 has several inches of snow on its surfaces, 1,500-2,000 liters (390-520 U.S. gallons) of fluid and about 20-minutes time will be required to remove the snow, they said. They agreed that a more routine task, such as removing frost from under the wings, may require only 40 liters (10.6 U.S. gallons) of fluid and a mere two-minutes time.

They explained that in their training they had been told that up to 3 mm (.12 inch) of frost and up to 2 mm (.08 inch) of ice could be allowed to remain on the underside of the wings (per manufacturer's operating approval) in the area of the fuel tanks. However, the pilot had to be informed of the condition so that he could make adjustments to takeoff calculations. Ice or frost outside the area of the fuel-tank area was not allowed and had to be removed.

Typically, an aircraft's engines were shut down (but when they were operating, they were at very low power settings); usually, the auxiliary power unit (APU) was operating. The two aircraft fitters used a minimum of fluid in the engine areas and avoided spraying into the engine inlets. Fluid sprayed into the APU created smoke in the cabin, a situation that they felt was embarrassing, as well as potentially harmful to the equipment. The driver communicated with the pilot and requested shutdown of the air conditioning system when spraying began in the empennage area.

During a brief period, when there were no aircraft to be deiced, the men talked about their work and sipped hot coffee poured from a thermos bottle. Both men spoke with confidence and seemed to have a clear understanding of not only what they did, but why they did it.

"We don't need sugar in the coffee," one of the fitters said with a big smile on his face. "It's sweet already." I understood what he really meant, because deicing fluid had finally made its way to my lips. It had a sweet taste.

During the non-winter periods, when deicing was not required, their duties changed, and they became responsible for changing seats, covers and cushions in the aircraft, or changing the physical configuration of an aircraft from tourist-class to business-class. They both agreed that they liked their work, but they looked forward to advancing and becoming mechanics "in a warm hangar."

The men recognized that they had very responsible positions that were related directly to the safety of Finnair's passengers, crews and aircraft. They expressed no misgivings about their responsibilities and said that they believed that they were well-equipped and well-trained to perform their work.

"We know our work is important," said Tomas and echoed by Veijo, each of them looking forward to a long shower and hot sauna at the end of the shift. "The pilots never hurry us to do the job. They treat us with respect."♦

— RR

New U.S. Rules Established for Aircraft Ground Deicing and Anti-icing

The U.S. Federal Aviation Administration (FAA) has established (by way of an Interim Final Rule, which became effective November 1, 1992) a requirement for Federal Aviation Regulations (FAR) Part 121 certificate holders to develop an FAA-approved aircraft ground deicing and anti-icing program and to comply with that established program anytime conditions are such that frost, ice or snow could adhere to an aircraft's wings, control surfaces, propellers, engine inlets and other critical surfaces.

The FAA deemed the rule necessary following a number of accidents attributed to aircraft icing. The FAA said that the U.S. National Transportation and Safety Board (NTSB) attributed at least 13 accidents in the past 24 years (Table 1, page 147) to the failure to deice aircraft adequately before takeoff. It was noted that contamination on the aircraft surfaces during takeoff was the cause or a contributing cause.

The NTSB has also issued 30 safety recommendations that cover such subjects as informing operators about the characteristics of deicing/anti-icing fluids; informing flight crews about ice formation after deicing; reviewing information that air carrier operators provide to flight crews on runway contamination and engine anti-ice during ground operations; requiring flight crew checks before takeoff if takeoff is delayed following deicing; emphasizing to air carrier maintenance departments the importance of maintaining ground support equipment; and requiring air carrier training programs to examine the effect of wing leading edge contamination on aerodynamic performance.

A contributing factor in the FAA's decision to publish this rule was a determination made during the 1992 International Conference on Airplane Ground Deicing that (under existing procedures at the time) the pilot-in-command might be unable to determine effectively whether the aircraft's critical surfaces were free of all frost, ice or snow prior to takeoff.

The FAA rule is designed to provide an added level of safety to flight operations in adverse weather conditions and to provide enhanced procedures for safe takeoffs in such conditions.

The new FAA rule also follows a July 23, 1992, Notice of Proposed Rulemaking (NPRM) that allowed only 15 days for comments. Many industry observers felt that this was insufficient time to develop adequate in-depth responses. The new Interim Final Rule allows for additional comments until April 15, 1993. Those comments must be marked Docket No. 26930 and should be mailed in triplicate to: Attention: Rules Docket (AG-10) Docket No. 26930, Federal Aviation Administration, Office of the Chief Counsel, 800 Independence Ave., SW, Washington, DC 26930. The FAA states that it will consider all comments received and that it will make changes to the Interim Final Rule, if warranted.

An Unofficial Official Reports on Winters in Finland

The bellboys grunted as they passed the first bag into the back of his cab, and he chuckled. He was my kind of taxi driver. Even in their foreign tongue, I understood that they were all complaining to the somewhat rotund taxi driver dressed in a thin leather jacket and warning him about the very heavy bags.

"Schwarzenegger," I spoke, and lifted my arms as a weightlifter might, and the two bellboys laughed loudly. (Later, I wondered if they laughed at the joke or perhaps at the mighty sag that must have been pushed over my belt as I raised my arms.) The taxi driver chuckled and carefully arranged the computer bag (11 kilos), camera bag (14 kilos), and the soft bag (22 kilos) of clothing and other paraphernalia, now stuffed with booty [trinkets] acquired during my trip, and stacks of paper from Capt. Eloranta.

Taxi drivers, in my experience, are often great storehouses of local knowledge, and during the ride to the airport to catch the Finnair flight to New York, the next stop on my way home to Washington, D.C., the driver of the black Opel lived up to my expectations.

The 60-year-old man, with thinning dark hair, a balding forehead and dark-rimmed glasses, spoke in halting and thickly accented English, but he was easily understood. He said that he had been driving cabs for 30 years. Yes, sometime by the middle of those years he could say that he knew all of Helsinki's streets. But today, he had forgotten many of them. He chuckled.

Asked about the weather, he said the newspaper had reported that the Finnish winter of 1991-1992 was the shortest one during this century — a mere 47 days had been recorded with temperatures of freezing or below. He offered his own weather observations based on a digital weather system installed at his home within the city: The lowest temperature recorded by the device during the winter was -17 degrees C (1 degree F) and the highest was +9 degrees C (48 degrees F) he said.

The Interim Final Rule reads as follows:

The Amendment

In consideration of the foregoing, the Federal Aviation Administration amends Part 121 of the Federal Aviation Regulations as follows:

PART 121 — CERTIFICATION AND OPERATIONS: DOMESTIC, FLAG, AND SUPPLEMENTAL AIR CARRIERS AND COMMERCIAL OPERATORS OF LARGE AIRCRAFT

1. The authority citation of Part 121 continues to read as follows:

Authority: 49 U.S.C. 1354(a), 1355, 1356, 1357, 1401, 1421-1430, 1472, 1485, and 1502; 49 U.S.C. 106(g) (revised, Pub. L. 97-449, January 12, 1983).

2. Section 121.629 is amended by revising current paragraph (b) and by adding new paragraphs (c) and (d) to read as follows:

121.629 Operation in icing conditions.

(b) No person may take off an aircraft when frost, ice, or snow is adhering to the wings, control surfaces, propellers, engine inlet, or other critical surfaces of the aircraft or when the takeoff would not be in compliance with paragraph (c) of this section. Takeoffs with frost under the wing in the area of the fuel tanks may be authorized by the Administrator.

(c) Except as provided in paragraph (d) of this section, no person may dispatch, release, or take off an aircraft any time conditions are such that frost, ice, or snow may reasonably be expected to adhere to the aircraft, unless the certificate holder has an approved ground deicing/anti-icing program in its operations specifications and unless the dispatch, release, and takeoff comply with that program. The approved ground deicing/anti-icing program must include at least the following items:

(1) A detailed description of:

(i) How the certificate holder determines that conditions are such that frost, ice or snow may reasonably be expected to adhere to the aircraft and that ground deicing/anti-icing operational procedures must be in effect;

(ii) Who is responsible for deciding that ground deicing/anti-icing operational procedures must be in effect;

(iii) The procedures for implementing ground deicing/anti-icing operational procedures;

(iv) The specific duties and responsibilities of each operational position or group responsible for getting the aircraft safely airborne while ground deicing/anti-icing operational procedures are in effect.

(2) Initial and annual recurrent ground training and testing for flight crew members and qualification for all other affected personnel (e.g., aircraft dispatchers, ground crews, contract personnel) concerning the specific requirements of the approved

He said that the next shortest winter had been recorded in 1929–1930, when there were 58 days of freezing temperatures or below. That one, he said, was followed by the longest recorded winter, in 1931, when there were 210 freezing days.

He said that the population seemed evenly divided about the cause or causes behind the unusually warm weather. News reports blamed dust from the recent volcanic eruption of Mount Pinatubo in the Phillippines. Others, he said, just followed an old Finnish tradition based on waiting: We wait for spring, we wait for summer, we wait for winter. And this year we wait for winter next year. He chuckled.

During the 18-kilometer (11-mile) ride to the Helsinki-Vantaa Airport, he explained that a river over which the road passed was usually frozen with thick ice. Today, he said, it is already moving to the sea, a trip that usually doesn't begin until early May. And a short distance from Helsinki, a historic fortress is built on an island. During winter it is usually accessible by auto. This year, he said, a boat is the preferred transportation to the island.

Winter has been difficult for the children. When they get skates and skis, there is no place to use them, he said — for three years it has been like this.

The white birch trees — plentiful and sharing the roadside with modern, low-rise business buildings and an occasional small, wooden cottage — hugged dark earth and brown grasses. Occasionally, there were small mounds of dirty snow, apparently the remnants of piles cleared from roads. No winter here.

And how is winter in Washington, he asked, as he placed my bags, without a grunt or a visible sign of strain, on the concrete outside the terminal?

Just like it is here in Helsinki, I said. Maybe colder.

He took the 130 Finnish marks from me for the fare, which included a small tip, waved goodbye and wished me a safe trip. And he chuckled. ♦

— RR

Table 1
13 Jet Transport Accidents Attributed to Ice Accumulation During Past 24 Years

Date	Airline	Aircraft	Location	Fatalities	Survivors
12/27/68	Ozark Airlines	DC-9	Sioux City, Iowa, U.S.	0	68
02/25/69	LTU International Airways	F-28	Lapenhagen, Netherlands	0	11
01/26/74	THY	F-28	Cumaovasi, Turkey	66	7
01/13/77	Japan Airlines	DC-8	Anchorage, Alaska, U.S.	5	0
11/27/78	Trans World Airlines	DC-9	Newark, New Jersey, U.S.	0	83
01/13/82	Air Florida	B-737	Washington, D.C., U.S.	78	9
02/05/85	Airborne Express	DC-9	Philadelphia, Pennsylvania, U.S.	0	2
12/12/85	Arrow Air	DC-8	Gander, Newfoundland, Canada	256	0
11/15/87	Continental Airlines	DC-9	Denver, Colorado, U.S.	28	54
03/03/89	Air Ontario	F-28	Dryden, Ontario, Canada	24	45
11/25/89	Korean Air	F-28	Kimpo, Korea	0	48
02/17/91	Ryan International Airlines	DC-9	Cleveland, Ohio, U.S.	2	0
12/27/91	Scandanavian Airlines System	MD-81	Stockholm, Sweden	0	129

Source: U.S. Federal Aviation Administration

program and each person's responsibilities and duties under the approved program, specifically covering the following areas:

(i) The use of holdover times;

(ii) Aircraft deicing/anti-icing procedures, including inspection and check procedures and responsibilities;

(iii) Communications procedures;

(iv) Aircraft surface contamination, (i.e., adherence of frost, ice, or snow) and critical area identification, and how contamination adversely affects aircraft performance and flight characteristics;

(v) Types and characteristics of deicing/anti-icing fluids;

(vi) Cold weather preflight inspection procedures;

(vii) Techniques for recognizing contamination on the aircraft.

(3) The certificate holder's holdover timetables and the procedures for the use of these tables by the certificate holder's personnel. Holdover time is the estimated time deicing/anti-icing fluid will prevent the formation of frost or ice and the accumulation of snow on the protected surfaces of an aircraft. Holdover time begins when the final application of deicing/anti-icing fluid commences and expires when the deicing/anti-icing fluid applied to the aircraft loses its effectiveness. The holdover times must be supported by data acceptable to the Administrator. The certificate holder's program must include procedures for flight crew members to increase or decrease the determined holdover time in changing conditions. The program must provide that takeoff after exceeding any maximum holdover time in the certificate holder's holdover timetable is permitted only when at least one of the following conditions exists:

(i) A pretakeoff contamination check, as defined in paragraph (c)(4) of this section, determines that the wings, control surfaces, as defined in the certificate holder's program, are free of frost, ice, or snow;

(ii) It is otherwise determined by an alternate procedure approved by the Administrator in accordance with the certificate holder's approved program that the wings, control surfaces, and other critical surfaces, as defined in the certificate holder's program are free of frost, ice or snow;

(iii) The wings, control surfaces, and other critical surfaces are redeiced and a new holdover time is determined.

4. Aircraft deicing/anti-icing procedures and responsibilities, pretakeoff check procedures and responsibilities, and pretakeoff contamination check procedures and responsibilities. A pretakeoff check is a check of the aircraft's wings or representative aircraft surfaces for frost, ice, or snow within the aircraft's holdover time. A pretakeoff contamination check is a check to make sure the wings, control surfaces and other critical surfaces as defined in the certificate holder's program, are free of frost, ice, and snow. It must be conducted within five minutes prior to beginning takeoff. This check must be accomplished from outside the aircraft unless the program specifies otherwise.

(d) A certificate holder may continue to operate under this section without a program as required in paragraph (c) of this section, if it includes in its operations specifications a requirement that, any time conditions are such that frost, ice or snow may reasonably be expected to adhere to the aircraft, no aircraft will take off unless it has been checked to ensure that the wings, control surfaces, and other critical surfaces are free of frost, ice and snow. The check must occur within five minutes prior to beginning takeoff. The check must be accomplished from outside the aircraft.

NPRM Comments Reviewed

A review of some of the comments the FAA received to its July NPRM and FAA's response to those comments may be useful in understanding how the FAA decided what the Interim Final Rule should contain:

Takeoff Remains Pilot's Decision

Several respondents expressed concern that nothing in the proposed rulemaking should change the existing policy that places the ultimate responsibility for a takeoff on the pilot-in-command. Others believed that the dispatcher's role in releasing an aircraft, possibly including the determination of holdover times jointly with the pilot-in-command, should be made clear.

The FAA agreed that nothing in its rule would change FAR Part 91.3(a), which states that, "The pilot-in-command of an aircraft is directly responsible for, and is the final authority as to the operation of that aircraft." The new approach is to give the pilot-in-command (and certificate holders) additional guidance, developed procedures and, under certain conditions, ground personnel support in determining the aircraft's airworthiness in potential icing conditions. Even though the pilot-in-command and supporting personnel will receive additional training and the certificate holder establishes additional procedures, FAA states that the ultimate authority and responsibility for the operation of the aircraft remain with the pilot-in-command."

The FAA did not agree that the role of the dispatcher needed to be addressed any further in paragraph 121.629(c), which clearly states that "no person may dispatch … an aircraft any time conditions are such that frost, ice, or snow may reasonably be expected to adhere to the aircraft, unless the certificate holder has an approved deicing program and unless the dispatch, release, and takeoff comply with that program."

The FAA said the dispatcher is part of the team that will initially determine whether it is safe for a flight to be dispatched in existing and anticipated icing conditions. However, a dispatcher might not have all or the most current icing and weather information that becomes available to the pilot-in-command and that is used by that pilot in initially determining and possibly changing a holdover time.

Pretakeoff Checks Aimed At Contamination

Numerous questions were raised concerning the pretakeoff contamination check and the optional outside check. The most frequently raised concern was that the proposed five-minute limitation is impractical because most airports did not have a facility at a location close enough to the end of the takeoff runway to perform these checks. Other concerns were: pretakeoff contamination checks with the engines running (particularly propeller drive aircraft) are inherently unsafe; a pretakeoff contamination check should be required following ground operations in all icing condition operations, not just when holdover times are exceeded; checks from within the aircraft should be allowed in all cases, according to some commenters, and should never be allowed, according to others.

The FAA responded that the rule would allow a takeoff after the expiration of a holdover time if a check conducted within five minutes prior to takeoff determined that the wings, control surfaces, and other critical surfaces were free of frost, ice, or snow and if the check was "accomplished from outside the aircraft unless the program specifies otherwise." The rule would also allow for a check that must be conducted within five minutes prior to takeoff as an optional alternative for a certificate holder who does not have a deicing program, but this check must be accomplished from outside the aircraft.

The FAA said that those who commented confused the pretakeoff contamination check in 121.629(c)(3) and (c)(4) with the outside-the-aircraft check that is required by 121.629(d). The following describes the different procedures and checks in the final rule:

Pretakeoff check. This check is completed any time the aircraft is deiced or anti-iced and is integral to the use of holdover times. It is accomplished within the holdover time and is normally accomplished by the flight crew from inside the aircraft who will check the aircraft's wings or representative aircraft surfaces for contamination. For clarification, and to be consistent with the intended use of holdover timetables, this check is included in 121.629(c)(4).

Pretakeoff contamination check. This check is to determine the condition of an aircraft after the maximum holdover time has been exceeded and may be performed from either inside or outside the aircraft depending on the type aircraft, lighting and weather conditions, as specified in the certificate holder's approved program. When the pretakeoff contamination check is used, it must be accomplished within five minutes of beginning the takeoff. The aircraft's critical surfaces, as defined in the certificate holder's program, must be checked.

Part 121.629(d) outside-the-aircraft check. This check is required only if a certificate holder does not have an approved program and must be accomplished from outside the aircraft within five minutes of beginning the takeoff.

The FAA points out that none of the aforementioned checks are substitutes for any Airworthiness Directive requirements. As to the feasibility of the five-minute limitation on pretakoff contamination checks or outside-the-aircraft checks, the FAA recognized that in many situations neither of the checks may be viable at certain airports, at certain peak departure times or during certain weather conditions. The FAA observed that in the long term, as airport remote deicing and checking facilities are built or expanded, those checks would be more feasible. However, the FAA pointed out that the five-minute limitation would arise in only two situations. One is when a certificate holder does not have an approved ground deicing/anti-icing program. The other is after a maximum holdover time is exceeded.

The FAA assumed that a certificate holder would elect not to have an approved ground deicing/anti-icing program only if it concluded that it would be more cost-effective to operate without such a program. In electing not to have an approved program, the certificate holder has to take into consideration the possibility that it would have to delay or cancel flights in icing conditions. As a practical matter, the FAA did not expect that such a certificate holder's operations under its rule would differ significantly from its past operations.

The outside-the-aircraft check conducted within five minutes of beginning takeoff would be the only alternative means of operating in icing conditions in the absence of an approved program under paragraph (c). Even if a certificate holder was to use the deicing facilities of another certificate holder who has an approved program, the first certificate holder could not use the holdover times of the deicing certificate holder. This, said the FAA, is because the five-minute limitation under 121.629(d) recognizes that pilots who operate without an operator-approved program, as compared to pilots who operate under an approved program, may lack proper training and knowledge to determine effectively whether the aircraft is free of contamination prior to takeoff. Without the proper training provided under an approved program, the pilot-in-command in possession of a holdover time could easily make an uninformed decision in attempting to take off. In the absence of an approved program, the FAA will require the aircraft to be checked from outside the aircraft within five minutes of beginning takeoff.

To certificate holders with an approved program where a maximum holdover time is exceeded, the FAA noted three alternatives. The aircraft can be redeiced and a new holdover time established. The aircraft can take off if the certificate holder has obtained approval of an alternate procedure (e.g., a new technology) that is capable of determining that the wings, etc., are clean. The third alternative is to accomplish a pretakeoff contamination check and begin the takeoff within five minutes of completing the check. If the takeoff could not be initiated within the five-minute limitation, and if no alternate procedure has been established, the worst-case scenario for the certificate holder is that the aircraft must be redeiced and a new holdover time established. The FAA did not consider the potential delay to be unacceptable given the risks of taking off when there would be considerable uncertainty about the possibility of aircraft surface contamination.

Underwing Frost Allowed

Comments expressed concern that the proposed rule could lead to rescinding previous FAA policy that allows takeoffs with a small amount of frost on the underside of the wing in the area of fuel tanks when consistent with the aircraft manufacturer's operating and servicing instructions.

The FAA responded that it did not intend to change its policy of permitting takeoff with small amounts of frost on the underwings caused by cold soaked fuel within aircraft manufacturer-established limits accepted by FAA aircraft certification offices and stated in aircraft maintenance manuals and aircraft flight manuals. Language was added to the final rule to make it clear that takeoffs with frost under the wing in the area of the fuel tanks are permitted if authorized by the Administrator. The FAA said that affected certificate holders should include the type of aircraft involved and justification for these operations, including manufacturer-supplied data showing how these operations are safely accomplished, as part of their proposed deicing program.

Type-specific Holdover Times Not Required

More than half of the comments addressed the issue of the use of holdover times, and the majority of the comments concerned the following issues: Appropriateness of holdover times being specific either to a certificate holder or to an aircraft type; use of holdover times as mandatory rather than as guidelines; and determining or changing holdover times.

The FAA's rule requires certificate holders to develop holdover times with data acceptable to the FAA. The FAA acknowledged that the only holdover time data currently available to the industry and acceptable to the FAA are those developed by the Society of Automotive Engineers (SAE) and the International Organization for Standardization (ISO). Studies have been initiated to develop more precise holdover timetables, and, as new data become available, new tables will be developed and made available to the industry. Certificate holders may develop other tables, but they should be aware that the FAA may need considerable time to verify the acceptability of newly developed tables.

SAE/ISO-developed holdover times have been compiled into tables that are specific to fluid type (Type I or Type II) rather than being specific to any aircraft. The tables use outside air temperature (OAT) ranges, fluid concentrations or freezing point (FP) limitations and the general type of contamination (i.e., frost, freezing fog or rain, snow and rain on a cold soaked wing) to determine an approximate holdover time range.

The tables state that "the responsibility for the application of these data remains with the users" and caution that they are for use in departure planning only and that they shall not be used as substitutes for a pretakeoff check. The tables provide approximate time ranges and are subject to individual interpretation. The FAA determined that takeoff after exceeding any maximum holdover time in a certificate holder's table is permitted only when acceptable alternatives are taken to ensure that the aircraft surfaces are free of contamination.

Several comments objected to the proposed language of 121.629(c)(3), which states that an approved deicing program must include "the certificate holder's holdover times, specific to each aircraft type" and stated that holdover times should not be aircraft-type specific. Most believed that holdover times should be standard for all certificate holders.

In response, the FAA repeated that the only holdover timetables available were those developed by the SAE/ISO and that these times are not aircraft-specific. Because holdover times are generally given as acceptable ranges, the FAA said, it is conceivable that a rational analysis could lead to an acceptable deicing program in which type-specific holdover times are provided within the ranges of acceptable holdover times given in the SAE/ISO tables. In the final rule, the language does not prohibit the use of type-specific holdover times, but they are not required.

Several comments stated that holdover times were developed as guidelines and not as mandatory times. One comment suggested that the holdover guidance provided in current and proposed advisory circulars was too general to be of genuine use and that the FAA should commission SAE to recalibrate its charts to match standard U.S. National Weather Service reporting criteria.

The FAA reiterated that each certificate holder must develop its own holdover times with data acceptable to the FAA and, if the maximum holdover time developed by the certificate holder is exceeded, other actions must be accomplished before the aircraft can take off. The FAA will continue to work with the NWS to enhance reporting criteria.

Dispatchers commented that the proposed rule did not adequately reflect the role of the dispatcher under existing Part 121 rules. They recommended that the dispatcher's role be reflected in the rule language and that the dispatcher and pilot-in-command must work together in determining holdover times. One suggested that the dispatcher would be in a better position to enforce holdover times than the pilot-in-command. Several suggested that the proposed rule placed an unreasonable burden on the pilot-in-command, particularly in a case where the pilot would be expected to increase or decrease the determined holdover time based on changing conditions. Other comments suggested that it would be better to have each airport establish one central agency to determine and revise, as appropriate, holdover times for all certificate holders operating at that airport.

The FAA responded that the information required to determine or change the proper holdover time includes outside air temperature, type and concentration of fluid, weather conditions, and time the last application of fluid began. This information is most readily available to the pilot-in-command, allowing the pilot to determine quickly from the holdover timetable the appropriate holdover time. The certificate holder's program may include holdover coordination with the dispatcher, but the information required to determine or change the proper holdover time may be available only to the pilot-in-command.

Certificate Holder Determines Type of Fluid Used

Several comments recommended that the FAA mandate or at least encourage the use of Type II fluids, while others raised questions about using Type II fluids, ranging from potential environmental problems to higher cost and limited availability.

The FAA responded that it was up to the certificate holder to determine the type of fluids it would use, as each type has its benefits and intended usage. The FAA said that all the information available indicated that there is no availability problem with Type II fluids.

Other general comments included statements that NTSB accident statistics related to icing problems do not address the thousands of successful takeoffs made annually during icing conditions and that the NTSB investigation of the 1982 Air Florida accident showed that improper engine thrust was the main cause of the accident and that perhaps icing problems alone were not the problem. The FAA responded that the NTSB's recommendations are based on its accident investigations and its other studies and do, in effect, consider successful operations. In its investigation of the Air Florida accident, NTSB cited as one of the probable causes the flight crew's decision to take off with snow and ice on the aircraft's airfoil surfaces.

Another comment suggested that the FAA should include in the docket any studies that it relied on to reach its conclusions, such as the conclusion that non-slatted aircraft wings are more susceptible to lift loss than slatted aircraft wings. The FAA stated that it has included in the docket a summary of wind tunnel tests of hard leading edge wings and slatted leading edge wings completed by the U.S. National Aeronautics and Space Administration's Lewis Research Center, although the difference in accident history of these designs may not be fully explained by design differences. Pilot techniques, said the FAA, including rotation rates and angles, are also important factors to be considered in assessing stall propensity, along with the rotation speed and the initially computed climb speed. A single factor has not been isolated as the major explanation for differences in accident rates, the FAA said.♦

In addition to the persons quoted in the icing-related articles, the following Finnair personnel contributed information:

Rolf Selin, supervisor; Paul Ruponen, supervisor; Tina Kunnas, secretary, flight simulator department; Antero Harras, head of security; Jussi Ekman, pilot; Tapani Vanttinen, supervisor, line stations maintenance and training; Paavo Turtiainen, former manager line maintenance; Tapani Hakola, head of simulator department; and Kaj Grundstrom, vice president, investor relations & cooperation projects.

Tapio Kilpinen, director of Finland's Civil Aviation Administration, also contributed information.

ICEMAN: State-of-the-art Ground Deicing/ Anti-icing Training on CD-ROM

Flight Safety Foundation, which was a major contributor in the technical development of this product, strongly advocates comprehensive training for the ground deicing and anti-icing of aircraft.

ICEMAN, an interactive multimedia training aid, addresses U.S. Federal Aviation Administration (FAA) Advisory Circular 120-60, *Ground Deicing and Anti-icing Program*, training requirements for obtaining FAA approval of an air carrier's winter operations program. AC 120-60 grew out of attention focused on aircraft accidents associated with inadequate ground deicing and anti-icing after a USAir Fokker F-28 stalled during takeoff at LaGuardia Airport in Flushing, New York, U.S., on March 22, 1992.

In CD-ROM format for IBM-compatible computers running Microsoft Windows® 95, ICEMAN has been updated and streamlined for the 1997–98 winter season. Customized versions are being developed for several major domestic airlines, while affordable generic versions are available for flight crews and ground personnel. Canadian and other international variations are under development. A version tailored to corporate aviation combines affordable pricing with the thorough training developed for use by major carriers.

Stuart Matthews, president, chairman and CEO of Flight Safety Foundation, said that ICEMAN's training methods promote uniform communication and consistent procedures. "A 'common language' is especially important when pilots, ground crews and dispatchers all perform essential tasks in ground deicing and anti-icing of aircraft. Standardized training also contributes to reliable results when contractors, including fixed-base operators (FBOs), are responsible for application of deicing and anti-icing fluids."

ICEMAN was developed by AVEDSOFT, a Colorado-based software development company, and in cooperation with the Foundation.

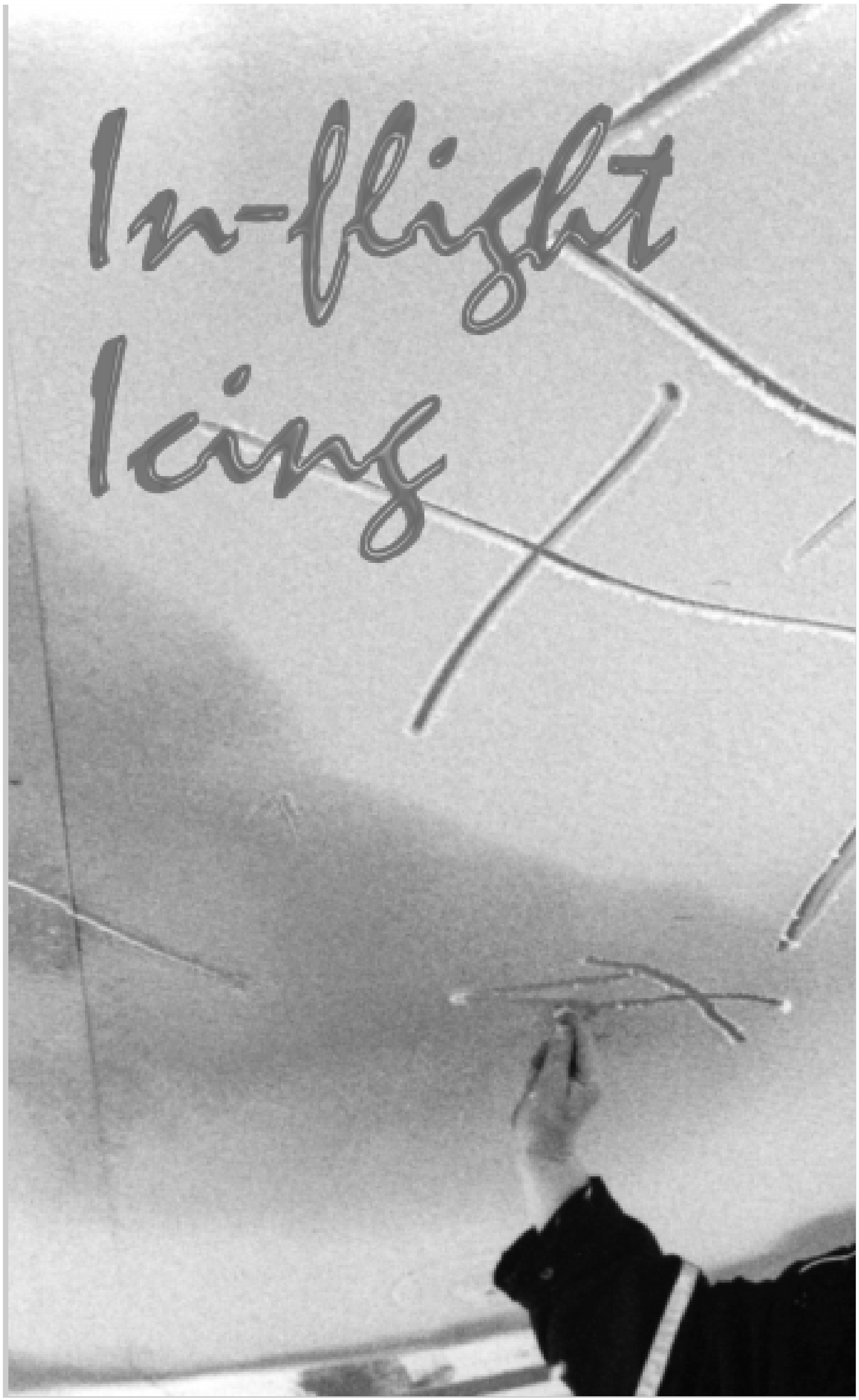
Like other interactive multimedia products, ICEMAN allows trainees to move at their own pace in a convenient location — even with a laptop computer in a pilots' lounge during a layover. The software exemplifies the trend toward delivery of computer-based training using off-the-shelf personal computers, rather than expensive media suites that often require specialized computer personnel for operation.

ICEMAN's self-directed training is appropriate for adults of all educational backgrounds and attention spans. If a trainee decides to end a training session, he or she can leave an electronic bookmark permitting return to the same point in the training later. A combination of video, photographs, animation and narration presents the training in a form conducive to understanding. Multimedia lets students learn by virtually doing. Consistency is achieved in both the content and delivery of training, and students have the opportunity to repeat a task until they are comfortable with and competent at it.

ICEMAN's format permits easy reproduction, transmission from one location to another, compact and inexpensive storage, easy editing, augmentation and transformation, and rapid access by anyone. Students receive immediate feedback on incorrect understanding or performance.

Initial training in ICEMAN takes about 45 minutes for the airline flight crew version and the corporate flight crew version, and about 75 minutes for the ground crew version. Individual users can progress more quickly or slowly, based on their knowledge base. Multiple modules cover topics such as the clean aircraft concept; aircraft deicing and anti-icing procedures; the types, purposes and characteristics of Type I, II and IV fluids; holdover times; and proper checks, communications and situational awareness. The ground personnel version covers additional information on using refractometers and other deicing equipment. Industry experts, Flight Safety Foundation and FAA resources contributed to the accuracy and thoroughness of ICEMAN's contents.♦

For more information about ICEMAN, contact Kathryn Beller, AVEDSOFT vice president, at (303) 768-8960, by fax at (303) 768-8965 or by e-mail at kbeller@avedsoft.com.


In-flight
Icing

Inflight Icing: Certification vs. Reality … Where the Difference Can Mean Life or Death

Jan W. Steenblik
Technical editor, Air Line Pilot

I remember from my days in Lester's school that this temperature is supposedly ideal for icing conditions. Yet so far there is no evidence of ice, and I am even a little disappointed because the most I have ever seen is a delicate tracery across the windshield. … ♦ In less than a minute, I am … sweating. Things are beginning to happen very fast … not good things. … ♦ The air is still not unduly rough, but … the ship is beginning to porpoise in an unbelievable manner. Hughen is having a very rough time with the controls. Now the sweat is dripping from his cheekbones, and he is breathing heavily. ♦ "Try Knoxville again! On the loop!" ♦ His voice is controlled, but there is the constriction of fear beneath his control. The ordered words come like pistol shots. ♦ … My attention is caught by the airspeed. One hundred and twenty miles an hour! Only a few minutes before, we were cruising at 170. Yet Hughen has not touched the power. A queasy sensation passes through my stomach. The blood rushes to my head until my cheeks feel aflame. My hands are suddenly hot and throbbing. I catch myself working my lips. These I know to be the beginning signals of fear. I cannot seem to stop it. ♦ Because my lips insist on making these silly formations, I cannot say anything about the airspeed. One hundred and twenty. We must not lose any more. With a load of ice, this ship will cease to fly at 100, possibly even sooner. … ♦ A sudden, terrible shudder seizes the entire airplane. At once Hughen shoves the throttles wide open and the nose down. ♦ The shuddering ceases. Hughen wipes the sweat from his eyes. ♦ "She almost got away from me!" ♦ The incipient stall has stolen an additional 300 feet from our altitude. We must not risk a repetition, and yet the engines cannot remain at full power forever. But Hughen leaves the throttles where they are.

… from Fate Is the Hunter*, by Ernest K. Gann*

Novelist and former airline pilot Ernest K. Gann was lucky. Although he and Capt. Hughen were obliged to "shake [fear's] filthy hand" many times that night, Gann and his mentor and their eight passengers all survived, without a scratch, his harrowing initiation into the rigors of winter flying as a DC-2 copilot during the 1930s. Gann eventually told the tale of that nearly fatal flight in his magnificent nonfiction bestseller, *Fate Is the Hunter*.

As F/O Gann and Capt. Hughen struggled to stay alive long enough to divert to Knoxville in their ice-laden DC-2, they were in serious trouble. Yet they were able to stay aloft for a relatively long period of time. After they landed, mechanics cut the ice off the airplane with fire axes.

The DC-2/-3-era airplanes could do that — i.e., take on a frightening amount of ice and still stagger through the sky. With forgiving airfoils like the DC-3's Clark Y, a little ice might not bring the airplane down. Pilots grew used to slogging through it and pressing on.

In fact, many pilots today believe, based on their past experiences flying Beech 18s, DC-3s, or older turboprop regional airliners or corporate aircraft with less sensitive airfoils, that slogging through it is just part of life on the line in winter. They might not realize that, in the more efficient aircraft they now fly, they may be closer to putting their *life* on the line.

Simmons 4184 — A Wake-up Gong

The Oct. 31, 1994, high-speed inverted dive of Simmons Airlines Flight 4184 — an ATR 72 — into a soybean field near Roselawn, Ind., hammered a wakeup gong that was heard around the world.

During the weeks and months that followed that accident, the design, certification, and operation of ATR 42 and 72 turboprop regional airliners came under intense public, news media, and government scrutiny.

A joint U.S.-French special certification review conducted after the SAI accident showed that the ATR 42 and 72 met current certification requirements for flight into icing conditions. The SAI accident thus raised anew some old and disturbing questions about the fundamental soundness of the certification process that FAA and foreign airworthiness authorities use to approve civil transport airplanes for flight in icing conditions.

In November 1994, ALPA's Executive Central Air Safety Chairman, Capt. David J. Haase (TWA), named an ALPA Inflight Icing Certification Working Group (IICWG). Chaired by F/O Steve Green (TWA), a member of ALPA's national Accident Investigation Board and a former regional airline pilot with thousands of hours of turboprop experience, the IICWG also includes Capt. Steve Erickson (SAI) and Capt. Scott McKee (TWE), both experienced ATR pilots, and F/O Jim Bettcher (DAL), a former Air Force test pilot.

One of the prime responsibilities of the ALPA IICWG is to develop recommendations to give to FAA for overhauling the icing certification regulations.

As the ALPA group has dug deeper into these issues during the last several months, it has found a disturbing series of shortcomings in icing certification.

The Problem

Since the days of the DC-2, more than 60 years ago, manufacturers have equipped transport airplanes with airframe anti-icing and deicing systems. These systems have never been intended to cope with all types or severities of inflight icing.

The problem, says F/O Green, is the "serious disharmony between the criteria used for certification of an aircraft and the criteria used for dispatch and operation of that aircraft."

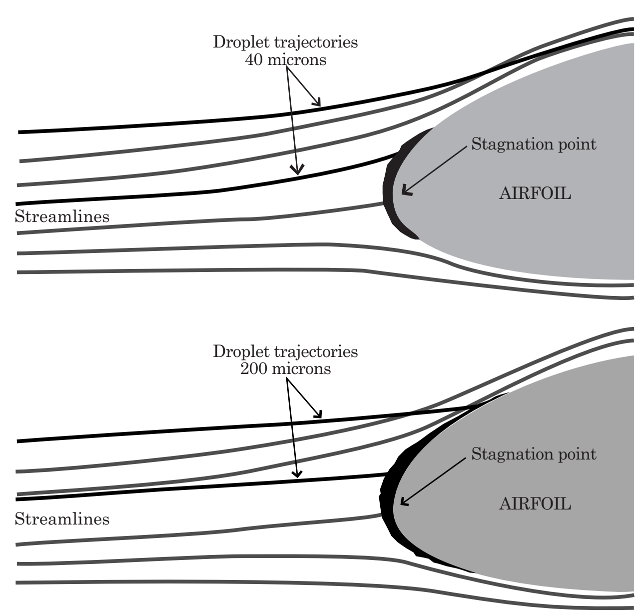
Regarding certification, he continues, "the FAA certification requirements concern only the icing protection systems on the aircraft, and then only in a limited icing environment. The FARs do not contain any requirement or specification for certificating the airplane to any standard of handling or performance in icing conditions — though the certification requirements for handling and performance with an *un*contaminated wing are extensive."

To fully appreciate the inadequacies of FAA's current certification requirements for airframe icing protection systems, we need to take a few moments to review the basic aerodynamics of icing in flight.

Imagine that we are flying from clear air into cloud that contains icing conditions: The wing cleaves the cloud like a dull knife, parting the air, redirecting it, pushing it down, creating lift. Most of the air molecules flow over or under the wing in smooth, curving paths called streamlines (see Fig. 1).

A few of the air molecules smash into the most forward part of the leading edge, milling around in a frenzied eddy in front of what engineers call the stagnation point of the airfoil. Some air molecules whirl in other small, tight eddies, caught between the upper wing surface and the laminar air flow above the wing.

The cloud we just entered is a fine mist of water droplets — we won't quantify their size yet — suspended in the air. The droplets are "supercooled" — colder than 32 degrees F, ready to freeze on the first solid object they touch.



Size of supercooled droplets greatly affects severity and location of wing icing in flight. Larger droplets, having more inertia, penetrate streamlines more easily and hit the wing farther aft.

Source: ATR; Rendered by: William A. Ford

Figure 1

Most of the tiny droplets, having little inertia, follow the streamlines closely; the wing rushes smoothly between the droplets, pushing them out of the way without touching most of them. Some of the droplets penetrate the confused air immediately in front of the stagnation point, strike the leading edge, and freeze.

We fly on into a region where some of the droplets are bigger. The bigger droplets do not follow the streamlines as well as the smaller droplets do. Some of the bigger drops hit the upper and lower surfaces of the leading edge and freeze. The largest drops strike the wing farther aft than the smaller drops. Some of the larger drops also splash and run aft along the wing before they freeze completely. If they are big enough, they will actually strike the wing behind the area protected by the deicer boot.

The ice continues to accrete on the wing, contaminating the wing's so carefully designed shape. The streamlines close to the wing begin to break up; more and more of the wing's energy is wasted on sending air molecules swirling in unproductive eddies.

The wing's lift decreases, and drag increases.

This is the classic icing scenario — which Capt. Hughen and F/O Gann experienced in an extreme form. Gann wrote that Capt. Hughen struggled to keep the DC-2 under control — but his struggle was to maintain slow flight on the edge of a stall, not a struggle to outmuscle a control wheel gone berserk.

The DC-2 wallowed along, slow and sloppy. It did not, however, abruptly pitch over, overpowering the pilots' attempts to pull the control yokes rearward (tailplane icing stall; see "Turboprop Tailplane Icing," *Air Line Pilot*, January 1992). The airplane did not abruptly roll over, its ailerons suddenly deflecting nearly to their stops despite the pilots' struggle to center them (SAI Flight 4184).

As tests conducted during the special certification review of the ATR 42/72 — plus pilot reports involving these and other turboprop regional airliners — have shown, certain ice shapes on the wing can suddenly, dramatically change the airplane's handling characteristics. In the worst case, a relatively small amount of ice on the wing can make the airplane difficult or even impossible to control — without first causing a significant increase in drag and decrease in lift.

So far we've used only relative terms such as "tiny," "bigger," "colder," and "farther aft" to describe the mechanics of icing. We haven't put hard numbers on these elements of the icing equation. For better or worse, FAA has.

FAA Certification Requirements

FAA's current certification requirements for large transport airplanes' icing protection systems are contained in FAR Part 25, Appendix C.

Appendix C, the "Bible" for FAA and manufacturers, spells out the range of environmental conditions that manufacturers must show their equipment can handle satisfactorily. Appendix C defines a different environmental icing "envelope" for each of two conditions —

(1) *continuous* maximum icing (stratiform clouds), and

(2) *intermittent* maximum icing (cumuliform clouds).

For each of the two basic cloud types, Appendix C shows in diagrams the maximum intensity of the atmospheric conditions the icing protection systems must deal with — the limits of the certification envelope.

The edges of each envelope are set by a combination of three variables:

(1) the liquid water content of the cloud,

(2) the ambient air temperature, and

(3) the diameter of the cloud droplets.

The phrase "diameter of the cloud droplets" sounds about as plain and simple as you can get; it isn't. We'll come back to that.

But first, let's look at the two icing "envelopes" diagrammed in Appendix C: The envelope for continuous maximum icing (the kind found in stratiform clouds) assumes that the icing conditions exist (1) across a horizontal distance of 17.4 nautical miles (nm), (2) in an altitude band as much as 6,500 feet deep, and (3) within a pressure altitude range from sea level to FL220 (see Fig. 3, page xx).

This envelope also covers a temperature range from +32 to -22 degrees F, cloud liquid water content ranging from 0.04 to 0.80 grams/cubic meter (about 1/125 to 1/6 teaspoon of water per cubic meter), and a "mean effective droplet diameter" (MED) of 15-40 microns. One micron is one thousandth of a millimeter; one millimeter is about half the diameter of the lead in a wooden pencil.

For intermittent maximum atmospheric icing conditions — the type associated with cumuliform clouds — the Appendix C certification model assumes a horizontal extent of 2.6 nm, a pressure altitude range from 4,000 feet to FL220, and a mean effective droplet diameter of 15-50 microns (maximum size 10 microns larger than the continuous maximum icing limit). For these conditions, the model assumes a liquid water content of 0.25-2.9 grams/cubic meter (1/20 to 6/10 teaspoon of water per cubic meter), and ambient air temperature of +26 to -40 degrees F.

For each type of icing, an Appendix C diagram plots cloud liquid water content as a function of cloud horizontal extent — liquid water content decreasing as cloud horizontal extent increases — for cloud conditions more extensive than the 17.4-nm stratiform cloud and the 2.6-nm cumuliform cloud.

In other words, Appendix C assumes that you might fly through a longer cloud than the model's standard icing cloud, but that the longer the cloud, the less water it would hold per cubic meter. The model thus implies that the wing would be exposed to icing conditions for a longer period of time but that the *rate* of icing accretion would be slower.

The diagram stops at 310 nm for stratiform clouds and 5.21 nm for cumuliform clouds.

The rationale for these seemingly arbitrary numbers still used in today's certification requirements lies buried in the distant past. Appendix C is largely based on technical reports prepared by the National Advisory Committee for Aeronautics (NACA, predecessor to NASA) more than 40 years ago.

One of those sources, NACA Technical Note No. 1855, "Recommended Values of Meteorological Factors to be Considered in the Design of Aircraft Ice-Prevention Equipment," was published in March 1949 — when the queens of the fleet were early-model Connies and DC-6s.

Why Appendix C Is Flawed

Appendix C may be dry and arbitrary, but on the surface, it seems perfectly straightforward. Unfortunately, applying Appendix C is not.

Particularly vexing are several issues relating to droplet size. Larger supercooled droplets pose more of a threat to aviation safety than do smaller droplets because, as described earlier, larger droplets are more likely to hit the wing — and to hit it farther aft.

If the droplets strike the wing aft of the anti-icing/deicing devices (on turboprops, pneumatic boots) on the leading edge, and/or run back aft of the devices, ice may accrete on the wing where the flight crew is powerless to get rid of it.

When Appendix C was developed, it was assumed that very, very few large droplets ever occurred in nature. Researchers are now beginning to believe that assumption was erroneous and that large droplets may occur somewhat more frequently.

As discussed earlier, Appendix C requires manufacturers to design their airframe icing protection systems to manage icing conditions created by supercooled droplets up to 40 microns for continuous maximum icing conditions and up to 50 microns for intermittent maximum icing conditions.

But those droplet sizes aren't even close to those of freezing drizzle, which FAA's *Aircraft Icing Handbook* defines as supercooled droplets in the 200- to 500-micron range, and those of freezing rain, which is about 1,000 microns (1 millimeter) in diameter (see Fig. 2, page x).

In other words, no transport category aircraft is certificated for flight in freezing drizzle or freezing rain. The meteorologists who analyzed the weather data recorded at the time and location of the SAI Flight 4184 accident concluded in their report to NTSB that they had found "a high probability that supercooled drizzle drops were present in the ATR-72 holding pattern."

Muddled Measurement Techniques

Appendix C's failure to deal with large droplets represents a limitation that is becoming more serious as research continues. But even within the envelope, Appendix C is rife with problems.

For one thing, the industry uses different standards and methods for measuring droplet diameter that can lead to significantly different results.

Each of these methods attempts to deal with the fact that no cloud contains droplets all exactly the same size. Measuring the number, concentration, and size of the droplets is not easy.

Appendix C refers to "mean effective droplet diameter" (MED), an archaic term that was used decades ago with measurement devices that are now obsolete. The principal difference between MED and the parameter generally used today in icing certification tests — mean volumetric diameter, or MVD — is that measuring MED requires using statistical assumptions about the actual distribution of the droplet sizes in the cloud.

Measuring MVD, on the other hand, requires no such statistical assumptions; the measuring probes protruding from the flight test aircraft can measure, in real time, all but a short range of droplet diameters.

So far, no definitive work has been done to correlate the two measures.

Recently, moreover, ALPA's icing team learned that different methods used by manufacturers to calculate MVD may yield results that differ by as much as two to one.

"This is simply intolerable," F/O Green charges. "It calls into question the validity of all icing certification."

Droplet "Populations"

Mean volumetric diameter, or MVD, may be superior to the older MED measure of droplet size, but it is the subject of a statistical controversy that has significant implications for aircraft icing certification — especially in light of what more has been learned about turboprop wing icing since the SAI Flight 4184 accident.

"Understanding the meaning of 'mean volumetric diameter' is important," F/O Green cautions.

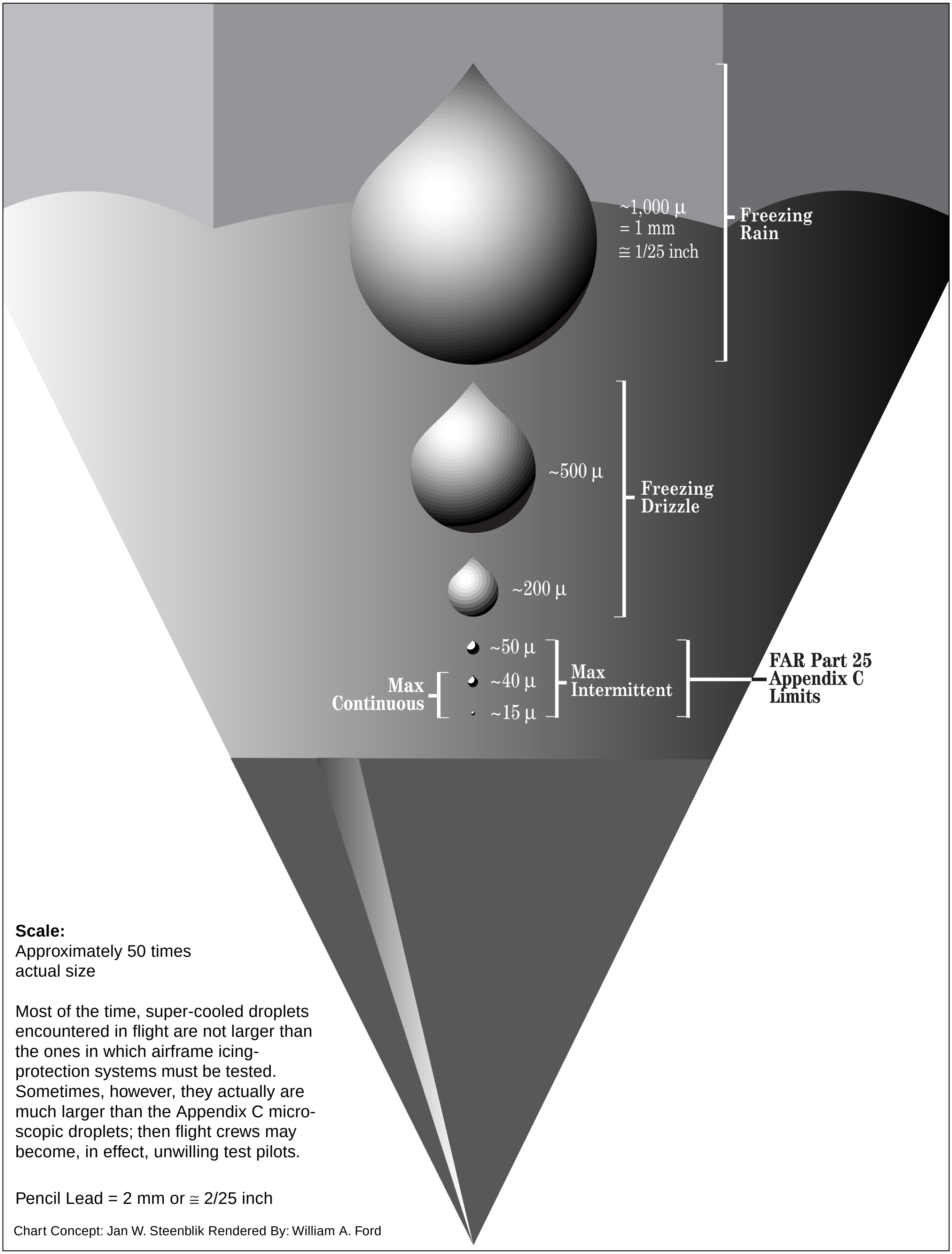
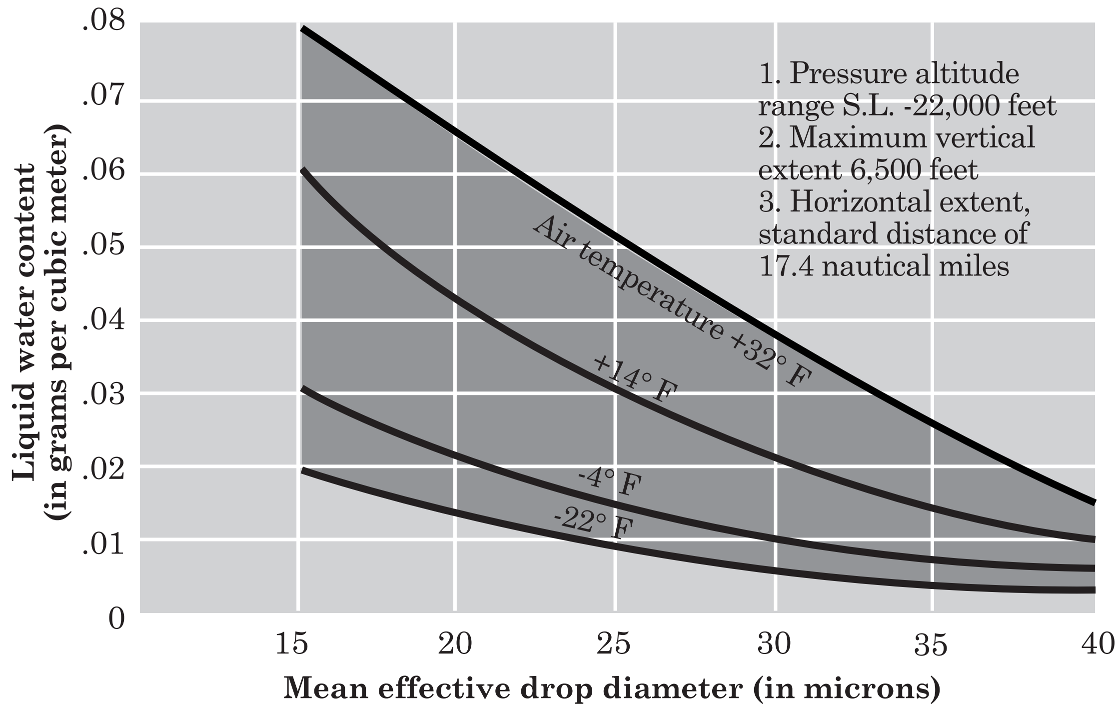

~1,000 µ
= 1 mm
≅ 1/25 inch
Freezing
Rain
~500 µ
Freezing
Drizzle
~200 µ
~50 µ
~40 µ
~15 µ
Max
Continuous
Max
Intermittent
FAR Part 25
Appendix C
Limits
Scale:
Approximately 50 times
actual size
Most of the time, super-cooled droplets encountered in flight are not larger than the ones in which airframe icing-protection systems must be tested. Sometimes, however, they actually are much larger than the Appendix C microscopic droplets; then flight crews may become, in effect, unwilling test pilots.
Pencil Lead = 2 mm or ≅ 2/25 inch
Chart Concept: Jan W. Steenblik Rendered By: William A. Ford

Figure 2

Continuous Maximum (Stratiform Clouds) Atmospheric Conditions
Liquid Water Content vs. Mean Effective Drop Diameter



FAR Part 25, Appendix C, includes several diagrams — including this one — that define the environmental conditions aircraft icing-protection systems must deal with satisfactorily to obtain FAA certification.

Source: NACA TN NO. 1855 Class III-M Continuous Maximum

Figure 3

"Mean volumetric diameter," he explains, "is a statistical term that means that half the droplets within the parcel of air are smaller than the MVD, and half are larger. Any given parcel of air containing supercooled water will have in it some very small droplets and some very large droplets."

Traditionally, this distribution was considered to be "monomodal" — i.e., a graph showing the number of droplets of a certain diameter within the parcel of air would look like the traditional "bell-shaped curve" (or, for dromedary lovers, a single-humped camel) beloved by statisticians and teachers who "grade on the curve."

In other words, in a given parcel of air, most of the droplets would have approximately the same diameter as the MVD; only a small percentage would be much smaller or much larger.

Recent studies, however, have suggested that nature may not follow the simple bell curve in this case. A new, alternative concept holds that the actual distribution of the droplet diameters is "bimodal" — i.e., it looks like a two-humped camel.

A cloud with a "bimodal distribution" of droplet sizes would be like the "duplex" shotgun loads some hunters shoot at geese — for example, a mix of T (large) and BB (smaller) shot — but with a modest sprinkling of shot of other sizes added.

In the case of the bimodal droplet distribution, the recent studies suggest that droplets in the 100-200 micron range — larger than Appendix C covers but smaller than FAA's definition of drizzle — make up a statistically larger percentage of the droplet population than previously thought, *without* affecting the measured MVD.

Remember, this population of larger droplets — hiding their true numbers behind the cloak of statistics — can cross the aircraft's streamlines and hit the wing farther aft, and thus pose a bigger threat to safety, than the droplets that actually are the size of the MVD.

Acceptable Risk?

Another sobering issue that has come to light is that FAA assumes that the probability of the aircraft flying into icing conditions outside the Appendix C certification envelope is 1 in 1,000.

By contrast, FAA requires manufacturers to show that the risk of catastrophic failure of certain aircraft parts, systems, or operations is 1 in a *billion*.

In other words, FAA is saying, in effect, that the risk of, for example, losing a wing to an extreme gust is acceptable if it is not likely to occur more often than once in a billion flights, but that flying outside the Appendix C icing envelope is acceptable if it happens only once in a thousand flights.

Put another way, to enjoy the same low level of risk in the two situations, you'd have to be sure that flight outside the Appendix C envelope was not likely to result in an accident more than once in a million of those flights.

F/O Green points out that FAA's permissive assumption that the airplane can and will exceed the Appendix C envelope one in a thousand times "is quite a high probability.

"In light of the better understanding we have today of the effects of inflight icing on modern, high-efficiency airfoil designs, reexamining it may be appropriate," he argues.

"An older, more ice-tolerant but less fuel-efficient airfoil may have provided adequate handling qualities during maneuvering to escape an encounter with icing that exceeds the Appendix C envelope, but newer wings may not."

Over much of the United States, as every regional airline pilot knows, a regional airliner operating in scheduled service is more likely to be in icing conditions than out of them during many days in the winter.

"The bottom line," says F/O Green, "is that we need to be sure that the aircraft will fly well enough to let us escape an icing encounter. At the very least, we need to be able to keep the blue side up for the forced landing."

Just like Capt. Hughen and F/O Gann in their DC-2.♦

U.S. Department of Transportation

Federal Aviation Administration

Advisory Circular

Effect of Icing on Aircraft Control and Airplane Deice and Anti-ice Systems

Advisory Circular (AC) 91-51A, July 17, 1996

1. **Purpose.** This advisory circular (AC) provides information for pilots regarding the hazards of aircraft icing and the use of airplane deice and anti-ice systems.

2. **Cancellation.** AC 91-51, Airplane Deice and Anti-ice Systems, dated September 15, 1977, is cancelled.

3. **Related Reading Material.** The information contained in this AC complements the documents listed below.

   a. **Current editions of the following AC's** may be obtained at no cost by sending a written request to U.S. Department of Transportation, Subsequent Distribution Center, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785:

   (1) AC 20-117, Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing.

   (2) AC 135-16, Ground Deicing and Anti-icing Training and Checking.

   (3) AC 135-17, Pilot Guide, Small Aircraft Ground Deicing.

   b. **Current editions of the publications below** may be purchased from: New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

   (1) AC 00-6, Aviation Weather.

   (2) AC 00-45, Aviation Weather Services.

   (3) AC 61-21, Flight Training Handbook.

   (4) AC 61-23, Pilot's Handbook of Aeronautical Knowledge.

4. **Background.** A review of aircraft accident and incident reports indicates that pilots may not be fully aware of the effects of icing on aircraft control. The review also indicates that pilots may be unaware of the limitations of aircraft deice and anti-ice systems and the conditions under which those systems are approved for flight into icing conditions.

5. **Discussion.** One of the hazards to flight is aircraft icing. Pilots should be aware of the conditions conducive to icing, the types of icing, the effects of icing on aircraft control and performance, and the use and limitations of aircraft deice and anti-ice equipment.

   a. **It is important that a pilot understand the conditions which are conducive to icing.** An understanding of these conditions allows the pilot to evaluate the available weather data and make an educated decision as to whether an intended flight should be made. One of the best sources of available weather data is pilot reports. The Federal Aviation Administration (FAA) encourages all pilots to report their flight conditions when warranted.

   (1) For ice to form, there must be moisture present in the air and the air must be cooled to a temperature of 0˚C (32˚F) or less. Aerodynamic cooling can lower the temperature of an airfoil to 0˚C even though the ambient temperature is a few degrees warmer. However, when the temperature reaches -40˚C (-40˚F) or less, it is generally too cold for ice to form. Ice is identified as clear, rime, or mixed. Rime ice forms if the droplets are small and freeze immediately when contacting the aircraft surface. This type of ice usually forms on

areas such as the leading edges of wings or struts. It has a somewhat rough looking appearance and is a milky white color. Clear ice is usually formed from larger water droplets or freezing rain that can spread over a surface. This is the most dangerous type of ice since it is clear, hard to see, and can change the shape of the airfoil. Mixed ice is a mixture of clear ice and rime ice. It has the bad characteristics of both types and can form rapidly. Ice particles become imbedded in clear ice, building a very rough accumulation.

(2) The following table lists the temperatures at which the various types of ice will form.

Table 1
Temperature Ranges for Ice Formation

Outside Air Temperature Range	Icing Type
0˚C to -10˚C	Clear
-10˚C to -15˚C	Mixed Clear and Rime
-15˚C to -20˚C	Rime

b. There are two kinds of icing that are significant to aviation: structural icing and induction icing. Structural icing refers to the accumulation of ice on the exterior of the aircraft; induction icing affects the powerplant operation. Significant structural icing on an aircraft can cause aircraft control and performance problems. The formation of structural icing could create a situation from which the pilot might have difficulty recovering and, in some instances, may not be able to recover at all. To reduce the probability of ice buildup on the unprotected areas of the aircraft, a pilot should maintain at least the minimum airspeed for flight in sustained icing conditions. This airspeed will be listed in the airplane flight manual (AFM).

(1) Structural icing can block the pitot tube and static ports and cause the breakage of antennas on the aircraft. This can cause a pilot to lose or receive erroneous indications from various instruments such as the airspeed indicator and altimeter and can cause a loss of communications and radio navigation capabilities.

(2) The most hazardous aspect of structural icing is its aerodynamic effects. Ice can alter the shape of an airfoil. This can cause control problems, change the angle of attack at which the aircraft stalls, and cause the aircraft to stall at a significantly higher airspeed. Ice can reduce the amount of lift that an airfoil will produce and increase drag several fold. Additionally, ice can partially block or limit control surfaces which will limit or make control movements ineffective. Also, if the extra weight caused by ice accumulation is too great, the aircraft may not be able to become airborne and, if in flight, the aircraft may not be able to maintain altitude. For this reason, Title 14 of the Code of Federal Regulations (14 CFR) prohibits takeoff when snow, ice, or frost is adhering to wings, propellers, or control surfaces of an aircraft. This clean aircraft concept is essential to safe flight operations.

(3) Another hazard of structural icing is the possible uncommanded and uncontrolled roll phenomenon referred to as roll upset that is associated with severe in-flight icing. Pilots flying airplanes certificated for flight in known icing conditions should be aware that severe icing is a condition that is outside of the airplane's certification icing envelope. Roll upset may be caused by airflow separation (aerodynamic stall) inducing self-deflection of the ailerons and loss of or degraded roll handling characteristics. This phenomena can result from severe icing conditions without the usual symptoms of ice accumulation or a perceived aerodynamic stall.

(4) The term "severe icing" is associated with the rapid growth rate of visible ice shapes most often produced in conditions of high liquid water content and combinations of other environmental and flight conditions. Severe icing is often accompanied by aerodynamic performance degradation such as high drag, aerodynamic buffet, and premature stall.

(5) In addition, ice associated with freezing rain or freezing drizzle can accumulate on and beyond the limits of an ice protection system. This kind of ice may not produce the familiar performance degradation; however, it may be potentially hazardous. Freezing rain and freezing drizzle contain droplets larger than the criteria specified by certification requirements. Temperatures near freezing can produce severe icing.

(6) Another hazard of structural icing is the tailplane (empennage) stall. Sharp-edged surfaces are more susceptible to collecting ice than large blunt surfaces. For this reason, the tailplane may begin accumulating ice before the wings and can accumulate ice faster. Because the pilot cannot readily see the tailplane, the pilot may be unaware of the situation until the stall occurs. There have been reports of ice on the tailplane without any visible ice on the wing. This can occur if the tailplane has not or cannot be deiced.

(7) A tailplane stall occurs when, as with the wing, the critical angle of attack is exceeded. Since the horizontal stabilizer counters the natural nose down tendency caused by the center of lift of the main wing, the airplane will react by pitching down, sometimes uncontrollably, when the tailplane is stalled. Application of flaps can aggravate or initiate the stall. The pilot should use caution when applying flaps during an approach if there is the possibility of icing on the tailplane.

(8) Perhaps the most important characteristic of a tailplane stall is the relatively high airspeed at the onset and, if it occurs, the suddenness and magnitude of the nose down pitch. A stall is more likely to occur when the flaps are approaching the fully extended position, after nose down pitch and air speed changes following flap extension, or during flight through wind gusts.

c. **Small aircraft engines commonly employ a carburetor fuel system** or a pressure fuel injection system to supply fuel for combustion. Both types of induction systems hold the potential for icing which can cause engine failure.

(1) The pilot should be aware that carburetor icing can occur at temperatures between -7˚C (20˚F) and +21˚C (70˚F) when there is visible moisture or high humidity. This can occur in the carburetor because vaporization of fuel, combined with the expansion of air as it flows through the carburetor, causes sudden cooling, sometimes by a significant amount within a fraction of a second. Carburetor ice can be detected by a drop in rpm in fixed pitch propeller airplanes and a drop in manifold pressure in constant speed propeller airplanes. In both types, usually there will be a roughness in engine operation. Some airplanes are equipped with carburetor heat for use in both prevention and removal of ice. The pilot should consult the AFM or the pilot's operating handbook for the proper use of carburetor heat.

(2) Fuel injection systems are less susceptible to icing than the carburetor system. Ice, which can partially or totally block the air from entering the engine, forms on the air intake of the engine. The usual indication of icing in a fuel injection system is the same as in a carburetor system. An alternate air source located inside the engine cowling is used to provide air to the engine to continue combustion. Usually, this source is operated automatically and has a manual backup system that can be used if the automatic system malfunctions.

d. **Ice detection is very important** in dealing with icing in a timely manner. A careful preflight of the aircraft should be conducted to ensure that all ice or frost is removed before takeoff. This is especially true in larger aircraft where ice is difficult to see in some locations. Also, it is more difficult to detect ice during flight on such areas as the tail, which may be impossible to see. At night, aircraft can be equipped with ice detection lights which will assist in detecting ice. Being familiar with the airplane's performance and flight characteristics will also help in recognizing the possibility of ice. Ice buildup will require more power to maintain cruise airspeed. Ice on the tailplane can cause diminished nose up pitch control and heavy elevator forces, and the aircraft may buffet if flaps are applied. *Ice on the rudder or ailerons can cause control oscillations or vibrations*.

e. **When operating in icing conditions on the ground or in flight**, a pilot must have knowledge of aircraft deicing and anti-icing procedures. Deicing is a procedure in which frost, ice, or snow is removed from the aircraft in order to provide clean surfaces. Anti-icing is a process that provides some protection against the formation of frost or ice for a limited period of time. There are various methods and systems which are used for deicing and anti-icing. A pilot must be knowledgeable regarding the systems and the procedures to be used on the specific aircraft before operating in icing conditions.

(1) There are numerous methods which are capable of removing ice from an aircraft surface. One method is pneumatic boots. This system is commonly used on smaller aircraft and usually provides ice removal for the wing and tail section by inflating a rubber boot. Ice can also be removed by a heat system or by a chemical fluid. Deicing the propeller is usually done by electrical heat, but it can also be done with a chemical fluid.

(2) Anti-icing can be accomplished by using chemical fluid or a heat source. Anti-ice systems are activated before entering icing conditions to help prevent the ice from adhering to the surface. These methods provide protection for the wings, tail, propeller, windshield, and other sections of the aircraft that need protection.

(See Table 2, page 164)

f. **For an airplane to be approved for flight into icing conditions**, the airplane must be equipped with systems which will adequately protect various components. There are two regulatory references to ice protection: the application to airplane type certification in 14 CFR parts 23 and 25 and the operating rules contained in 14 CFR parts 91 and 135.

Table 2
Icing Intensity, Accumulation, and Pilot Action

Intensity	Airframe Accumulation	Pilot Action
Trace	Ice becomes perceptible. Rate of accumulation of ice is slightly greater than the rate of loss due to sublimation.	Unless encountered for one hour or more, deicing/anti-icing equipment and/or heading or altitude change not required.
Light	The rate of accumulation may create a problem if flight in this environment for one hour.	Deicing/anti-icing required occasionally to remove/prevent accumulation or heading or altitude change required.
Moderate	The rate of accumulation is such that even short encounters become potentially hazardous.	Deicing/anti-icing required or heading or altitude change required.
Severe	The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard.	Immediate heading or altitude change required.

(1) With regard to ice protection, airplane type certification is currently accomplished by meeting either the requirements of § 23.1419 or § 25.1419. These rules require an analysis to establish the adequacy of the ice protection system for the various components of the airplane based on the operational needs of that particular aircraft. In addition, tests of the ice protection system must be conducted to demonstrate that the airplane is capable of operating safely in the continuous maximum and intermittent maximum icing conditions, as described in part 25, appendix C. The type certificate data sheet (TCDS) gives the certification basis for the airplane and lists the regulations with which the airplane has demonstrated compliance. Therefore, when an airplane complies with one of the regulations which refers to part 25, appendix C, the icing certification is indicated on the TCDS and in the AFM. The AFM lists the equipment required to be installed and operable. The AFM or other approved material will also show recommended procedures for the use of the equipment.

(2) The operating rules contained in § 91.527 and § 135.227 also permit flight into specified icing conditions provided that the aircraft has functioning deice and/or anti-ice equipment protecting specified areas of the aircraft. There are aircraft with partial installations of deicing and/or anti-icing equipment that do not meet the certification or the operating regulatory requirements for flight into icing conditions. Those installations are approved because it has been demonstrated that the equipment does not adversely affect the aircraft's structure, systems, flight characteristics, or performance. In such cases, the AFM or other approved material must explain the appropriate operating procedures for the partial deicing and/or anti-icing equipment and contain a clear statement that the aircraft is *not* approved for flight into known icing conditions.

(3) *It is important for pilots to understand that an airplane equipped with some types of deice and/or anti-ice systems may not be approved for flight into known icing conditions*. To be approved for such flight, the airplane must be specifically certificated to operate in known icing conditions.

(4) Also, it is important to remember that the certification standards provide protection for the majority of atmospheric conditions encountered, but not for freezing rain or freezing drizzle or for conditions with a mixture of supercooled droplets and snow or ice particles. Some airfoils are degraded by even a thin accumulation of ice aft of the deicing boots which can occur in freezing rain or freezing drizzle.

6. Summary. It is extremely important that pilots understand the dangers of aircraft icing. Even if an airplane is equipped and certificated to operate in known icing conditions, there are limitations. Flight into known or potential icing situations without thorough knowledge of icing and its effects and appropriate training and experience in use of deice and anti-ice systems should be avoided. It is important to know both the pilot's and the airplane's limitations. Pilots should become familiar with the types of weather associated with and conducive to icing and understand how to detect ice forming on the airplane. Pilots should know the adverse effects of icing on aircraft systems, control, and performance. They should also know how to respond to the situation if accidentally caught in icing conditions. A knowledgeable pilot is better prepared to make timely decisions and promptly recognize the factors that can contribute to aircraft icing accidents.

7. **Advisory Material.** The procedures and techniques discussed in this AC are advisory in nature. They are general guidance and should not be construed as required operating practices. This AC also contains numerous references to compliance with 14 CFR. The regulations themselves are not advisory, and compliance is required. Applicable operating limitations and procedures contained in manufacturers' FAA-approved flight manuals and other approved documents take precedence over the information contained in this AC. For specific guidance, pilots should consult the appropriate FAA-approved flight manual.

William J. White, Deputy Director, Flight Standards Service

Appendix 1. Roll Upset

This appendix is a summary of the cues that a pilot should recognize and corrective actions that can be taken if the aircraft encounters an uncommanded or uncontrolled roll upset due to severe in-flight icing. It is based on the FAA's investigation of airplane accidents and incidents during or after flight in freezing rain or freezing drizzle conditions causing severe in-flight icing. The term "supercooled large droplets" (SLD) includes freezing rain or freezing drizzle.

The most effective means to identify severe icing are cues that can be seen, felt, or heard. The general information provided in this appendix is intended to assist pilots in identifying inadvertent encounters with SLD conditions. The suggestions below are not intended to be used to prolong flight in conditions which may be hazardous. Because of the broad range of environmental conditions, limited data available, and various airplane configurations, pilots must use the manufacturer's airplane flight manual (AFM) for specific guidance on individual types of aircraft.

Warning: This document describes two types of upset: roll upset and tailplane stall (pitch upset). The procedures for recovery from one are nearly opposite those for recovery from the other. Application of the incorrect procedure during an event can seriously compound the event. Correct identification and application of the proper procedure is imperative.

Detecting SLD

Cues:

1. Ice visible on the upper or lower surface of the wing aft of the active part of the deicing boots. It may be helpful to look for irregular or jagged lines or pieces of ice that are self-shedding. All areas to be observed need adequate illumination for night operation.

2. The aft limit of ice accumulation on the propeller spinner. Nonheated propeller spinners are useful devices for sorting droplets by size. SLD icing will extend beyond normal ice limits.

3. Granular dispersed ice crystals or total translucent or opaque coverage of the unheated portions of the front or side windows. This may be accompanied by other ice patterns on the windows such as ridges. These patterns may occur within a few seconds to one-half minute after exposure to SLD conditions.

4. Unusually extensive coverage of ice, visible ice fingers, or ice feathers on parts of the airframe not normally covered by ice.

Additional Cues Significant at Temperatures near Freezing:

1. Visible rain (consisting of very large water droplets). In reduced visibility conditions, select taxi/landing lights "On" occasionally. Rain may also be detected by the sound of droplets impacting the aircraft.

2. Droplets splashing or splattering on impact with the windshield. Droplets covered by icing certification envelopes are so small that they are usually below the threshold of detectability. The largest size of the drizzle droplets covered is about the diameter of a 0.5mm pencil lead.

3. Water droplets or rivulets streaming on heated or unheated windows. The droplets or rivulets are an indication of high liquid water content (LWC) of any sized droplet.

4. Weather radar returns showing precipitation. Returns showing precipitation suggest that increased vigilance for all of the cues is warranted. Evaluation of the radar may provide alternative routing possibilities.

Prevention/Correction

Before Takeoff:

1. Know the pilot weather reports (PIREP) and the forecast.

2. Know where the potential icing conditions are located in relation to the planned route and which altitudes and directions are likely to be warmer or colder. About 25% of the cases of SLD are found in stratiform clouds colder than 0˚C at all levels with a layer of wind shear at the cloud top. There need not be a warm melting layer above.

In-Flight:

1. Maintain awareness of the outside temperature. Know where the freezing level static air temperature (SAT) is located. Be especially alert for severe ice formation at total air temperature (TAT) near 0˚C or warmer (when the SAT is 0˚C or colder). Many icing events have been reported at these temperatures.

   a. SAT is what would be measured from a balloon, and would be the temperatures given in a forecast.

   b. TAT is measured by a probe having velocity with respect to the air. Because of heating due to compression upstream of the probe, the total temperature will be warmer than the SAT. The difference is kinetic heating or the so called "ramrise." There is less kinetic heating in saturated air than in dry air because it takes less heat to raise the same unit mass by one degree. TAT and SAT are normally associated with air data systems.

2. Avoid exposure to SLD icing conditions, usually at temperatures warmer than -10˚C (+14˚F) SAT but possible at temperatures down to -18˚C (-1˚F) SAT. Be alert for cues and symptoms of SLD at temperatures down to -15˚C (+5˚F) SAT. Normally, temperature decreases between approximately 1.5˚C (2.7˚F) for saturated air to 2.75˚C (5˚F) for dry air with each 1,000 foot increase in altitude. In an inversion, temperature may actually increase with altitude.

Actions When Exposed to SLD Conditions:

1. Disengage the autopilot. Hand-fly the airplane. The autopilot may mask important cues or may self-disconnect and present unusual attitudes or control conditions.

2. Advise air traffic control and promptly exit the condition, using control inputs that are as smooth and small as possible.

3. Change heading, altitude, or both to find an area that is warmer than freezing, substantially colder than the current ambient temperature, or clear of clouds. In colder temperatures, there may still be ice that has not completely shed adhering to the airfoil. It may be hazardous to make rapid descents close to the ground to avoid severe icing conditions.

4. When severe icing conditions exist, reporting may assist other crews in maintaining vigilance. Submit a PIREP of the observed icing conditions. It is important not to understate the conditions or effects of the icing observed.

Roll Control Anomaly:

1. Reduce the angle of attack (AOA) by increasing airspeed or extending wing flaps to the first setting if at or below the flaps extend speed (V_{FE}). If in a turn, roll wings level.

2. Set appropriate power and monitor the airspeed/AOA. A controlled descent is a vastly better alternative than an uncontrolled descent.

3. If flaps are extended, do not retract them unless it can be determined that the upper surface of the airfoil is clear of ice because retracting the flaps will increase the AOA at a given airspeed.

4. Verify that wing ice protection is functioning normally and symmetrically by visual observation of the left and right wing. If not, follow manufacturer's instructions.

Summary

Roll upset may occur as a consequence of, or prior to, a wing stall due to anomalous forces that cause the ailerons to deflect or because the ailerons have lost effectiveness. Deflection of ailerons or loss of aileron effectiveness may be caused by ice accumulating in a sensitive area of the wing aft of the deicing boots under unusual conditions associated with SLD and, rarely, normal cloud droplets in a very narrow temperature range near freezing.

Pilots can minimize the chance of a roll upset by being sensitive to cues that identify severe icing conditions and promptly exiting the severe icing conditions before control or handling characteristics of the airplane are degraded to a hazardous level.

It is important to review the AFM for aircraft type-specific information. Also, pilots should check any available icing related bulletins from the airplane manufacturer.

Appendix 2. Suspected Tailplane Stall

This appendix is a summary of the symptoms a pilot should recognize and corrective actions that can be taken if the airplane encounters a tailplane stall. This appendix applies only to airplanes having tailplane pitch control. It is not applicable to aircraft with foreplane (canard) pitch control.

On some airplane designs, if the horizontal tailplane is inadequately cleared of ice, either by anti-ice/deice system failure, failure to operate the system properly, or by ice, snow, or frost left on critical sections of the airfoil, a tailplane stall could occur. Generally, tailplane stall would be encountered immediately after extension of the trailing edge flaps to an intermediate position or, more commonly, after extension from an intermediate position to the full down position. Usually, tailplane stall (or impending stall) can be identified by one or more of the symptoms listed below occurring during or after flap extension. The symptom(s) may occur immediately or after nose down pitch, airspeed changes, or power increases following flap extension.

Warning: This document describes two types of upset: roll upset and tailplane stall (pitch upset). The procedures for recovery from one are nearly opposite those for recovery from the other. Application of the incorrect procedure during an event can seriously compound the event. Correct identification and application of the proper procedure is imperative.

Tailplane Stall Symptoms

1. Elevator control pulsing, oscillations, or vibrations*
2. Abnormal nose down trim change*
3. Any other unusual or abnormal pitch anomalies (possibly resulting in pilot induced oscillations)*
4. Reduction or loss of elevator effectiveness*
5. Sudden change in elevator force (control would move nose down if unrestrained)
6. Sudden uncommanded nose down pitch

** May not be detected by the pilot if the autopilot is engaged*.

Corrective Actions

If any of the above symptoms occur, the pilot should:

1. Immediately retract the flaps to the previous setting and apply appropriate nose up elevator pressure.
2. Increase airspeed appropriately for the reduced flap extension setting.
3. Apply sufficient power for aircraft configuration and conditions. (High engine power settings may adversely impact response to tailplane stall conditions at high airspeed in some aircraft designs. Observe the manufacturer's recommendations regarding power settings.)
4. Make nose down pitch changes slowly, even in gusting conditions, *if* circumstances allow.
5. If a pneumatic deicing system is used, operate the system several times in an attempt to clear the tailplane of ice.

Warning: Once a tailplane stall is encountered, the stall condition tends to worsen with increased airspeed and *possibly* **may worsen with increased power settings at the same flap setting. Airspeed, at any flap setting, in excess of the airplane manufacturer's recommendations for the flight and environmental conditions, accompanied by uncleared ice contaminating the tailplane, may result in a tailplane stall and uncommanded pitch down from which recovery may not be possible. A tailplane stall may occur at speeds less than VFE.**

Summary

Ice can form on the aircraft's tail at a greater rate than on the wing and can exist on the tail when no ice is visible on the wing. When ice is visible, do not allow ice thickness to exceed the operating limits for deicing system operation or the system may not shed the tail ice. If the control symptoms listed above are detected or ice accumulations on the tail are suspected, land with a lesser flap extension setting and increase airspeed commensurate with the lesser flap setting. Avoid uncoordinated flight (side or forward slips) and, to the extent possible, restrict crosswind landings because of the possible adverse effect on pitch control and the possibility of reduced directional control. Avoid landing with a tailwind component because of the possibility of more abrupt nose down control inputs. Increased landing distances must also be considered because of increased airspeed at reduced flap settings.

Warning: Freezing rain, freezing drizzle, and mixed conditions (snow and/or ice particles and liquid droplets) may result in extreme ice buildup on and aft of protected surfaces, possibly exceeding the capability of the ice protection system. Freezing rain, freezing drizzle, mixed conditions, and descent into icing conditions in clouds from above freezing temperatures may result in runback ice forming beyond protected surfaces where it cannot be shed and may seriously degrade airplane performance and control.♦

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Pilots Can Minimize the Likelihood of Aircraft Roll Upset in Severe Icing

Under unusual conditions associated with supercooled large droplets, roll upset can result from ice accretion on a sensitive area of the wing, aft of the deicing boots. Pilots must be sensitive to cues — visual, audible and tactile — that identify severe icing conditions, and then promptly exit the icing conditions before control of the airplane is degraded to a hazardous level.

John P. Dow Sr.
U.S. Federal Aviation Administration

On Oct. 31, 1994, an Avions de Transport Regionale (ATR) 72-212, operating as American Eagle Flight 4184, suffered a roll upset during descent after holding in severe icing conditions. The airplane crashed, killing all 64 passengers and the four crew members.

Although the U.S. National Transportation Safety Board (NTSB) has not announced its finding of probable cause for the American Eagle accident, the NTSB reported that "evidence from air traffic control (ATC) sources and the airplane's flight recorders have prompted the [NTSB's] concern that the loss of control leading to the steep dive might be attributed to the weather conditions encountered by the flight and the characteristics of the aerodynamic design and flight control systems of the airplane."

[The U.S. Federal Aviation Administration (FAA) on Dec. 9, 1994, prohibited ATR-42 and ATR-72 airplanes from flying in "known or forecast" icing conditions, a restriction that was withdrawn on Jan. 11, 1995, provided that new training and flight procedures were followed, and pending the fitting of the affected ATRs with deicing boots covering a larger wing area.]

Uncommanded and uncontrolled roll excursion, referred to as roll upset, is associated with severe in-flight icing. Roll upset can occur without the usual symptoms of ice or perceived aerodynamic stall. Roll upset can be caused by airflow separation (aerodynamic stall), inducing self-deflection of the ailerons and/or degradation of roll-handling characteristics. It is a little-known and infrequently occurring flight hazard that can affect airplanes of all sizes. Recent accidents, however, have focused attention on such hazards in relation to turboprop aircraft.

Despite the U.S. Federal Aviation Regulations (FARs) and the most current aircraft certification requirements, the American Eagle accident is evidence that icing conditions and their effects on airplanes are not completely understood. Simply put, pilots must not be overreliant on deicing/anti-icing equipment fitted aboard airplanes that have been certified for flight into icing conditions. Severe icing conditions can be outside the airplane-certification icing envelope, and each pilot must be vigilant to avoid conditions beyond an airplane's capabilities.

The U.S. *Aeronautical* (formerly *Airman's*) *Information Manual* (*AIM*) defines severe icing as, "the rate of accumulation is such that the deicing/anti-icing equipment fails to control the hazard. Immediate flight diversion is necessary."

Severity in the context of the *AIM* is associated with rapid growth of visible ice shapes, most often produced in conditions of high liquid water content (LWC) and other combinations of environmental and flight conditions. This kind of severe ice is often accompanied by aerodynamic degradation such as high drag, aerodynamic buffeting and premature stall.

Ice associated with freezing rain or freezing drizzle accreting beyond the limit of the ice-protection system is also described as severe. This kind of ice may not develop large shapes, and may not produce familiar aerodynamic degradation such as high drag, but nonetheless, may be hazardous. Freezing rain and freezing drizzle contain droplets larger than those considered in meeting certification requirements, and temperatures near freezing can produce this kind of severe icing.

As prescribed by FAA policy, a 40-micron (one micron is one thousandth of a millimeter) sized droplet diameter is normally used to determine the aft limit of ice-protection system coverage. Drizzle-size drops may be 10 times that diameter (400 microns), with 1,000 times the inertia, and approximately 100 times the drag, of the smaller droplets.

Drizzle drops not only impinge on the protected area of the airplane, but may impinge aft of the ice-protection system and accumulate as ice where it cannot be shed.

Freezing raindrops can be as large as 4,000 microns (four millimeters). Freezing rain, however, tends to form in a layer — sometimes coating an entire airplane.

Freezing drizzle tends to form with less extensive coverage than freezing rain, but with higher ridges. It also forms ice fingers or feathers, ice shapes perpendicular to the surface of the airfoil. For some airfoils, freezing drizzle appears to be far more adverse than freezing rain to stall angle, maximum lift, drag and pitching moment.

A little-known form of freezing drizzle aloft — also described as supercooled drizzle drops (SCDD) — appears to have been a factor in the American Eagle ATR-72's roll upset.

SCDD Is New Challenge

SCDD is a new challenge. The physics of ice formation and altitude vs. temperature profiles differ between freezing drizzle and SCDD, but for the discussion of ice accretion only, freezing drizzle and SCDD may be considered synonymous. Droplets of supercooled liquid water at temperatures below 0 degrees C (32 degrees F) having diameters of 40 microns to 400 microns are found in both freezing drizzle and SCDD.

Like freezing rain and freezing drizzle, SCDD conditions tend to be limited in horizontal and/or vertical extent. These conditions are reported in AIRMETs but are not usually reported in SIGMETs, which report on conditions in areas of less than 3,000 square miles (7,770 square kilometers).

Language used in AIRMETs and SIGMETs to indicate the potential for freezing rain or freezing drizzle would be "moderate," "severe clear" or "mixed icing in cloud in precipitation." Amplifying terminology in abbreviated form (ZL/ZR ALF) indicating freezing rain or freezing drizzle aloft may be found in the remarks section.

[AIRMETs are in-flight weather advisories issued only to amend the area forecast concerning weather phenomena of operational interest to all aircraft and hazardous to aircraft whose capability is limited by lack of equipment, instrumentation or pilot qualifications. According to the *AIM*, AIRMETs "cover moderate icing, moderate turbulence, sustained winds of 30 knots or more at the surface, widespread areas of ceiling less than 1,000 feet [305 meters] and/or visibility less than three miles [4.8 kilometers] and extensive mountain obscurement." SIGMETs are advisories concerning weather significant to all aircraft, including severe icing, severe and extreme turbulence and widespread dust or sandstorms that reduce visibility to less than three miles (4.8 kilometers)].

During the American Eagle accident investigation, the FAA found additional accidents and incidents involving other types of airplanes in freezing rain, freezing drizzle and SCDD. Collectively these icing conditions are referred to as supercooled large droplets (SLD).

No aircraft is certificated for flight in supercooled-large-droplet (SLD) conditions.

Ice can form aft of the ice-protection system in SLD conditions where the droplets strike and freeze aft of the boots. Ice formation may be rapid in large-droplet and near-freezing conditions where ice accretes aft of the boots because of the direct impingement of the large droplets and because temperatures do not allow rapid heat transfer from the droplets that strike the leading edge. The droplets do not freeze immediately, but flow aft to the spanwise ice formation and then freeze.

Normal Symptoms May Be Absent

SLD conditions may challenge contemporary understanding of the hazards of icing. Moreover, an airplane may not exhibit the usual symptoms (warnings) associated with severe icing prior to loss or degradation of performance, stability or control characteristics. *No aircraft is certificated for flight in SLD conditions.*

The American Eagle accident airplane was operating in a complex icing environment that likely contained supercooled droplets having an LWC estimated to be as high as 0.7 grams per cubic meter and a temperature near freezing. Estimates of the droplet diameter vary significantly depending on the estimating methodology, but the droplets with the most severe adverse consequences appear to be in the range of 100 microns to 400 microns, or up to 10 times larger than the droplets upon which normal certification requirements are based.

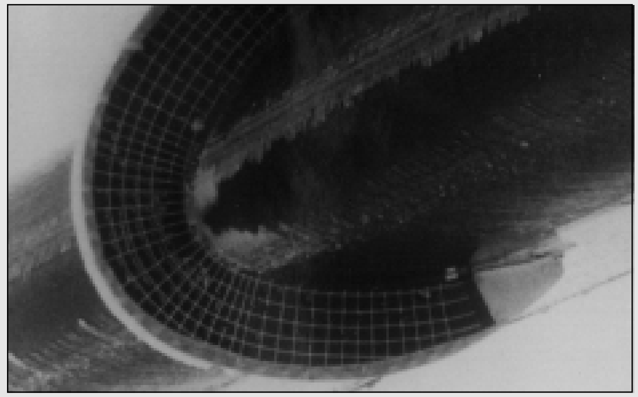
Measuring Temperature

Static air temperature (SAT) is what would be measured from a balloon, and is the temperature given in a forecast or report. It is also referred to as outside air temperature (OAT).

Total air temperature (TAT) is obtained by a probe having velocity with respect to the air. Because of kinetic heating on the upstream side of the probe, TAT is warmer than SAT. SAT is computed from TAT and other flight conditions by an air data computer for dry air. There is less kinetic heating in saturated air than in dry air.

Indicated outside air temperature (IOAT) is measured by a simple sensor in the airstream — essentially a thermometer. Typically, IOAT values will be SAT or OAT plus approximately 80 percent of the difference between SAT and TAT.

Surface temperature varies with air pressure along the airfoil. At the leading edge, where pressure is the highest, the surface temperature will also be higher than farther aft. If the local surface temperature on the airfoil is warmer than freezing, no ice will form. Infrared measurements of a typical airfoil in the icing tunnel at a true air speed of 150 knots show that there can be a decrease in temperature of more than 1.9 degrees C (3.5 degrees F) along the airfoil. At temperatures close to freezing, there may be no ice on the leading edge, but ice can form farther aft because of the lower temperatures. Because there is liquid runback, any ice formation aft of the leading edge tends to act like a dam, making ice growth more rapid.



Source: U.S. National Transportation Safety Board

Supercooled drops are at temperatures below freezing, yet still in a liquid phase. To change to solid, heat (called the "heat of fusion") must be removed from the liquid. Ice-free area shows that temperature at the leading edge is too warm to remove heat of fusion from the supercooled drops, but the temperature is colder on upper and lower surfaces.

The severe icing conditions caused ice to form on, and aft of, the deicing boots while the accident airplane was holding with the flaps extended. The ice aft of the boots could not be shed, because the ice was not affected by the deicing boots, which were functioning normally. When the flaps were retracted while the aircraft's airspeed remained constant, the airplane suffered a roll upset.

Although the crew of the accident airplane may not have been aware that they were holding in severe icing conditions, the cockpit voice recorder indicated that they were aware of ice accretion on their aircraft. Up to the time of the upset, the autopilot was controlling the airplane, and the pilot was not feeling physical changes in control-wheel forces that related to accumulation of ice on the aircraft.

Airfoil Sensitivity Varies

Although ice can accrete on many airplane surfaces, concern is focused on wing-airfoil icing. Some airfoil designs tend to be less sensitive to lift loss with contamination than other, more efficient, airfoils. Traditionally, the industry has relied on the infrequency of occurrence, limited extent of coverage, forecasting and reporting to avoid freezing rain and freezing drizzle, and recognition to exit the conditions.

An infinite variety of shapes, thicknesses and textures of ice can accrete at various locations on the airfoil. Each ice shape essentially produces a new airfoil with unique lift, drag, stall angle and pitching moment characteristics that are different from the wing's own airfoil, and from other ice shapes.

These shapes create a range of effects. Some effects are relatively benign and are almost indistinguishable from the wing's airfoil. Others may alter the aerodynamic characteristics so drastically that all or part of the airfoil stalls suddenly and without warning. Sometimes the difference in ice accretion between a benign shape and a more hazardous shape appears insignificant.

The effects of severe icing are often exclusively associated with ice thickness. For example, it is reasonable, in a given set of conditions, to believe that a specific three-inch (7.6-centimeter) shape would be more adverse than a similar 1.5 inch (3.8-centimeter) shape in the same place. Contrary to that one criterion, however, a five-inch (12.7-centimeter) ice shape on one specific airfoil is not as adverse as a one-inch (2.54-centimeter) ice ridge located farther aft on the chord. In another example, a layer of ice having substantial chordwise extent is more adverse than a three-inch ice accretion having upper and lower horn-shaped ridges (double horn).

Ice can contribute to partial or total wing stall followed by roll, aileron snatch or reduced aileron effectiveness.

Wing stall is a common consequence of ice accretion. Ice from freezing drizzle can form sharp-edged roughness elements approximately 0.5-centimeter to one-centimeter (0.2-inch to 0.4-inch) high over a large chordwise expanse of the wings' lower surfaces (perhaps covering 30 percent to 50 percent) and fuselage, increasing drag dramatically, thereby reducing speed. Correcting for this demands increased power, increased angle-of-attack (AOA) or both to maintain altitude. Ultimately, such unmitigated adjustments lead to exceedance of the stall angle and a conventional stall, likely followed by a roll.

Aileron snatch is a condition that results from an imbalance in the sum of the product of aerodynamic forces at an AOA that may be less than wing stall, and that tends to deflect the aileron from the neutral position. On unpowered controls, it is felt as a change in control-wheel force. Instead of requiring force to deflect the aileron, force is required to return the aileron to the neutral position. With all else equal, smaller ailerons would have smaller snatch forces. Aileron instability sensed as an oscillation, vibration or buffeting in the control wheel is another tactile cue that the flow field over the ailerons is disturbed.

Although flight testing using simulated ice shapes on the ATR-72 (intending to simulate the conditions at the crash location) demonstrated that these forces were less than the 60-pound certification limit for temporary application in the roll axis, the forces' sudden onset and potential to cause a rapid and steep roll attitude excursion were unacceptable. FAA investigation has revealed similar roll attitude excursions affecting other aircraft types that are equally unacceptable.

Ailerons that exhibit the snatch phenomenon have control-wheel forces that deviate from their normal relationship with aileron position. Nevertheless, the ailerons may be substantially effective when they are deflected.

Flow Disruption Handicaps Ailerons

Degradation of roll control effectiveness results from flow disruption over the wing ahead of the ailerons, and the controls do not produce the rolling moments associated with a given deflection and airspeed.

Degradation of aileron control caused by ice may or may not be accompanied by abnormal control forces. If, for example, the airplane is displaced in roll attitude, through partial stall caused by ice, the pilot's efforts to correct the attitude by aileron deflection are defeated by the ailerons' lack of effectiveness.

Ice tends to accrete on airfoils in different ways, depending on the airfoil, the AOA and other aircraft variables, and of course the atmospheric variables controlling the size, density, temperature, etc. of the water droplets. Similarly, the ice has differing effects on the airfoils.

The implications can be illustrated with a wing. The airfoil at the tip is in all probability a different airfoil than at the root. It is probably thinner, may have a different camber, be of shorter chord, and there are likely two degrees or three degrees of twist or washout relative to the root section.

Stall May Begin at Wing Tip

Twist or washout helps to ensure that the symmetric stall starts inboard, and spreads progressively, so that roll control is not lost. Greater ice accretion has probably occurred at the tip, leaving it more impaired aerodynamically than the inboard wing section. Stall, instead of starting inboard, may start at the tip.

Because the tip section may have a sharper nose radius and probably has a shorter chord, it is a more efficient ice collector. As a result, ice accretion at the wing tip may be thicker, extend farther aft and have a greater adverse effect than ice at the root.

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Even if the ice does build up at the root to nearly the same thickness as that at the tip, ice still tends to affect the smaller chord section, such as the wing tip, more adversely.

Power effects can aggravate tip-stall. The effect of the propeller is to reduce the AOA of the section of the wing behind it. At high-power settings, stall on the inner wing tends to be delayed by propeller wash. But the outer wing does not benefit from the same flow field, so the outer wing tends to stall sooner.

Finally, because of its greater distance from the flight deck to the outer wings, the crew may have difficulty in assessing ice there.

This means that at some AOAs, the outer wings maybe undergoing partial aerodynamic stall, while normal flow conditions still prevail over the inner parts of the wing. If such a stall occurs, there may be no pronounced break and the pilot may not sense the stall, so the stall is insidious. This partial stall condition also accounts for a degree of degradation of aileron effectiveness.

Where ice builds up on a given airfoil depends on the AOA, airspeed and icing variables. For example, the ATR accident flight testing included flying in drizzle-size drops. At the test airspeed, ice would predominantly build on the upper surfaces of the wings with the flaps extended to 15 degrees (resulting in a smaller AOA) and predominantly on the lower surfaces of the wings with the flaps retracted (resulting in a larger AOA).

On the upper surfaces, there was little drag increase until separation. On the lower surfaces, the expanse of rough ice was accompanied by a substantial drag increase.

In an icing environment, the propeller wash also tends to influence icing impingement on the airfoil. Unless the propellers are counter-rotating, the flow field is asymmetric over the wings, and ice impingement tends to be slightly asymmetric as well.

After aerodynamic stall occurs, reattaching flow generally requires a marked reduction of AOA and then refraining from increasing the AOA to the stall angle for that part of the wing. This characteristic is configuration-dependent, and is not limited to just one airplane type.

For example, in two different airplane types studied in detail, the stall angle for the outer wings was about five degrees with ice accretion forward of the ailerons on the upper wing surface aft of the deicing boots. The normal stall angle was near 20 degrees with no ice accretion. In both aircraft, reattachment of flow occurred when the AOA was reduced to substantially less than the stall angle. Applying power and maintaining attitude may not be most effective in recovering from an outer wing stall, because the reduction in AOA does not occur as rapidly.

In recent years, reports of roll excursions associated with icing appear to have increased in frequency, especially among turboprop airplanes used in regional airline commuter operations. One possible reason for this increase is that exposure to icing conditions in general has dramatically increased.

In 1975, the number of annual departures for all U.S. major airlines was 4.74 million. In 1994, almost two decades later, the regional segment alone has grown to 4.60 million annual departures.

Regional Airlines Have Higher Icing Exposure

Annual regional airline exposure to icing may be double that of jet aircraft, which service the longer routes and tend to operate above most icing conditions at higher altitudes for a greater percentage of their flight time.

The increase in operations suggests increased exposure to all icing conditions, so a commensurate increase in the number of flights involving SLD could be expected. For whatever reasons, exposure to these hazardous conditions appears to be more frequent than was previously believed.

Substantial effort is being placed into improving forecasts for all SLD. Since fall 1995, there have been preliminary changes to mathematical models used to forecast these conditions. The models will be reviewed and updated periodically, based on correlation with observations and pilot reports (PIREPs).

Pilots are best situated to submit a real-time report of actual icing conditions. But there is no assurance that another airplane will transit that small volume of the sky containing SLD. If it does, there must be some way for the pilot to identify that the icing is caused by SLD and then submit the PIREP. Not all pilots may be sensitive to what SLD icing looks like on their airplane, and PIREPs are a low priority during periods of high cockpit workload.

In-flight meteorological conditions reported by the crew of one airplane may not reflect the hazards of that same airspace for other airplanes, because of the many variables involved.

The variables include the size and type of the airplane's airfoil, configuration, speed, AOA, etc. If the reporting airplane was a large transport, the effect of icing may have been unnoticed and unreported, but the conditions could be a problem for a smaller airplane.

To avoid ambiguity, meaningful terminology must be well-defined.

PIREPs from an identical-model airplane are most likely to be more useful, but even the identical-model airplane climbing through an icing layer would likely result in a different ice accretion than one descending.

Ice accreted beyond ice-protection system coverage will not be shed and will continue to accrete until the airplane exits the icing conditions. Remaining in such icing conditions cannot improve the situation.

Severity indices of trace, light, moderate and severe vary among airplanes for the same cloud and tend to be subjective. Not too far from the American Eagle ATR accident site at about the same time, a jet airplane experienced a rapid ice accretion. The jet airplane's captain said that he had never experienced such a fast ice build-up. One inch (2.54 centimeters) of milky ice accumulated on a thin rod-shaped projection from the center windshield post in one to two minutes. The captain reported the buildup as light rime. In these extraordinary conditions, does "light" icing convey a message to others suggesting vigilance or complacency?

Descriptions Not Always Accurate

Extent of accretion, shape, roughness and height of ice are the most important factors affecting an airfoil. Unfortunately, operational descriptors of rime, clear or mixed ice are not adequate to convey nuances of the icing environment and the hazards of SLD. Ice forming aft of the boots may be white, milky or clear. Nonhazardous ice may also be described using the same terms. In the same cloud, one airplane may accrete rime ice, while another airplane — at a higher speed — accretes mixed ice. To avoid ambiguity, meaningful terminology must be well-defined.

PIREPs are very useful in establishing a heightened sense of awareness to a possible icing condition and to aid forecasters in correlating forecast meteorological data with actual ice. Although a forecast projects what may be, and a PIREP chronicles what was, the most important issue is: What is the icing condition right now?

Cues that can be seen, felt or heard signal the potential for ice to form, the presence of ice accretion or icing severity. Cues may vary somewhat among airplane types but typically cues include:

- Temperature below freezing combined with visible moisture;
- Ice on the windshield-wiper arm or other projections, such as engine-drain tubes;
- Ice on engine-inlet lips or propeller spinners;
- Decreasing airspeed at constant power and altitude; or,
- Ice-detector annunciation.

For example, experienced pilots rely on visual cues to determine the presence of SLD. After confirming SLD, they reroute to exit immediately from the SLD conditions. Because SLD conditions tend to be localized, the procedure has proved to be practical and safe. Using cues requires alertness to existing conditions and a very clear understanding of the airplane and its systems. Pilots should have an equally clear understanding of aviation weather and know what the temperatures and conditions are likely to be to the left, right, ahead, behind, above and below the route of flight, and how to recognize severe icing.

Tactile cues such as vibration, buffeting or changes in handling characteristics normally trigger a mental warning that ice has already accreted to a perceptible, and perhaps detrimental, level. Typically, as ice increases in thickness, cues become more prominent.

Using meaningful cues, pilots are trained to activate the various elements of airplane ice-protection systems, and when necessary, to exit the conditions.

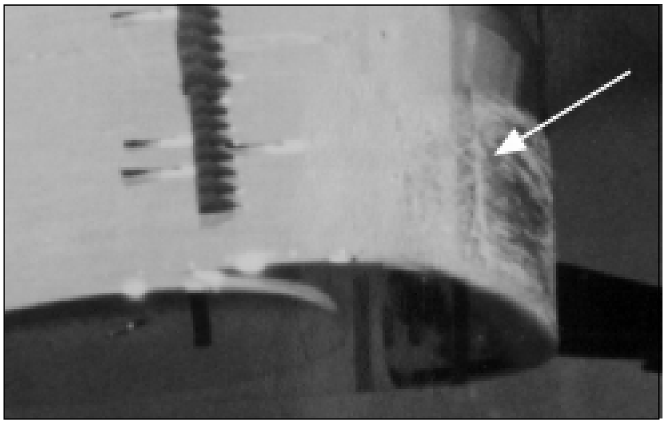
Experience suggests that it has been impractical to protect airplanes for prolonged exposure to SLD icing because at its extreme — it tends to cover large areas of the airplane. A conventional pneumatic ice-protection system able to deal with such extensive ice accretion would likely affect airfoil performance as much as the ice, would be expensive and would be heavy. Conventional electrothermal systems would require extraordinary amounts of power.

Because of the broad range of environmental conditions, limited data available and various airplane configurations, the manufacturer’s pilot’s operating manual should be consulted for guidance on a specific airplane type. The suggestions below are not intended to prolong exposure to icing conditions, but are a warning to exit the conditions immediately.

- **Ice visible on the upper or lower surface of the wing aft of the active part of the deicing boots.** It may be helpful to look for irregular or jagged lines or pieces of ice that are self-shedding. For contrast, a portion of the wing may be painted a dark color with a matte finish, different than the color of the boots. The matte finish can help identify initial formation of SLD ice, which may be shiny. All areas to be observed need adequate illumination for night operation.
- **Ice accretion on the propeller spinner.** Unheated propeller spinners are useful devices for sorting droplets by size. Like a white wing, a polished spinner may not provide adequate visual contrast to detect SLD ice. If necessary, a dark matte circumferential band may be painted around the spinner as a guide.
- **Granular dispersed ice crystals, or total translucent or opaque coverage of the unheated portions of the front or side windows.** These may be accompanied by other ice patterns, such as ridges, on the windows. After exposure to SLD conditions, these patterns may occur within a few seconds to approximately one minute.
- **Unusually extensive coverage of ice, visible ice fingers or ice feathers.** Such ice can occur on parts of the airframe not normally covered by ice.

At temperatures near freezing, other details take on new significance:

- **Visible rain** (which consists of very large water droplets). In reduced visibility, occasionally select taxi/aircraft landing lights ON. Rain may also be detected by the sound of impact.
- **Droplets splashing or splattering on impact with the windshield.** Droplets covered by the icing certification envelopes are so small that they are usually below the threshold of detectability. The largest size of the drizzle drops is about the diameter of an 0.002-inch (0.05-centimeter) pencil lead.



Source: Avions de Transport Regional (ATR)

Ice tends to accrete more on the upper surface (arrow) at low angle-of-attack associated with higher speeds or flap extension.

- **Water droplets or rivulets streaming on the heated or unheated windows.** These may be an indication of high LWC of any size droplet.

- **Weather radar returns showing precipitation.** These suggest that increased vigilance is warranted for all of the severe icing cues. Evaluation of the radar display may provide alternative routing possibilities.

Preventive and remedial measures include the following.

Before takeoff:

- **Know the PIREPs and the forecast** — where potential icing conditions are located in relation to the planned route, and which altitudes and directions are likely to be warmer and colder. About 25 percent of SLD icing conditions are found in stratiform clouds colder than 0 degrees C (32 degrees F) at all levels, with a layer of wind shear at the cloud top. There need not be a warm melting layer above the cloud top.

In flight:

- **Stay aware of outside temperature.** Know the freezing level (0 degrees C static air temperature [SAT]). Be especially alert for severe ice formation at a total air temperature (TAT) near 0 degrees C or warmer (when the SAT is 0 degrees or colder). Many icing events have been reported at these temperatures.

- **Avoid exposure to SLD icing conditions** (usually warmer than -10 degrees C [14 degrees F] SAT, but possible to -18 degrees C [-0.4 degrees F] SAT). Normally temperature decreases with each 1,000-foot (305-meter) increase in altitude between approximately 1.5 degrees C (2.5 degrees F) for saturated air, to 2.75 degrees C (5 degrees F) for dry air. In an inversion, temperature may increase with altitude.

When exposed to severe icing conditions:

- **Disengage the autopilot and hand-fly the airplane.** The autopilot may mask important handling cues, or may self-disconnect and present unusual attitudes or control conditions.

- **Advise air traffic control, and promptly exit the icing conditions.** Use control inputs as smooth and as small as possible.

- **Change heading, altitude or both.** Find an area that is warmer than freezing, or substantially colder than the current ambient temperature, or clear of clouds. In colder temperatures, ice adhering to the airfoil may not be completely shed. It may be hazardous to make a rapid descent close to the ground to avoid severe icing conditions.

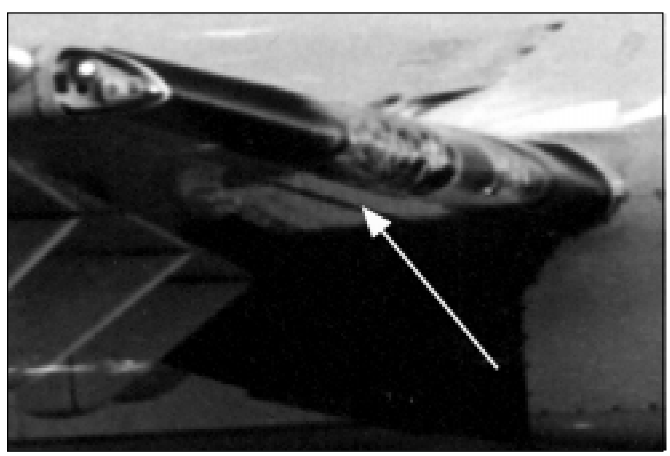
- **Reporting severe icing conditions may assist other crews in maintaining vigilance.** Submit a PIREP of the observed icing conditions. It is important not to understate the conditions or effects.

If roll control anomaly occurs:

- **Reduce AOA** by increasing airspeed or extending wing flaps to the first setting if at or below the flaps-extend speed (V_{FE}). If in a turn, roll wings level.

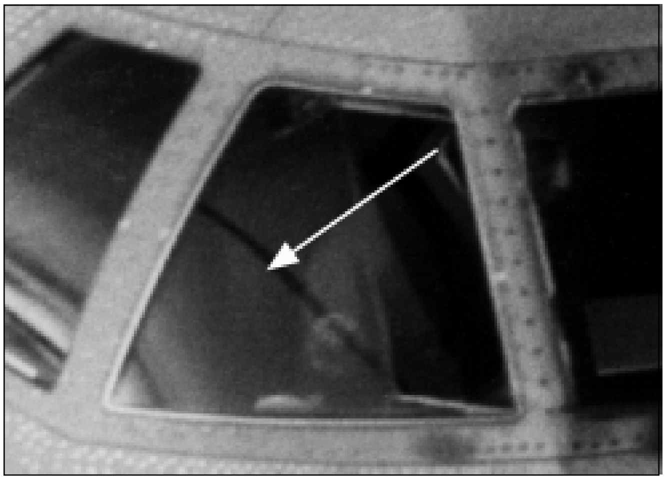
- **Set appropriate power and monitor airspeed/AOA.** A controlled descent is vastly better than an uncontrolled descent.

- **If flaps are extended, do not retract them unless it can be determined that the upper surface of the airfoil is clear of ice.** Retracting the flaps will increase the AOA at a given airspeed.



Source: Avions de Transport Regional (ATR)

Ice tends to accrete more on the lower surface (arrow) at higher angle-of-attack (slower air speed).



Source: Avions de Transport Regional (ATR)

Granular pattern on the unheated portion of a window (arrow) indicates freezing drizzle drops.

- **Verify that wing ice protection is functioning normally and symmetrically.** Verify by visual observation of the left and right wings. If the ice-protection system is dysfunctional, follow the manufacturer's instructions.

Although there is ongoing atmospheric research, the SLD environment has not been extensively measured or statistically characterized. There are no regulatory standards for SLD conditions, and only limited means to analyze, test or otherwise confidently assess the effects of portions of the SLD environment.

Ice shape–prediction computer codes currently do not reliably predict larger ice shapes at temperatures near freezing because of complex thermodynamics.

Near freezing seems to be where SLD conditions are most often — but not exclusively — reported. Further research using specially instrumented airplanes will be necessary to accurately characterize the SLD environment.

In addition to energy balance problems, there are other challenges not addressed by computer codes, such as the shape (and therefore drag) of large droplets as they are influenced by the local flow field; fragmentation of drops; and the effect of drops splashing as they collide with the airfoil. Ice shedding and residual ice are not currently accounted for, either.

The U.S. National Aeronautics and Space Administration (NASA) and others are working on these computational tasks and simultaneously pursuing validation of icing tunnels to simulate SLD conditions. Those efforts will require comparison against measured natural conditions, but there is no universally accepted standard on how to process or accurately characterize data collected in the natural icing environment. Clearly, until these tasks are complete, more specific certification issues cannot be resolved.

Assuming that a natural SLD icing environment data base is developed, that the icing envelope is amended and that test means are modified and are validated to adequately evaluate aircraft in all, or part, of the SLD environment: What then?

Three-phase Program Established

To minimize the hazard of SLD, the FAA established a three-phase program:

- Phase I — remedy problems in the accident airplane type;
- Phase II — screen other airplane types similar to the ATR-42 and ATR-72 for susceptibility to roll upset in severe icing and correct susceptible airplanes; and,
- Phase III — re-examine all aspects of icing certification, including the large-droplet environment, weather forecasting, crew training and aircraft operation.

Phase I is complete. All ATR-42 and ATR-72 airplanes are now equipped with extended deicing boots that approximately double the coverage on the upper surface of the outer wings. The increased coverage of the ATR boots is intended to minimize the hazard during inadvertent exposure to drizzle-size drops while the crew takes steps to exit the icing condition.

Phase II examined types of turboprop airplanes used in scheduled passenger service with unboosted controls and pneumatic boots for susceptibility to roll upset in freezing rain or freezing drizzle.

In January 1996, the FAA issued 17 notices of proposed rulemaking (NPRMs) for these airplanes, to require revising the airplane flight manuals (AFM) to specify procedures that would prohibit flight in freezing rain or freezing drizzle (as determined by certain visual cues), limit or prohibit the use of various flight control devices, and provide the flight crews with recognition cues for, and procedures for exiting from, severe icing.

The proposals were prompted by results of a review of the requirements for certification of the airplane in icing conditions, new information on the icing environment and icing data provided currently to the flight crews.

Phase III response will encompass all aircraft and the freezing rain/freezing drizzle icing environment. Included will be a re-examination of the adequacy of current aircraft certification regulations, and requirements for training, forecasting and flight in operations of aircraft in icing. Phase III will commence with an FAA-sponsored international conference scheduled for May 6–8, 1996, in Springfield, Virginia, U.S.

Two new technologies offer promise for SLD detection and protection systems. There are improvements in the ability of ice detection systems to recognize ice. Increasingly sophisticated designs of such systems appear able to measure the effect of ice on aerodynamic parameters.

Surface ice detectors sense the presence of contamination on the detector surface. Some distinguish among ice, slush, water, freezing point depressants and snow. Strip and area detectors are capable of detecting the thickness of ice on a deicing boot.

A recent design innovation measures the stall angle and other aerodynamic parameters of a contaminated airfoil. This could be a valuable tool for pilots because ice thickness is not the only determining factor. Location, roughness and shape are important too. For example, on one airfoil, an 0.5-inch (1.3-centimeter) step on the upper surface of the airfoil at 4 percent chord reduces maximum lift by more than 50 percent. Yet the same shape at 20 percent chord decreases maximum lift by only 15 percent. On another airfoil, distributed sandpaper-like roughness elements on the upper wing may decrease lift by 35 percent.

These new aerodynamic performance monitors also claim a somewhat predictive function, not just warning of airflow stall as it occurs, but before stall occurs.

For detectors to reduce the hazard of SLD conditions, sufficient detection and warning time for the crew to safely exit the condition must be shown. The FAA has generally preferred preventing or removing the formation of ice on a critical surface rather than advising of its presence.

Recent advancements in ice-protection systems include a high-pressure pulsed pneumatic system with a conformal metallic or composite leading edge that could replace the familiar black rubber boot. The system uses a 600 pounds per square inch (PSI) pulse of air to reliably clear ice in the range of 0.02-inch (0.05-centimeter) thickness. Current pneumatic systems generally are operated when ice is allowed to build to 0.25-inch to 0.5-inch (0.6-centimeter to 1.3-centimeter) thickness.

Electrothermal systems consisting of metal-coated fibers embedded within the paint system are being tested. One device boasts a low power consumption between 0.5 watt to more than six watts per square inch, depending on the ambient temperature. Conventional systems consume 10 watts to 15 watts per square inch. Hybrid systems that combine conventional pneumatic boots and advanced electrothermal ice protection are also being explored.

Other low-energy innovations are electro-impulsive/expulsive deicing systems (EIDI/EEDS) that rapidly discharge electrical energy stored in a capacitor through a coil or conductive ribbons. Eddy currents or magnetic repulsion forces cause the iced surface to move at extremely high acceleration, but small distance, to shed ice in the 0.02-inch thickness range or larger.

Another proposed feature of emerging systems is a closed-loop operation where a detector signals that ice has accreted, actuates the system and then waits for another build-up. This feature would allow surfaces to be individually operated at optimum ice thickness.

These systems are in various stages of maturity and testing. As with any system, testing must be successfully completed before there can be assurance that the system will perform its intended function reliably in the entire icing certification envelope — whatever that may be ultimately.♦

About the Author

John P. Dow Sr. is an aviation safety engineer with the U.S. Federal Aviation Administration (FAA) in Kansas City, Missouri, U.S. He was the icing specialist on the FAA team investigating the susceptibility of turboprop airplanes to roll upset in freezing rain and freezing drizzle. Dow was a codeveloper of an international program to identify and remedy ice-induced tailplane stall.

Dow participated in the U.S. National Transportation Safety Board (NTSB) Performance Group and Special Certification Review Team for the American Eagle ATR-72 accident. He has coordinated design approval of non-U.S.-manufactured airplanes among the FAA, other airworthiness authorities and manufacturers. He also has a commercial pilot certificate with multi-engine and instrument ratings.

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Tailplane Icing and Aircraft Performance Degradation

Ice accretions on horizontal tail surfaces can decrease stall margins, impair control, increase drag and decrease lift.

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Although the sensitivity of airplanes to inflight icing has been recognized for many years and can be minimized by ice protection systems, the advent of the medium-altitude turboprop commuter transport aircraft has resulted in renewed attention to the icing problem. This review of icing has been prompted by several recent accidents that apparently were caused by an oversensitivity to ice buildup on the horizontal stabilizer of these aircraft.

Icing Phenomenon Reviewed

Icing cloud characteristics

Aircraft icing can occur: if the aircraft surface temperature (which rises with increasing airspeed) is below freezing; some water in a cloud is liquid; and, the sizes of the cloud droplets are large enough to strike an aircraft surface rather than follow the streamlined airflow around them. Also, the clouds must be extensive enough along the flight path to form a discernible amount of ice.

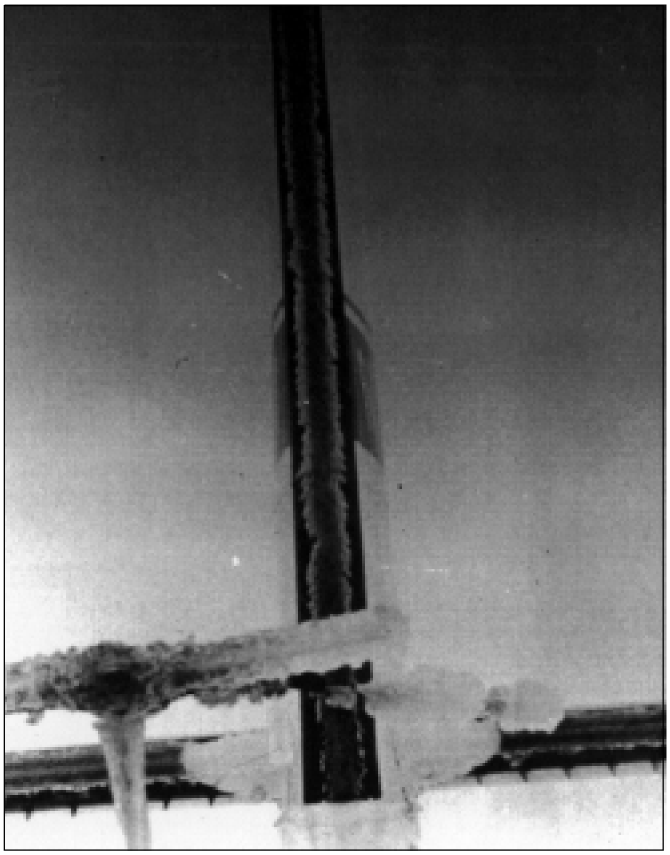
Ice forms when supercooled liquid water droplets turn to ice upon or after striking a moving surface. Two ice accretion factors have the most adverse influence on aircraft performance: the shape of the ice formation on the surface; and, the amount or thickness of the ice.

Shape of ice accretions

Aerodynamic performance degradation is primarily influenced by the shape of the ice that forms and the amount of ice that accumulates. The amount of liquid water in the cloud and the duration of the exposure to icing primarily determine the quantity of ice collected. Cloud droplet size is generally a secondary consideration. Temperature can determine the amount of accretion; if it is close to freezing, some of the intercepted water droplets blow off before they can freeze.

Ice accretion shape is a result of the rate of freezing on the surface. Low temperatures and droplet impingement rates (water concentration X velocity), along with small droplets, promote rapid freezing on the surface. Such conditions produce a rather smooth ice surface and pointed accretion shape called rime ice. However, temperatures near freezing, higher rates of accretion and larger droplet sizes result in delays in freezing when the droplets strike the surface. These conditions create irregular ice formations with flat or concave surfaces sometimes having protuberances ("double-horn" ice formation) facing the airstream either side of the airflow center or stagnation line. This type of ice formation is usually described as glaze ice.

Ice shapes are of extreme importance because the contour, roughness and location of the ice formation on the various aircraft components can significantly deteriorate aerodynamic performance. Glaze ice shapes, runback ice (formed when water droplets flow in liquid form to freeze on a colder region of the airfoil) and ice caused by freezing rain (large droplets that do not follow the airflow but form ice on all surfaces they strike) can produce significant aerodynamic penalties by decreasing lift and stall angle and increasing drag and stall speed. This is caused by the ice destroying the aerodynamics necessary for peak airfoil performance.



Ice can form on tailplanes and antennas faster than on wings.

Ice thickness factors

In addition to the distance flown in icing clouds, the amount of ice collected depends upon the concentration of liquid water in the clouds and a factor called the collection efficiency (the higher the efficiency the greater the amount of ice collected). Values of collection efficiency depend upon airspeed, size of the cloud droplets and size and shape of the moving surface.

In general, the collection efficiency is greatest for high airspeeds, large droplets and small objects (windshield wiper posts, outside temperature probes, airfoils). For aircraft wings, the collection efficiency can vary from near zero for very small droplets to nearly 100 percent for large droplets in freezing rain. Because of their smaller leading edge radius and chord length, tail surfaces have higher collection efficiencies than wings and can collect two to three times greater ice thickness.

Parameters determining icing intensity

Two significant parameters of icing intensity for a given aircraft component are: the amount of liquid water and distribution of droplet sizes in the clouds, which for a given airspeed determine the rate of ice accretion; and, the total amount of ice accumulated in a given encounter, which depends upon the amount of liquid water and the distance flown during the icing encounter. The rate of ice build-up and the amount collected may depend on whether the aircraft is in a layer type (stratiform) cloud or a cumulus type cloud with large vertical development. Ice can generally build up twice as fast in cumulus clouds because of their high water content; but the extent of the icing exposure in cumulus clouds is not nearly as long as that of stratus clouds, and the total amount accumulated could be small.

Data acquired in past research studies[7] have indicated the very limited vertical extent of icing clouds (90 percent within less than 3,000 feet vertically) so that during climb and descent, icing will continue for only a short time, depending upon airspeed and rate of climb. A survey[2] has disclosed that, at constant altitude, 90 percent of the icing encounters are less than 50 miles in horizontal extent and none measured longer than 180 miles.

The greatest amount of liquid water, and therefore the highest rate of ice accretion, occurs generally near the tops of clouds. This condition is to be expected from the physics of cloud formation, i.e. the cooling of ascending air and resulting increase in condensation with height above the cloud base.

Probability of encountering icing when in clouds

If an aircraft is flying in clouds and the outside air temperature (OAT) is sufficiently below freezing to form ice on it, will the airplane pick up ice? Not necessarily. On the average, this aircraft has only approximately a 40 percent chance of icing, and that occurs near freezing temperatures[3]. As the temperature gets further from the freezing point (colder) there is less chance of picking up ice. If the temperature is below -20^{o} C, the chance for accumulating ice is 14 percent. Why does he temperature effect the existence of icing? Most clouds below freezing are starting to glaciate (change over to ice crystals), and the colder the temperature the more rapidly this process occurs. Also, the droplets may be too small to strike the wing in any significant amount.

If one were free to choose a flight level under 20,000 feet and vary it as required between points A and B to avoid icing, the frequency and intensity of icing would be cut to a minimum, except for encounters during climb and descent. In these cases, the amount of ice formed would be a function of the thickness of the icing cloud layer and the rate of climb through it. Only about one in 10 single icing cloud layers exceed a thickness of 3,000 feet. None of the icing cloud thicknesses (single or multiple layers) that were measured totaled more than 6,000 feet in thickness. These data were acquired from instrumented fighter-interceptor aircraft operating from air bases in the northern United States.

U.S. Federal Aviation Regulations (FAR) on icing

Extremes of icing have been defined in ice protection design standards adopted by the U.S. Federal Aviation Administration (FAA) in FAR Part 25, Appendix C for the certification of ice protection systems for transport aircraft[4]. Tests of these systems must be conducted to demonstrate that the airplane is capable of operating safely in the conditions defined by the cloud parameters that produce maximum icing.

Maximum icing conditions are treated separately for cumulus clouds and for stratiform clouds. Icing cloud parameters are called "maximum intermittent" for cumulus clouds and "maximum continuous" for stratiform clouds. Separate parameters were required because of the differences in vertical and horizontal extents of the two cloud types. Cumulus clouds are limited in horizontal extent but extend through a wide range of altitudes; stratiform clouds can extend long horizontal distances but are limited in vertical thickness.

In severe icing conditions, evasive action would be required.

Icing cloud meteorological parameters for FAR Part 25 were based on historical data obtained more than 40 years ago by the U.S. National Advisory Committee for Aeronautics (NACA). Their use in establishing ice protection design standards has proved successful for many different types of aircraft. These design standards were determined on the basis of an ice protection system providing nearly complete protection in 99 percent of the icing encounters, and that some degradation of aircraft performance would be allowed[5]. A statistical study determined that in the 99 percent of the icing encounters, the probability of exceeding the maximum values of all three icing parameters simultaneously (liquid water, temperature and droplet size) would be equivalent to one in 1,000 icing encounters[6].

In severe icing conditions, evasive action would be required. In previous recommendations for inflight reporting of icing intensity, the definition of heavy or severe icing was stated as that situation where the rate of ice accumulation is such that the ice protection system fails to reduce or control the hazard and immediate diversion of the flight becomes necessary. Not knowing the quantitative value of an existing icing condition, the point to emphasize is that a pilot cannot become complacent by assuming that the aircraft's certified ice protection system will provide complete protection under all conditions. For example, it is not possible for designers to provide complete protection against ice accretions caused by freezing rain.

One might suggest that the certification values are too conservative and that designs based on them provide over-protection. Yet, with the volume of air traffic that exists worldwide, encountering extreme values of icing becomes a possibility. Extreme values do exist and have been measured, and can be extrapolated by statistical analysis beyond the measured values. However, the extreme values are limited in horizontal extent and are a function of air temperature, decreasing with colder temperatures. Maximum instantaneous values occur in very short distances (one-half mile) usually in cumuliform clouds; this situation could be critical for certain aircraft components.

Ice Crystals, Freezing Rain or Drizzle Are Determining Factors

Ice is not accreted if a cloud is composed only of ice crystals. If some liquid water is present (mixed clouds), ice does form, but the condition does not last long. In the presence of ice crystals, liquid drops evaporate because of the difference in saturation vapor pressure between ice crystals and liquid droplets. Usually, little, if any, icing is found in areas of snow.

However, when flying below the snow level, aircraft icing can occur if a temperature inversion exists to melt the snow and the resulting rain falls to a below-freezing level — the conditions for freezing rain. These conditions are characterized by very large drops and low values of liquid water. Despite the low concentration of liquid water, a considerable amount of ice can accumulate because of the high collection efficiency of the large drops. In freezing rain, ice can form on many different surfaces of the aircraft.

Freezing drizzle can occur under different conditions than freezing rain. Drops smaller than freezing rain are produced by the joining process of coalescence and collisions of small droplets; an above-freezing level is not necessary. Both freezing rain and drizzle can exist down to ground level below a cloud deck and thereby cause ice to form on aircraft surfaces during landing, takeoff and ground operations if the aircraft surface temperature is below freezing.

Stall Can Be Caused by Ice On Tail Surfaces

Tailplane stall is certainly not a new phenomenon. However, it has recently been thrust into the spotlight by a series of accidents involving turboprop aircraft. Several FAA airworthiness directives (ADs) have been issued that affect several different turboprop aircraft. The common element leading to these ADs appears to be a sensitivity to ice build-up on the horizontal stabilizer that results in control problems which can include an uncontrollable pitch-down during flap extension. The specifics of ice formation on the tailplane and the penalties associated with it may not be fully understood by many aircraft crew members exposed to the icing environment.

A joint U.S. National Aeronautics and Space Administration (NASA)/FAA International Tailplane Icing Workshop to address this problem was held November 4-5, 1991, at the NASA Lewis Research Center in Cleveland, Ohio, U.S. Approximately 100 representatives from manufacturers, key special interest groups and airworthiness authorities of Canada, China, France, Germany, Italy, Japan, the Netherlands, Sweden, the United Kingdom, and the United States attended. The problem of horizontal tailplane stall caused by ice accretions also has been studied by the Swedish-Soviet Working Group in the Field of Flight Safety[7].

The workshop provided the most complete information to date on the tailplane icing problem. Among numerous recommendations resulting from it were the need for a survey of the current fleet to determine whether unsafe conditions exist on various aircraft and the need for ice detection capability on the horizontal tail. The FAA is planning to conduct such a survey with upcoming ice-detection studies.

The tailplane almost always has a sharper leading edge than the wing, and therefore becomes a more efficient collector of ice as speed and droplet size increase. It is possible to have very little or no accumulation on the wing and yet have a significant accretion on the tailplane.

The specifics of ice formation on the tailplane … may not be fully understood … .

In addition to the fact that the horizontal stabilizer is a more efficient collector, the aerodynamic effect of a given thickness of ice on the tail will generally be more adverse than the same thickness of ice on the wing because of the ratio of thickness to chord length and leading edge radius.

Tailplane stall due to ice contamination is seldom a problem in cruise flight. However, when trailing edge flaps are extended, some new considerations enter the picture. On conventional aircraft, the horizontal tail provides longitudinal stability by creating downward lift (in most cases) to balance the wing and fuselage pitching moments. With flaps extended, the wing center of lift moves aft, downwash is increased and the horizontal tail, as a result, must provide greater downward lift. In some aircraft, depending on forward center of gravity (CG), the tail may be near its maximum lift coefficient and a small amount of contamination could cause it to stall.

As the aircraft slows after flap extension, the requirement for downward lift by the horizontal tail increases to increase the angle of attack of the wing and produce a given amount of lift at a slower speed. With flaps full down and the aircraft at approach speeds, the angle of attack of the horizontal stabilizer is very high. It is high also because of the downwash over the tail created by the extended flaps. This will increase the angle of attack of the stabilizer even more.

This situation is where tailplane ice can cause trouble. A small amount of ice contamination on the leading edge of the horizontal stabilizer can interfere with the airflow on the underside of the stabilizer because it may be working near its maximum angle of attack.

Landing Approach After or During an Icing Encounter May Cause Problems

Current aviation wisdom advises the pilots of boot-equipped aircraft to wait until one-quarter inch to one-half inch of ice has collected on the wing before activating the de-icing system. On some horizontal stabilizers one-half inch of a ice shape may cause unacceptable aerodynamic penalties. In addition, since the horizontal stabilizer is normally a more efficient collector of ice, it is very possible that it has collected much more than the half inch of ice a wing may have collected. Remember, it is possible to have very little or no accumulation of ice on the wings and yet have significant accumulation on the tail.

It also seems to be an accepted practice to increase the landing airspeed some amount if the wings are contaminated. It also may be that the pilot has opted not to deice because there is only a minor accumulation of ice on the wing. Trouble may now come from two sides. There may be much more ice on the horizontal stabilizer than on the wing, and the increased speed will create a much greater wing downwash and therefore higher angle of attack for the stabilizer. This may lead to separation of the flow on the lower surface of the stabilizer, a sudden change in elevator hinge moment and forward stick force that may overpower the pilot. In aircraft without boosted controls, the pilot may notice lightening stick forces, although the above sequence has happened suddenly and without a recognizable warning when flaps are extended. The answer is to reduce flap angle immediately, if altitude and airspeed permit.

In most instances, this problem manifests itself when the final segment of flaps is extended (creating the greatest amount of downwash) at very low altitude during the landing phase. The odds of recovery from uncontrollable nose pitch-down at low altitude are poor. Adding airspeed in this case may actually reduce the margin of safety. The remedy is to land at a reduced flap angle or get rid of all of the ice.

Generally, the tailplane stall problem that has been presented here seems to be associated with aircraft which have the following characteristics. They:

- Do not have powered control surfaces, and rely on aerodynamic balance to keep stick forces low;

- Have high efficiency flaps that produce relatively high downwash which results in high angle of attack on the tailplane;
- Have non-trimmable stabilizers;
- Have efficient stabilizers with short chord length and small leading edge radii; and,
- Mostly have inflatable boots for ice protection.

The characteristics listed above fit most of the turboprop aircraft used in the regional airline fleet today. The six ADs regarding the effects of tailplane ice on turboprop commuter aircraft plus several recent accidents have prompted a closer look at the problem.

One of the highlights of the NASA/FAA workshop was the recognition of the need for more education and training for pilots. This workshop recognized that much training, both initial and recurrent, has been provided for recognition and proper actions related to windshear; however, crew training for operations in icing conditions have been emphasized less. Some of the current recommended procedures suggested during crew training (e.g., increased airspeed) may actually exacerbate an already adverse situation at the horizontal tail.

Other Adverse Affects of Ice on Aircraft Performance Examined

Ice accretions can degrade the performance of aircraft by:

- Causing loss of control, particularly during a critical maneuver such as landing (e.g. tailplane stall as discussed above);
- Increasing total drag substantially;
- Reducing lift and climb capability;
- Losing the capability to maintain altitude with one engine out on a twin-engine aircraft; and,
- Causing the loss of artificial stall warning.

Increase in total drag

Research measurements taken on an aircraft with a glaze ice accretion disclosed a substantial increase of more than 60 percent in total drag compared to an un-iced condition. These data were from a typical twin engine commuter type aircraft operating at a normal lift coefficient[8].

Loss of lift

Accompanying the above increase in drag was a 17 percent loss of lift.

Loss of engine-out capability

Analysis of the power required vs power available curves for the above situation with the aircraft at 6,000 feet, where the measurements were made, indicated that without de-icing, the aircraft would descend if one of the two engines failed. On many routes, a 6,000-foot minimum en route altitude (MEA) could spell disaster.

Loss of artificial stall warning

Activation of an artificial stall warning device, such as a stick shaker, is based on a preset angle-of-attack several knots above stall speed. This setting allows warning prior to stall onset characteristics where buffeting or shaking of the aircraft occurs. Thus, for an un-iced aircraft, the pilot has adequate warning of impending stall. However, an iced aircraft may exhibit stall onset characteristics before stick shaker activation because of the affect of ice formations on reducing the stall angle-of-attack. In this case, the pilot does not have the benefit of an artificial warning of stall.♦

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In-flight Icing Operations and Training Recommendations

U.S. Federal Aviation Administration Order 8400.10
Flight Standards Information Bulletin for Air Transportation (FSAT) 97-03
March 17, 1997

1. **Purpose.** This bulletin provides Flight Standards Service (AFS) principal operations inspectors (POI) guidance and information concerning approved training programs for flight crewmembers should they inadvertently encounter in-flight icing conditions, including freezing drizzle/ freezing rain. It directs POI's to ensure that all pertinent meteorological information is provided to flight crewmembers and dispatchers, both for preflight planning and in-flight decision making when the route of flight may be near areas of potentially hazardous weather conditions. This bulletin is applicable to all operators of turbo prop aircraft and not just operators of ATR-42 and ATR-72 aircraft.

2. **Background.**

   A. On October 31, 1994, an accident involving an ATR-72 occurred while the airplane was en route from Indianapolis to Chicago. Post accident investigation concluded the likely presence of freezing drizzle aloft (also called supercooled drizzle drops (SCDD)). For the purposes of ice accretion only, freezing drizzle, freezing rain, and SCDD are considered synonymous terms, comprising supercooled large droplets (SLD), i.e. those icing conditions containing droplets larger than the airplane icing certification specifications. SLD may result in ice formation beyond the capabilities of the airplane's ice protection system. While the flight crewmembers of the ATR-72 were not aware that the icing conditions they encountered would cause dramatic airplane control difficulties, they were aware of the presence of icing.

   B. As a result of the investigation of the ATR-72 accident, the National Transportation Safety Board (NTSB) expressed concerns that approved air carrier training programs may not fully address procedures, should flight into freezing rain or freezing drizzle be encountered. The NTSB expressed concern about a lack of pertinent weather information dissemination to flight crewmembers and dispatchers.

   C. The NTSB has not completed its investigation of COMAIR flight 3272 that crashed on January 9, 1997 while on approach to Detroit, however preliminary information indicates that in-flight icing may have been a factor.

3. **Discussion.**

   A. Safe operations during in-flight icing conditions requires flight crewmember awareness of the potential dangers of in-flight icing and under what conditions in-flight icing may be encountered.

   B. Knowing the type of in-flight icing and where in-flight icing might be encountered is essential to preflight planning and in-flight decision making, should severe icing be encountered. Information is available to both flight crewmembers and dispatchers through airman's meteorological information (AIRMET), significant meteorological information (SIGMET), Center Weather Advisories (CWA), and the hazardous in-flight weather advisory service (HIWAS).

C. After the ATR-72 accident, the Federal Aviation Administration (FAA) issued several aircraft specific airworthiness directives (AD) concerning procedures to identify severe icing conditions, knowledge of the airplanes certification limits, and procedures to safely exit in-flight icing conditions when necessary.

D. In September 1995, the FAA published a document entitled, "Roll Upset in Severe Icing," (ATTACHMENT I) which describes icing conditions outside the airplane's certification icing envelope and provides information about the background, preventative measures, symptoms, and corrective measures on the hazards of roll upset associated with severe in-flight icing. This document can also be found on the Internet at the Flight Standards Homepage. The address is http://www.faa.gov/avr/afshome.htm.

4. Actions. Training programs for pilots and dispatchers, if applicable, should be reviewed and amended, if required. Training programs should include:

(1) A discussion of approved ground deicing/anti-icing programs, specifically emphasizing that these programs apply only to airplane ground operations. This discussion should emphasize that holdover time is applicable only to ground operations. Should freezing drizzle/rain conditions exist at takeoff time, the possibility of severe in-flight icing must be considered since holdover time does not apply after the airplane reaches rotation speed.

(2) A review of meteorological conditions likely to cause freezing drizzle, freezing rain, or SCDD.

(3) Identification of weather information sources and their use relative to in-flight icing. This should include use of AIRMET's, SIGMET's, CWA's, and HIWAS, as appropriate, for the flight crewmember's and dispatcher's pre-flight planning and in-flight decision making processes.

(4) Discussion of procedures, including company and Air Traffic Control (ATC) procedures, for pilot weather reports (PIREP) on severe icing to include reporting procedures, content and use of PIREP's.

(5) Discussion of information provided to flight crewmembers including identification of severe icing conditions, freezing rain and freezing drizzle, exit procedures should severe icing conditions be encountered, and ATC procedures.

(6) Review of changes to the Airplane Flight Manual (AFM), Company Flight Manual (CFM), other appropriate company manuals, and minimum equipment list (MEL) resulting from the applicable AD's.

(7) For those airplanes affected by the AD's, POI's shall ensure that all relevant material and requirements from the applicable AD and all applicable MMEL changes are incorporated into their operator's company manuals.

(8) A review of the FAA publication, "Roll Upset in Severe Icing," (September 1995). [A revised version of that article appeared in *Flight Safety Digest*, January 1996, and is reprinted as the next section of this issue.]

5. Program Tracking and Reporting Subsystem (PTRS) Input. POI's assigned to operators using affected aircraft shall make PTRS entries to record the actions directed by this bulletin as outlined in HBAT 94-08. The PTRS entry shall be listed as activity code number 1381; the National Use field entry shall be listed as activity code, FSAT 97-03. POI's should use the comments section to record comments of interaction with the operators.

6. Inquiries. This bulletin was developed by AFS-200. Any inquiries regarding this bulletin should be directed to, AFS-200 at (202) 267-3755, or by fax at (202) 267-5229.

7. Expiration. This bulletin will remain in effect until March 31, 1998.♦

FSF editorial note: As part of a long-term effort to address in-flight icing issues, the U.S. Federal Aviation Administration released this action plan in April 1997. It is reprinted here slightly abridged.

Inflight Aircraft Icing Plan

U.S. Federal Aviation Administration

Introduction

The Federal Aviation Administration (FAA) Inflight Aircraft Icing Plan describes various activities, including rulemaking, development and revision of advisory material, research programs, and other initiatives that have already started or will be undertaken by the FAA in order to achieve safety when operating in icing conditions. This plan provides brief details and milestones that will be tracked by the FAA Icing Steering Committee.

In preparing this plan, the FAA made extensive use of information obtained during the FAA-sponsored International Conference on Aircraft Inflight Icing held in May 1996. Certification requirements, operating regulations, and forecast methodologies associated with aircraft icing were reviewed during the conference in an effort to determine if changes or modifications should be made to provide an increased level of safety. An important area of concern that was addressed involves icing due to supercooled large droplets (SLDs).

The conference included the following working groups: (1) Icing Environment Characterization; (2) Ice Protection and Ice Detection; (3) Forecasting and Avoidance; (4) Requirements for and Means of Compliance in Icing Conditions (including Icing Simulation Methods); and (5) Operational Regulations and Training Requirements. These working groups developed recommendations that call for specific actions. In addition, consensus items (propositions for which a consensus was achieved, but that do not call for action) were identified. Each recommendation and consensus item was considered by the FAA Icing Steering Committee in formulating this plan.

The FAA Aviation Weather Research (AWR) Program supports and manages most of the research described in the "Weather Forecasting" section of this plan as well as some activities described in the "SLD Characterization" section. AWR activities are described in greater detail in "FAA Inflight Icing Product Development Plan: Fiscal Year '97 & '98," dated October 15, 1996. All other FAA-funded research described in the plan is supported and managed through the William J. Hughes Technical Center (identified in this document as the FAA Technical Center). This research addresses safety issues of concern to the FAA Aircraft Certification and Flight Standards Services. All research described in the plan is contingent upon the availability of adequate funding.

The most current information was used in the development of the tasks and schedules contained in this plan. However, due to the complex nature of the tasks and the interrelationships between tasks, the plan may need to be revised periodically to reflect a change in scope or schedule.

The International Conference on Aircraft Inflight Icing was attended by representatives from 21 countries. During and after the conference, representatives of several of these countries expressed a commitment to improving the safety of airplanes when they are operated in icing conditions. Since aviation safety is a shared responsibility, the FAA welcomes these commitments and encourages other government agencies, foreign airworthiness authorities, industry, and other sectors of the aviation community to join together in pursuit of common goals or to undertake complementary activities. In an effort to optimize the various nations' limited resources, the FAA will actively seek international cooperation [regarding] icing activities.

Flight Standards Regulations and Guidance Material

Task 1. Improve training and operating regulations and guidance material related to icing.

Task 1A. The FAA will require Principal Operations Inspectors (POIs) to ensure that training programs for persons operating aircraft under Parts 121 and 135 of the Federal Aviation Regulations (FARs) (14 CFR [U.S. Code of Federal Regulations] Parts 121 and 135) include information about flight into freezing rain/freezing drizzle conditions as well as conventional icing conditions.

Plan Details, Task 1A

Responsible Party — Flight Standards Service.

Schedule — March 1997: Completed Flight Standards Handbook (Information) Bulletin requiring POIs to ensure that training programs include information about all icing conditions including flight into freezing drizzle and freezing rain.

Task 1B. A working group will review, revise, and develop regulations and advisory material as necessary to accomplish the following:

- Ensure that icing terminology (e.g., known, forecast, observed, trace, light, moderate, severe, and "Appendix C" icing [Appendix C of FARs Part 25 defines the range of icing conditions that aircraft seeking FAA certification must be able to encounter safely]) is used consistently and clearly by the Flight Standards Service, pilots, dispatchers, the National Weather Service (NWS) Aviation Weather Center, the Aircraft Certification Service, and Air Traffic.
- Update guidance related to icing reporting and pilot, air traffic control, and dispatcher actions.
- Provide advisory information concerning ice bridging.
- Consider the need for an icing regulation that is applicable to all general aviation aircraft operated under Part 91 of the FARs (14 CFR Part 91), since Section 91.527 does not apply to most general aviation aircraft.
- Direct POIs to ensure that all air carriers that operate aircraft under Part 121 of the FARs (14 CFR Part 121) require their dispatchers to provide pertinent weather information to flight crews.
- Require that Hazardous Inflight Weather Advisory Service broadcasts include pertinent weather information.

Plan Details, Task 1B. The review includes, but is not limited to the following documents:

- *Aeronautical Information Manual* (AIM)
- Advisory Circular 91-51
- ATC Handbooks 7110.65 and 7110.10
- Advisory Circular 135-9
- Winter Operations Guide
- Sections 91.527, 135.227, and 121.341 of parts 91, 135, and 121, respectively, of the FARs (14 CFR 91.527, 135.227, and 121.341)
- FAA Order 8400.10
- *Weather Service Operations Manual* (WSOM), Chapter D-22

The working group will also review the following documents and will attempt to coordinate with the international organizations that publish these documents. (The working group has no authority to revise the documents.)

- International Civil Aviation Organization's *Manual of Aeronautical and Meteorological Practice* (Document 8896-AN/893/4)
- World Meteorological Organization's Annex 3

Responsible Parties — Flight Standards Service; Aircraft Certification Service; FAA Technical Center; Aviation Weather Center; and Air Traffic.

Schedule —

- March 1997: Completed Flight Standards Handbook (Information) Bulletins on freezing drizzle and freezing rain training and pilots' and dispatchers' responsibilities regarding pilot reports (PIREPS).

- February 1999: Complete revisions to the FAA material listed above.

- April 1999: Determine whether or not a rule change is required.

Task 1C. The FAA will explore the feasibility of incorporating icing performance and handling characteristics in airplane training simulators.

Plan Details, Task 1C. To enhance pilot awareness of the effects of inflight icing, how inflight icing affects airplane performance, and to provide realism to pilot training in an inflight icing environment, the FAA will explore the feasibility of incorporating icing performance and handling characteristics in airplane training simulators.

Responsible Parties — Flight Standards Service; Simulator Team; Aircraft Certification Service.

Schedule — December 1997: Complete feasibility study.

Task 1D. The FAA will participate with appropriate organizations to encourage coordination among manufacturers, operators, associations, organizations, research communities, and pilots in the international community for development of inflight icing training aids (written, pictorial, video, etc.) and advisory material.

Plan Details, Task 1D

Responsible Party — FAA Icing Steering Committee.

Schedule — Ongoing.

Icing Forecasting

Task 2. Improve the quality and dissemination of icing weather information to dispatchers and flight crews.

Task 2A. The FAA will continue sponsoring icing forecasting research that is intended to refine the data and information being provided to forecasters at the Aviation Weather Center (AWC) in Kansas City [Missouri, U.S.] to improve the ability to forecast inflight icing, including icing due to SLDs.

Plan Details, Task 2A. The FAA sponsors icing forecasting research through the AWR program under the FAA Aviation Weather Research Program. Inflight icing is currently AWR's highest priority. Present work continues a seven-year history of FAA research in icing. (Activities described under 2A and 2B of this task are described in greater detail in "FAA Inflight Icing Product Development Plan: Fiscal Year '97 & '98," dated October 15, 1996.) The program also has provided leveraging of funds through cooperation with the National Science Foundation National Center for Atmospheric Research (NCAR), National Oceanic and Atmospheric Administration (NOAA), National Air and Space Administration (NASA), Department of Defense (DOD), NWS, various universities, and the private sector. The FAA has provided funding for three major field validation experiments: the Winter Icing and Storms Projects (WISP) in the winters of 1989–90, 1992–93, and 1994–95. Planning is under way for a joint freezing drizzle program with NASA Lewis Research Center (LeRC) during the winter of 1996–97 and for another WISP field effort in the winter of 1997–98.

The present AWR program direction is to refine the data and information being provided to forecasters at the AWC in Kansas City to improve the ability to forecast inflight icing, especially in the cases of freezing rain, freezing drizzle, and SLD aloft. The effort is focused on learning how to incorporate a variety of data sources into the forecast process, including satellite observations, wind profilers, Next Generation Weather Radar (NEXRAD), and Terminal Doppler Weather Radar (TDWR). The goal is to produce hourly three-dimensional icing forecast fields from model-based algorithms for aviation users with at least a one-hour lead time (up to as much as a 12-hour lead time) with high accuracy. The AWR program not only supports model and icing algorithm development, but also funds the Experimental Forecast Facility (EFF) within the AWC by which emerging icing forecasting technologies are tested in an operational setting. Icing forecasts from the EFF are distributed currently in text or 2-D graphic format. A three-dimensional gridded system for use by flight service specialists, pilots, and other users is planned. As a result of work completed thus far, in January 1996 the AWC issued the first-ever forecast of freezing precipitation aloft.

As the FAA continues to sponsor research, it will encourage other governmental, academic, private, and international organizations to pursue their own research. All such research should be conducted in mutual collaboration for maximum effectiveness.

Responsible Party — FAA Aviation Weather Research Program.

Schedule —

- November 1996–March 1997: NASA LeRC/NCAR freezing drizzle program to include forecasting of SLD conditions.

- July–September 1998: Statistical verification of icing algorithms completed. Determine upgrades to single input and combined model-sensor input algorithms. Report on NCAR-produced icing forecast guidance and value added by [Kansas City] AWC and Alaska AWC forecasters.

- Fiscal Year '99 and beyond: Complete combined sensor-model icing algorithm and implement at [Kansas City] AWC and Alaska AWC. Develop higher resolution icing guidance product (down to 10 kilometers horizontal scale) commensurate with the National Centers for Environmental Prediction (NCEP) capability improvement.

Task 2B. The FAA will continue to support the use of operationally available sensor technology (ground-based or airborne sensors that send data to ground-based equipment) for icing detection and diagnosis. The FAA also will consider funding the development of new sensor technologies for icing detection or diagnosis.

Plan Details, Task 2B. (See also Task 3). As a result of FAA efforts, in the summer of 1996, the first commercial aircraft having a humidity sensor was flown. Humidity sensors will be installed on five additional aircraft within the year. These sensors will allow automated reports of a key icing algorithm input parameter — atmospheric humidity — to supplement the temperature and wind data already reported. This effort is highly leveraged with NOAA and the National Science Foundation (NSF) in collaboration with United Parcel Service. Furthermore, AWR is working with the governments of France and the United Kingdom to obtain sensor certification on Airbus aircraft and Boeing 747 aircraft, respectively. After several months of flight tests and experience in using the humidity data to improve forecasts, as many as 160 sensors will be deployed on air carrier aircraft. This will greatly enhance the information available to meteorologists and numerical modelers.

While this airborne humidity sensor is an essential first step in icing detection and forecast verification, it does not directly identify the icing phenomenon itself. The FAA will consider funding research into icing detection technologies and facilitating transfer of these technologies to industry.

The AWR program-sponsored radar detection work has resulted in several methodologies to determine icing altitudes, to determine the amount and sizes of SLD, to discriminate between liquid droplets and ice crystals by combinations of ground- and satellite-based radars and radiometers, and to use low-cost balloon-borne packages for supercooled liquid detection and quantification. Preliminary results have been published, yet thorough testing under a variety of atmospheric conditions is needed to ensure the methods are sufficiently robust for technology transfer to operational systems such as NEXRAD and TDWR.

The FAA will encourage other governmental, academic, private, and international organizations to pursue their own research and technology transfer. All such research should be conducted in mutual collaboration for maximum effectiveness.

Responsible Party — FAA Aviation Weather Research Program.

Schedule —

- September–December 1996: Experimental, off-line (in the NCAR environment) implementation of combined model-sensor input icing diagnosis algorithm. NCAR installs satellite-based icing display at [Kansas City] AWC and Alaska AWC.
- September 1997: Report on the feasibility of using remote sensor data to determine icing severity. Report on theoretical studies of possible NEXRAD/TDWR upgrades for improving icing detection.
- October–December 1997: Implement upgrade to satellite algorithm at [Kansas City] AWC and Alaska AWC.
- November 1996–March 1998: (Tentative) Field experiment in western Great Lakes to test NEXRAD upgrade concepts.
- September 1998: Report on evaluation of NEXRAD upgrades tests.

Inflight Ice Detection

Task 3. Accelerate development of airborne technologies that remotely assess icing conditions by working with groups that already are supporting research in this area.

Plan Details, Task 3. The development of equipment carried on an aircraft that could detect icing conditions in an area that is remote from the aircraft would assist aircraft that are not certified for flight in icing conditions in avoiding those conditions. The ability to remotely detect icing is envisioned as an important capability of aircraft developed in accordance with the "avoid and exit" concept advanced as part of the Advanced General Aviation Transportation Experiment (AGATE). Such aircraft are not planned to be certified for flight in icing conditions.

Remote sensing could be useful to aid in avoidance of severe icing conditions by all aircraft including transport airplanes. The Department of Defense (DOD) and FAA are funding investigative research in this area; Cold Regions Research Engineering Laboratory (CRREL) will provide the primary technical management. NASA LeRC is organizing a workshop on the airborne remote sensing concept.

Responsible Parties — FAA Technical Center, DOD, CRREL, NASA LeRC.

Schedule — July 1998: Reports on airborne remote sensing technology proof of concept investigations.

Certification Regulations and Guidance Material

Task 4. Ensure that aircraft having unpowered ailerons and pneumatic deicing boots do not have roll control anomalies if exposed to certain SLD conditions.

Task 4A. The FAA will develop and publish interim procedures for aircraft receiving new, amended, or supplemental type certificates.

Plan Details, Task 4A. In 1994, an accident occurred in which severe icing conditions outside of the icing certification envelope contributed to uncommanded roll [on Oct. 31, 1994, to an ATR 72-212 operating as American Eagle Flight 4184]. The accident profile was nearly replicated during flight tests when the aircraft was flown with ice shapes developed from testing in an artificial icing cloud having droplets in the size range of freezing drizzle at a temperature near freezing. This condition created a ridge of ice aft of the deicing boots and forward of the ailerons. Dry air testing with this ice shape resulted in uncommanded motion of the ailerons and rapid roll. Subsequent mandatory modifications to enlarge the deicing boot to remove the ice formation corrected these unsafe characteristics. In addition, flight manual procedures were adopted that allowed flight crews to identify inadvertent flight into severe icing conditions, and provided restrictions and procedures to allow a safe exit from those severe conditions. The deicing system modification provides an increased margin of safety in the event of an encounter with freezing conditions exceeding the icing certification envelope.

The FAA initiated a review of aircraft similar to the accident airplane to determine if other type designs might experience control difficulties should a ridge of ice form aft of the deicing boots and forward of the ailerons. The investigation addressed Part 23 and Part 25 airplanes that are equipped with pneumatic deicing boots and nonpowered flight control systems and that are used in regularly scheduled revenue passenger service in the United States.

The FAA has determined that similarly equipped aircraft receiving new, amended, or supplemental type certificates should be evaluated for roll control problems if exposed to SLDs. The procedures will be based upon those used during the previous FAA evaluation program and will continue until specific regulations are adopted to address conditions outside of the current regulatory icing envelopes in Appendix C of Part 25 of the Federal Aviation Regulations (14 CFR Part 25).

Responsible Parties — Small and Transport Airplane Directorates

Schedule — July 1997: Develop and publish guidance applicable to airplanes receiving new, amended, or supplemental type certificates.

Task 4B. The FAA will issue Notices of Proposed Rulemaking (NPRMs) to require that certain aircraft exit icing conditions when specific visual icing cues are observed. The NPRMs will be applicable to aircraft that (1) have pneumatic deicing boots and unpowered ailerons and (2) were not addressed by the icing Airworthiness Directives ADs issued on April 24, 1996.

Plan Details, Task 4B. In April 1996, the FAA issued 18 ADs to require revisions to the FAA-approved Airplane Flight Manual to provide flight crews with recognition cues for, and procedures for exiting from, severe icing conditions. The ADs were written because flight crews were not provided with the information necessary to determine (1) when an airplane is operating in icing conditions that have been shown to be unsafe and (2) what action to take when such conditions are encountered.

The ADs applied primarily to Part 23 and 25 airplanes that have unpowered primary roll controls, pneumatic deicing boots, and [that] are used in regularly scheduled revenue passenger service in the United States.

The FAA will propose similar mandatory action through the NPRM process for all Part 25 and certain Part 23 airplanes that have unpowered roll controls and pneumatic deicing boots that were not addressed by the earlier ADs. The Part 23 NPRMs will address airplanes certificated in normal and utility categories (not used in agricultural operations) having unpowered roll controls and pneumatic deicing boots that are used in Part 135 on-demand and air taxi operation, and other airplanes regularly exposed to icing conditions.

These Part 23 NPRMs will include:

- All single and multi-engine turbopropeller powered airplanes
- All multi-engine piston powered airplanes
- Single-engine piston powered airplanes generally having retractable landing gear, constant speed propellers, and powered by engines rated at 200 horsepower or greater

Responsible Parties — Small and Transport Airplane Directorates

Schedule —

- August 1997: Publish NPRMs.
- February 1998: Publish Final Rules.

Task 5. Task the Aviation Rulemaking Advisory Committee (ARAC) with a short-term project to consider a regulation that requires installation of ice detectors, aerodynamic performance monitors, or another acceptable means to warn flight crews of ice accumulation on critical surfaces requiring crew action (regardless of whether the icing conditions are inside or outside of Appendix C). ARAC will also be tasked with a long-term harmonization project to develop certification criteria and advisory material — possibly including envelopes supplementing those currently in Appendix C — for the safe operation of airplanes in SLD aloft, in SLD (freezing rain or freezing drizzle) at or near the surface, and in mixed phase conditions.

Plan Details, Task 5. The current icing certification regulations ensure that airplanes are safe for operation in icing conditions defined by the envelopes in Appendix C of Part 25 of the FARs (14 CFR Part 25). However, service experience has shown that airplanes may encounter icing conditions exceeding [those covered in] Appendix C, which may have catastrophic consequences. The initiative will provide certification requirements to increase the level of safety when icing conditions exceeding Appendix C are encountered.

Another key issue that requires analysis is the recognition of aircraft icing. ARAC will be given the task to consider the need for a regulation that requires installation of ice detectors or other acceptable means to warn flight crews of ice accumulation on critical surfaces requiring crew action.

Responsible Party — FAA.

Schedule —

- September 1999: Reach technical agreement.
- October 2001: Publish Final Rule.

Task 6. Improve the regulations and guidance related to certification of airplanes for operation in icing conditions defined by Appendix C.

Task 6A1, 6A2, and 6A3. The FAA will review, revise, or develop the following guidance material:

- Review and revise Advisory Circular (AC) 20-73 "Aircraft Ice Protection."
- Review and revise AC 23.1419A "Certification of Part 23 Airplanes for Flight in Icing Conditions."
- Develop AC 25.1419 "Certification of Part 25 Airplanes for Flight in Icing Conditions."

Plan Details, Task 6A1, 6A2, and 6A3. A review of existing advisory material indicates that improvements can be made and new information incorporated to benefit all users. The ACs will address icing conditions that are defined by the current Appendix C. Consideration will be given to combining the information into one AC. It is anticipated that additional advisory material will be required for icing conditions outside [of those covered in] Appendix C (see Task 5).

Responsible Party — Aircraft Certification Service.

Schedule — September 1998: Issue proposed ACs.

Task 6A4. Review and update FAA *Icing Handbook*

Plan Details, Task 6A4. The FAA *Icing Handbook* is a compendium of technical information pertaining to design, analysis, testing, and certification of aircraft with ice protection. The handbook is intended primarily for use by airframe, powerplant, and flight test engineers. The update will include, but will not be limited to, new information on the following:

- Airfoil and aircraft aerodynamics, performance, and stability and control with ice accretions
- Characterization of SLD icing conditions
- Analytical icing accretion and performance codes
- Ice protection systems

Responsible Party — FAA Technical Center.

Schedule — December 1977: Complete update of the FAA *Icing Handbook*.

Task 6A5. Develop an engine and propulsion icing AC.

Plan Details, Task 6A5. The engine and propulsion icing AC will provide certification guidance that is more definitive than AC 20-73, *Aircraft Ice Protection*. It will also present information that will cover engine certification and Part 25 engine induction system certification as a coordinated process.

Major areas to be covered include:

- Ice shed damage conditions
- Power loss instability conditions (e.g., rollback, flameout, surge/stall, etc.)
- Acceptance criteria (acceptable damage, acceptable power loss, etc.)
- Natural icing flight tests (Part 25 of the FARs [14 CFR Part 25])

Responsible Parties — Engine and Propeller Directorate, Transport Airplane Directorate.

Schedule — September: Issue final AC.

Task 6A6. Develop an AC to provide guidance on how to evaluate the susceptibility of a horizontal tail to stall.

Plan Details, Task 6A6. Aerodynamic stalling of the horizontal tailplane when the leading edge was contaminated with ice has been responsible for a number of catastrophic accidents. It has been found that even the small amounts of ice that may accumulate before activation of an ice protection system can cause reductions in the tailplane stall margin.

Airplanes with powered pitch control systems may be susceptible to this phenomenon in terms of alteration of the aerodynamic characteristics of the tailplane. However, there has only been adverse service history with leading edge contamination on airplanes with unpowered pitch control systems. Airplanes with a history of accidents and incidents attributed to tailplane stall are required by the FAA to limit the use of flaps, modify the ice protection system, or modify the horizontal stabilizer airfoil design. These changes improve the performance of the ice protection system or increase tailplane stall margins. The FAA also evaluated the tailplane stall margins of other Part 121 and 135 airplanes with unpowered pitch control systems and found the margins to be adequate.

In 1992, the FAA published a memorandum that prescribed a zero-g pushover maneuver to investigate an airplane's susceptibility to tailplane stall. The FAA now plans to develop guidance material that will present design criteria and assessment methods that will aid manufacturers in the design of tailplanes that are not susceptible to stalling when the leading edge is contaminated.

Responsible Parties — Small Airplane Directorate, Transport Airplane Directorate.

Schedule — September 1999: Issue final AC.

Task 6B. The FAA will coordinate an evaluation of a reformatted Appendix C, which could [be easier to use for] certification and for other purposes and which could be incorporated into an AC.

Plan Details, Task 6B. Dr. Richard Jeck's paper "Other Ways to Characterize the Icing Atmosphere" (American Institute of Aeronautics and Astronautics 94-0482) suggests formats of the Appendix C data that could be used more easily by certification and research personnel. The FAA will consider writing an AC that contains the suggested formats, the use of those formats, and an explanation of the process of translation between the present Appendix C envelopes and the proposed formats. Dr. Jeck's proposals do not necessarily require any change in the Appendix C envelopes.

Responsible Parties — FAA Technical Center, Small and Transport Airplane Directorates, FAA Icing Steering Committee.

Schedule —

- August 1997: Solicit comments from the FAA, industry, and the research community. If the proposals are found to be desirable, then
- June 1998: Issue proposed AC.

Task 6C. Task an ARAC working group to harmonize the regulations of Section 23.1419 ("ice protection") of Part 23 of the FARs (14 CFR 23.1419), and Sections 25.1419 ("ice protection"), 25.929 ("propeller deicing"), and 25.1093 ("induction system ice protection") of Part 25 of the FARs (14 CFR Part 25.1419, 25.929, and 25.1093) and of Part 25 of the Joint Airworthiness Regulations (JARs), and to produce appropriate advisory material.

Plan Details, Task 6C

Responsible Parties — Small and Transport Airplane Directorates.

Schedule — October 2001: Publish Final Rule.

Task 7. The ARAC Flight Test Harmonization Working Group will complete the harmonization project to standardize performance and handling requirements and guidance material for certification of FAR/JAR 25 airplanes to safely operate in the icing conditions of Appendix C.

Plan Details, Task 7. Section 25.1419 of Part 25 of the FARs (14 CFR Part 25) and Section 25.1419 of the JARs require that the airplane must be able to safely operate in certain specified icing conditions. The Flight Test Harmonization Working Group was tasked with a project to standardize airplane performance and handling requirements for demonstrating safe operation in icing conditions. The harmonization project started when the JAA published Notice of Proposed Amendment (NPA) 25F-219, "Flight Characteristics in Icing Conditions." The NPA provides guidance for demonstrating acceptable airplane performance and handling characteristics for flight in icing conditions.

The Flight Test Harmonization Working Group began work on this project in October 1994. A number of technical issues are yet to be addressed, including coordination with other ARAC working groups relative to systems and avionics requirements during flight in icing conditions. However, agreement has been reached on the majority of performance and handling qualities issues.

Responsible Party — ARAC.

Schedule — March 1999: Publish Final Rule and AC.

Task 8. (This task is left blank intentionally)

Task 9. The FAA, in concert with airworthiness authorities throughout the world, will consider a comprehensive redefinition of certification envelopes (such as those that appear currently in Appendix C) for the global atmospheric icing environment when sufficient information is available worldwide on SLD, mixed phase conditions, and other icing conditions, and when adequate simulation tools are available to simulate and/or model these conditions.

Plan Details, Task 9. The lack of information to support a comprehensive redefinition of certification envelopes for the global atmospheric icing environment was emphasized by numerous participants at the May 1996 International Conference on Aircraft Inflight Icing. Additionally, as the number of aircraft increase, the probability of encountering intense icing conditions that were previously considered rare increases. As available icing cloud information and technologies improve, the FAA will consider a comprehensive change to the icing certification envelopes. This task is extremely complex — it requires information from around the globe and the cooperation of aviation authorities around the world. In the interim, the FAA will work with ARAC to improve the safety of airplanes exposed to icing conditions that exceed the current Appendix C icing envelopes (see Task 5).

Responsible Party — FAA Icing Steering Committee.

Schedule — June 2003: If appropriate, the FAA will propose a change to the envelope.

Task 10. The FAA Human Factors Team will review the design philosophy of automatic autopilot disconnection due to an external disturbance.

Plan Details, Task 10. Operational experience has shown that in some autopilot modes, the autopilot has disconnected after trimming the aircraft to stall entry during flight in icing. Loss of control from ensuing roll and pitch excursions has resulted [in] some instances. The human factors aspect of autopilot use and disconnect during flight in icing will be addressed.

Responsible Party — FAA Human Factors Team.

Schedule — September 1997: Publish a plan and schedule.

Icing Simulation Methods

Task 11. Develop validation criteria and data for simulation methods used to determine ice shapes on aircraft, including icing tunnel, ice accretion computer codes, and icing tankers.

Task 11A. *Validation Requirements*. A working group will be formed to identify validation requirements for icing facilities (tunnels and tankers), and droplet impingement and ice accretion computer codes. The validation requirements will be appropriate for use in certification. The working group will develop information describing validation criteria (including specification of limitations) for icing simulation facilities, including instrumentation and data processing methodologies as they relate to facility calibrations, and for impingement and ice accretion codes. This will be a coordinated effort among research organizations, industry, and regulatory authorities. This material will be evaluated by the FAA for adoption as guidance material.

Plan Details, Task 11A. The working group will establish a plan for development of validation criteria for experimental icing simulation facilities (tankers and tunnels) and icing simulation codes. The working group will develop level-of-acceptance criteria for validation comparisons. The group will examine correlation of ice shapes (including impingement) from icing facilities with those from flight in natural icing conditions. In addition, the group will examine correlation of ice shapes (including impingement) from ice accretion codes with those from both simulation facilities and natural conditions. The fidelity of artificial ice shapes needed to represent a natural event will be reviewed. Methods will be examined to provide quantifiable information on cloud characteristics, ice accretion shapes, and aero-performance measurements in natural icing to determine the comparison criteria for simulation. Methods for processing time-averaged flight data will be evaluated to support replicating natural icing events in ground-based facilities.

The working group also will address methods for defining tunnel/tanker cloud characteristics and their calibration and accuracy. This will include instrumentation employed in the establishment of those calibrations and methods to determine the facility's envelope. A set of equivalent icing conditions along with a standard model(s) will be identified for use in comparing icing simulation facilities. Means of comparison to cross reference individual facility results will be developed.

Issues related to the simulation of freezing drizzle, freezing rain, and mixed phase conditions either by a facility or a computer code also will be examined.

Responsible Parties — NASA LeRC, FAA Technical Center, and Aircraft Certification Service.

Schedule —

- August 1997: Develop interim recommendations on validation criteria.
- June 2001: Develop final recommendations on validation criteria.

Task 11B. *Validation Data*. The FAA shall support research aimed at developing ice accretion data and associated aerodynamic effects that can be used for the validation of ice accretion codes and analysis of aerodynamic performance degradation due to icing. This research also can be used to form the basis of an evaluation of ice shape features resulting in critical performance loss.

Plan Details, Task 11B. The NASA LeRC Modern Airfoils Ice Accretions Program receives funding support from the FAA. This program encompasses the development of ice accretions in icing tunnels on modern airfoils (2D) and wings (3D) of interest to industry and the FAA. It includes the acquisition of aerodynamic data using icing tunnel accretion models in high quality aerodynamic tunnels.

Responsible Parties — NASA LeRC, FAA Technical Center.

Schedule — September 1998: Report on ice accretions for modern airfoils (2D), including C_d, $C_{1, max}$, and stall angles.

Task 11C. *Simulation Improvement*. The FAA will support research on the development and improvement of ice simulation methods such as ice accretions codes, icing tunnels, and icing tankers. This research will be directed at understanding the physical processes underlying the ice accretion process, including phenomena associated with SLD ice accretion.

Plan Details, Task 11C. A working group will be formed to publish a research plan that addresses how the FAA can most cost effectively improve the simulation capabilities of industry and research facilities.

Responsible Parties — FAA Technical Center, Aircraft Certification Service.

Schedule — February 1998: Publish a Simulation Improvement Research Plan.

Ice Accretion and Its Effects on Performance/Stability and Control

Task 12. Develop guidance material on ice accretion shapes and roughness and resultant effects on performance/stability and control. This material will be relevant to the identification and evaluation of critical ice shape features such as ice thickness, horn size, horn location, shape, and roughness.

Task 12A. The FAA, along with industry and research organizations, shall form a working group to explore categories of ice accretions that represent potential safety problems on aircraft.

Plan Details, Task 12A. The certification process requires identification and evaluation of critical ice accretions. Criticality of possible ice accretions is not well understood, and guidance information is needed for compliance with established requirements. The working group will evaluate numerous ice shapes to help define areas of concern about the effects of ice accretion on airfoil performance and aircraft stability, control, and handling characteristics.

These ice accretion categories would include (but would not be limited to):

- “Sandpaper” ice (a thin layer of ice composed of roughness elements);
- Residual ice (ice remaining after a deicing cycle);
- Rime ice;
- Glaze ice;
- Large-droplet ice (spanwise step accretions beyond the “normal” impingement zone);
- Beak ice (single horn ice shape on the upper surface); and
- Intercycle ice (ice accumulated between deicing cycles).

These categories of ice would be considered during various phases of flight such as takeoff, landing, climb, hold, etc., for:

- Operational ice protection systems;
- Failed ice protections systems; and
- Unprotected surfaces.

Responsible Parties — Aircraft Certification Service, FAA Technical Center, NASA LeRC, Industry, Academia.

Schedule — December 1997: Publish a plan.

Task 12B. The FAA will establish a working group to visit various manufacturers to learn how they develop critical ice shapes and their rationale for the ice shapes used for certification. The working group will develop information to be considered for publication.

Plan Details, Task 12B

Responsible Party — Aircraft Certification Service.

Schedule —

- October 1997: Complete visits to manufacturers.
- December 1997: Report findings.

Task 12C1 and 12C2. The FAA will continue to support research on the effects of ice accretion on airfoil performance and aircraft stability, control, and handling characteristics. As the FAA continues to sponsor research, it will encourage other governmental, academic, private, and international organizations to pursue their own research. All such research should be conducted in mutual collaboration for maximum effectiveness. The following research efforts are current FAA-supported programs directed at addressing the issues associated with this task:

- The NASA LeRE/FAA Tailplane Icing Program and
- The University of Illinois/FAA Study of the Effect of Large-Droplet Ice Accretions on Airfoil and Wing Aerodynamics and Control

Plan Details, Task 12C1. *The NASA LeRC/FAA Tailplane Icing Program*. This program encompasses a study of tailplane icing using icing tunnel, wind tunnel, and computational methods, and flight tests. It includes the investigation of flight test and analytical methods to determine aircraft sensitivity to ice contaminated tailplane stall.

Responsible Parties — NASA LeRC, FAA Technical Center.

Schedule — April 1998: Final report.

Plan Details, Task 12C2. *University of Illinois/FAA Study of the Effect of Large-Droplet Ice Accretions on Airfoil and Wing Aerodynamics and Control.* The objective of this research is to study the effects of spanwise step ice accretions on subsonic aircraft aerodynamics and control. This type of ice accretion can occur in supercooled temperatures near freezing. Experimental and computational tasks will be conducted using simulated ice accretions to determine the sensitivity of ice shape and location on airfoil performance and control surface hinge moment as a function of angle-of-attack and flap detection. Critical conditions will be identified where the hinge moment or aerodynamic performance changes rapidly.

Responsible Parties — University of Illinois, FAA Technical Center.

Schedule —

- 1997: Interim report.
- 1999: Final report.

Task 12D. The FAA will request that industry form a committee to review data from the Phase II testing to determine if there are significant correlations that can be shared for future use and to identify realistic ice shapes due to SLD. The committee will consider the effect of airfoils, pressure distribution, aileron design, etc., on an aircraft's susceptibility to roll control problems.

Plan Details, Task 12D. During the May 1996 International Conference on Aircraft Inflight Icing, manufacturers indicated a willingness to contribute data to accomplish this task.

Responsible Party — Aircraft Certification Service

Schedule — July 1997: Prepare letter(s) to industry.

SLD Characterization and Mixed Phase Conditions Assessment

Task 13. Characterize SLD aloft and assess mixed phase conditions (ice crystals and supercooled liquid water droplets) in the atmospheric flight environment.

Task 13A. The FAA will circulate "trial" SLD dropsize distributions to participating research organizations to assess differences in liquid water content (LWC) and dropsize processing methods.

Plan Details, Task 13A. This subtask responds to the long recognized problem of trying to correct, or adjust, recorded dropsize distributions for systematic measurement errors that occur with modern, electro-optical, droplet sizing probes. In the absence of a standard procedure, different users employ different correction schemes that can give different results for the same initial SLD size distribution. Unacceptably large disagreements in computed median volume diameters and water concentrations can arise this way. In this situation, nobody knows how much artificially introduced error is contained in published SLD results. Therefore, this plan attempts to gauge the seriousness of the problem by allowing all interested researchers to use their preferred correction scheme — whatever it may be — on the same initial size distribution and to compare the results.

Responsible Party — FAA Technical Center.

Schedule — April 1998: Final report summarizing results.

Task 13B. The FAA will collect, consolidate, and analyze affordable and accessible existing SLD data. The FAA will recommend that individual civil aviation authorities (CAAs) sponsor an analyses of archived weather data in their own countries to provide statistics on the local occurrences of freezing rain and freezing drizzle.

Plan Details, Task 13B. A comprehensive data set was collected by the FAA Technical Center for icing conditions in clouds for which the processed data rarely revealed the presence of significant concentrations of droplets larger than 50 microns in diameter. Therefore, this database cannot be used for analysis of SLD conditions. Several research institutions have collected data in SLD conditions; inquiries must be made regarding additional organizations possessing in-situ measurements that may include these conditions.

A data compilation similar to that for the cloud icing database will be conducted. Processing techniques, whether done on site at the participating institutions or at the FAA Technical Center, will be determined as part of this project.

Records of freezing rain and freezing drizzle from surface observations exist in many countries. These data are valuable for assessing the threat of SLD worldwide and for determining the opportunities for possible flight tests or additional measurements in SLD conditions. Civil aviation authorities worldwide will be encouraged to undertake or sponsor the analyses of their archived weather data.

Responsible Party — FAA Technical Center.

Schedule

- June 1997: Prepare a letter to worldwide CAA's.

- March 1998: Final report on results from FAA effort.

Task 13C. The FAA will conduct a study to determine the magnitude of the safety threat that is posed by mixed phase conditions.

Plan Details, Task 13C

Responsible Party — FAA Technical Center.

Schedule — February 1998: Report on the findings and recommendations for possible further action.

Task 13D. (This subtask is left blank intentionally.)

Task 13E. The FAA will support basic research on the formation mechanism of freezing drizzle aloft and at ground level.

Plan Details, Task 13E. Through the FAA Aviation Weather Research Program, the FAA has supported ongoing work in this area since fiscal year 1990. The "FAA Inflight Icing Product Development Plan: Fiscal Year '97 & '98" includes a section on basic icing science, which focuses on the roles of turbulence and low cloud condensation nucleus concentrations in contributing to the formation of SLD.

Responsible Party — FAA Aviation Weather Research Program, AUA-460.

Schedule — This is ongoing work. Results from these analyses have already been incorporated into guidance products transferred to AWC as part of the FAA AWR Program. The two-year (FY 1997 and FY 1998) Inflight Icing Product Development Team Plan under review by the AWR Program includes further study and transfer of research results to operations.

Task 13F. The FAA will solicit knowledgeable individuals to provide guidance to researchers for developing SLD and mixed phase icing cloud characterizations for possible certification purposes (quantity, geographic location, and characterization format).

Plan Details, Task 13F. Guidance will be sought from researchers who collect and analyze the data, modeling and wind tunnel representatives, and industry and FAA representatives who would use any new characterizations (of SLD and mixed phase conditions) for certification purposes. The need is not solely meteorological (processes, characteristics, extents), but also depends on such factors as location relative to high traffic use areas, wind tunnel and numerical simulation requirements, and operational requirements.

Responsible Parties — FAA Technical Center, (Canadian) Atmospheric Environmental Service (AES), National Research Council of Canada (NRC), and Transport Canada (TC), NCAR, NASA LeRC, Aircraft Certification Service.

Schedule — April 1998: Report on findings.

Task 13G. The FAA [will support] tunnel testing by NASA LeRC and the Canadian AES with the objective of testing LWC meters for droplet sizes greater than 50 microns.

Plan Details, Task 13G

Responsible Parties — NASA LeRC, AES, FAA Technical Center.

Schedule —

- September 1996: Completed NASA LeRC and Canadian (AES/NRC/TC) tunnel testing.
- July 1997: Report on the tunnel testing.

Task 13H. The FAA will support further icing research to characterize SLD for operations, simulation, and certification purposes This research will include the collection of data in geographic areas where SLD aloft data has not been collected, such as the Great Lakes Region. Such field programs will be planned to provide information useful for verification of forecasting methodologies, training and guidance material pertaining to operation in SLD aloft (e.g., horizontal and vertical extent), SLD characterization, and simulation of SLD using icing tunnels/tankers and computer codes. The FAA will request that the international community (Canadian AES, NRC, and TC and European Research on Aircraft Ice Certification [EURICE]) continue their support of similar research efforts (or initiate similar studies) and enter into SLD data exchange agreements promoting compatible operational and data collection procedures, measurement techniques, and data processing procedures.

Plan Details, Task 13H. Existing SLD data for North America is almost entirely derived from mountainous regions of the western United States and the maritime provinces of eastern Canada. The mechanisms primarily responsible for icing in those areas (orographic, north Atlantic) are different from those in other geographic areas of North America. Thus, atmospheric sampling in geographic areas representative of other SLD formation mechanisms would be very valuable in the formulation of an SLD characterization envelope. These areas would include the Great Lakes Region and other areas determined through consultation with meteorologists and cloud physicists.

Most sampling of SLD aloft must, by definition, be done in flight. However, innovative approaches can be used in some geographic areas, as exemplified by the pilot project on Mount Washington in winter 1996–97.

A cooperative NASA LeRC/NCAR/FAA project, based at the NASA LeRC flight facility in Cleveland, Ohio, is planned for the 1996–97 icing season. Canada (AES/NRC/TC) has proposed a field project for the Canadian Great Lakes in 1997–

98. These projects will provide essential SLD data in the Great Lakes region, which is believed to be a geographic area where severe icing conditions occur with greater frequency than in most other areas of North America. This project is crucial both to possible short-term regulatory action and to effective planning of further SLD flight research.

A scientific field project (WISP98) is planned tentatively for the western Great Lakes area during winter 1997–98. That project will include SLD flight research if funding is available. A conservative estimate is that $600,000 would be required from FAA and other sources in order to include SLD flight research in this project. WISP98 involves NCAR, FAA, NASA LeRC and, possibly, several universities, local NWS offices, the National Oceanic and Atmospheric Administration's Environmental Technology Laboratory, and industry. Facilities available for this project are directly dependent on funding amounts and sources, both of which are unknown at this time. Canada (AES/NRC/TC) also is planning a field project for the Canadian Great Lakes in 1997–98.

The support of further SLD flight research in 1998–99 will be assessed in light of the outcome of the efforts in 1996–97 and 1997–98. The factors considered will include the success of the research already conducted, the need for further data for regulatory and other purposes, and available funding. If it is determined that three complementary flight programs are needed in different geographic areas of North America, and each costs at least $600,000 (a conservative estimate), then the total cost would be at least $1.8 million.

Data from all efforts will be provided to the FAA Technical Center. The Technical Center will enter the data into the FAA SLD data base, and will provide the data to the ARAC committee described in Task 5 of this report in a form appropriate for their deliberations.

Responsible Parties — FAA Technical Center, FAA Aviation Weather Research Program, Canada (AES/NRC/TC), JAA, NASA LeRC, NCAR.

Schedule —

- June 1997: Letter from FAA to Canadian AES and EURICE proposing consideration of an agreement on exchange of SLD flight research data.

- June 1998: New SLD data from Great Lakes Project and Mt. Washington Project entered in FAA SLD database and included in package provided to ARAC in appropriate form. FAA SLD database and data package for ARAC also will include data from Task 13B of this report.

- October 1998: New SLD data from WISP98 and other available field projects entered in FAA SLD database and provided to ARAC in appropriate form.

- 1998–99: Additional SLD atmospheric flight research based upon available resources and an evaluation of the research completed to date.

Task 13I. A feasibility study will be carried out by a working group to determine if the FAA should solicit cooperation of operational aircraft to carry icing, LWC and droplet probes.

Plan Details, Task 13I. A variety of simple to complex measurement devices exist. These devices are available for installation on aircraft to provide real-time or recorded measurements relevant to the icing problem. The appropriate instruments, aircraft, data collection, format, and applications must be assessed. Some instruments, such as ice detection equipment used for pilot warning/deicing equipment activation, already exist and are installed. Data recorders, including written or voice pilot notes, digital recording, or ground telemetry, are needed to document the information.

Responsible Parties — FAA Technical Center, Flight Standards, Canada (AES/NRC/TC), NCAR, NASA LeRC.

Schedule —

- June 1997: Working group formed.

- December 1997: Report and recommendations.

Coordination of Icing Activities

Task 14. The FAA Icing Steering Committee will coordinate inflight icing activities, including recommendations from the FAA International Conference on Aircraft Inflight Icing.

Plan Details, Task 14. The FAA Icing Steering Committee members are drawn from across the FAA, including representatives from the Flight Standards Service, Air Traffic, Aircraft Certification Service, and the FAA Technical Center. The committee was instrumental in the review of the recommendations from the FAA International Conference on Aircraft Inflight Icing and the subsequent development of this FAA Inflight Aircraft Icing Plan. The committee will monitor [the progress of the tasks in this plan to see that they are] proceeding on schedule and are achieving the desired results.

Responsible Party — FAA Icing Steering Committee.

Schedule — Biannual review of the FAA Inflight Aircraft Icing Plan to determine progress on accomplishing the plan and to identify areas where the plan should be revised.

[Appendices I and II of the report are omitted from this reprint. Appendix I lists the "recommendations," "consensus items" and "nonconsensus" items developed by the working groups

at the May 1996 International Conference on Aircraft Inflight Icing. Recommendations were defined as proposals calling for specific actions; consensus items as proposals about which a consensus was reached, but which did not call for immediate action; and nonconsensus items as proposals that were considered significant, but about which no consensus about action was reached. Appendix II is a table that illustrates how most of the recommendations and consensus items in Appendix I are incorporated into the icing plan tasks.]

Appendix III

Significant Recommendations Not Incorporated into the FAA Inflight Aircraft Icing Plan

Ice Protection and Ice Detection Working Group Recommendation: **It is essential that an icing environment severity index be developed as a generic scale.**

The icing ADs that were issued in April 1996 essentially acknowledge two levels of icing certification. One level consists of the icing conditions that are defined by the envelopes contained in Appendix C. The second level consists of icing conditions that exceed the capabilities of the airplane ice protection system. However, the FAA believes that this recommendation is for several additional levels of icing severity. Ice detection tools, icing simulation tools, and forecasting capabilities do not exist to support the fine differentiation of icing conditions that would be required to institute and certificate an aircraft for operation under such a system. Therefore, the FAA Inflight Aircraft Icing Plan does not incorporate a task to develop such an index. If technological advances make such an index possible, the issue should be revisited.

Requirements for and Means of Compliance in Icing Conditions Working Group Recommendation: **Recommend FAA accept principle of certification to less than full envelope such that with adequate detection systems rotorcraft manufacturers can certify to that icing envelope.**

The FAA has already developed two reduced icing envelopes as alternatives to the full icing envelope of Appendix C for rotorcraft certification. These two envelopes are presented in AC 29-2A. The FAA has no plans to further reduce this envelope.

Requirements for and Means of Compliance in Icing Conditions Working Group Recommendation: Develop and validate propeller icing performance code.

The FAA is not aware of any operational safety issues related directly to the performance of propellers in icing conditions. Ice will accrete on propellers near the propeller hub and can result in some power loss. However, most of the propulsive force from the propeller is generated near the tip of the blade where ice accretions are unlikely. The need to develop and validate propeller icing performance codes is not a priority issue; therefore, the FAA has not included such a task in the Aircraft Inflight Icing Plan.

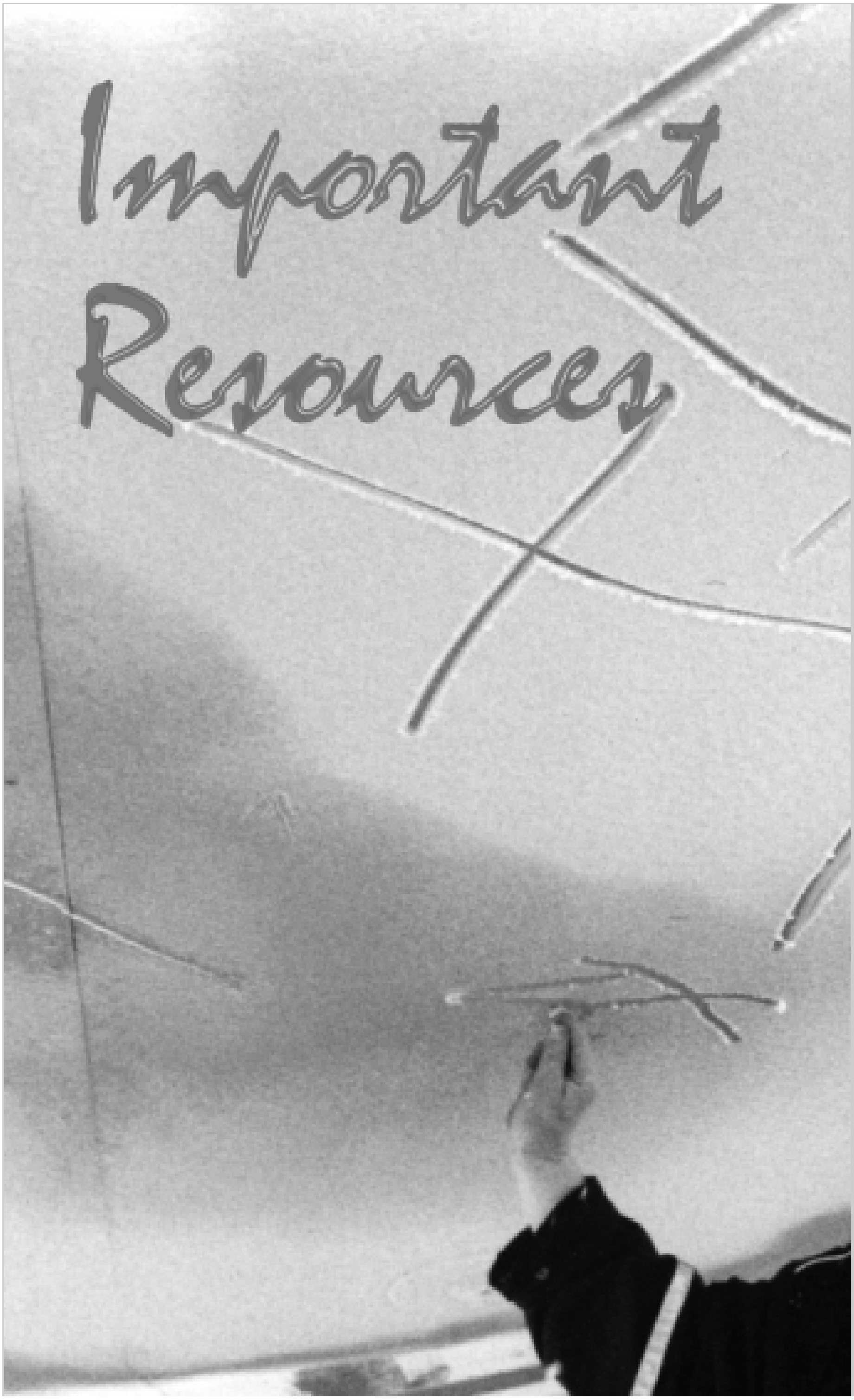
Forecasting and Avoidance Working Group Recommendation: The Aviation Surface Observation System (ASOS) program should continue the development and implementation of freezing rain and freezing drizzle sensors; stations that augment ASOS should routinely report this information.

This recommendation has already been accomplished. The development of freezing rain sensors has been completed by the NWS and the freezing rain sensor is currently being deployed as an integral component of ASOS. Augmenting stations are required to report freezing rain and freezing drizzle whenever those conditions are observed.

Operational Regulations and Training Requirements Working Group Recommendation: Review Master Minimum Equipment List (MMEL) restrictions in Airworthiness Directives (ADs) (i.e., the icing ADs that were issued on April 24, 1996).

The ADs contain a limitation that all icing detection lights must be operative prior to flight into icing conditions at night. This limitation supersedes any relief provided by the MMEL. It was the FAA's intent to require that lights be operational prior to flight in icing at night to help the flight crew to observe the visual icing cues identified in the ADs. It was not intended to include the lights that illuminate an ice detector or an ice evidence probe. For most of the airplanes affected by the ADs, the lights that help to illuminate the wing and spinner are the lights required to be operational in accordance with the AD. The FAA has no plans to revise the ADs. Any issues regarding the MMEL restriction may be handled through a request for approval of an alternative method of compliance.♦

[Appendices IV and V of the report are omitted from this reprint. Appendix IV is a glossary of acronyms, which are defined in the reprint in the text where they first appear. Appendix V is a list of contributors to the plan, both within FAA and from other organizations.]


Important Resources

U.S. Icing-related Regulations and Advisory Materials: Results of an AV-DATA 2000 Search

FSF Editorial Staff

The list that follows was compiled using AV-DATA 2000 CD-ROM's sophisticated search function to find official U.S. regulatory and advisory documents containing the word "deicing" or "anti-icing."

The compilation makes it evident that there is a very large body of icing-related FAA information. Pilots, ground handlers, dispatchers and others with a direct interest in icing might be surprised at the sheer volume of regulatory and advisory material on the subject.

The following abbreviations are used in the list to describe types of materials: FAR (U.S. Federal Aviation Regulations); FR (U.S. *Federal Register*); NPRM (Notice of Proposed Rulemaking); FSF (Flight Safety Foundation — from the archives of recent FSF publications included in the AV-DATA 2000 database); AD (Airworthiness Directive); AC (Advisory Circular); TCD (Type Certificate Data Sheet); FO (FAA Order); SDR (Service Difficulty Report); and STC (Summary of Supplementary Type Certificates).

The list is published here to provide references to relevant documents.

Doc. Type	Est. Pg.	Date	Title
FAR	1	1996-01-26	14 CFR § 121.629 Operation in Icing Conditions
FAR	1	1993-12-30	14 CFR § 125.287 Initial and Recurrent Pilot Testing Requirements
FAR	1	1996-01-26	14 CFR § 135.227 Icing Conditions: Operating Limitations
FAR	1	1993-12-30	14 CFR § 135.345 Pilots: Initial, Transition, and Upgrade Ground Training
FAR	1	1993-12-30	14 CFR § 125.221 Icing Conditions: Operating Limitations
FAR	1	1983-01-31	14 CFR § 29.C Appendix C to Part 29 — Icing Certification
FAR	1	1995-12-20	14 CFR § 121.341 Equipment for Operations in Icing Conditions
FAR	1	1964-12-24	14 CFR § 25.C Appendix C to Part 25
FAR	1	1989-08-18	14 CFR § 91.527 Operating in Icing Conditions
FAR	1	1996-02-09	14 CFR § 23.1093 Induction System Icing Protection
FAR	1	1988-09-02	14 CFR § 27.1093 Induction System Icing Protection
FAR	1	1983-01-31	14 CFR § 27.1419 Ice Protection
FAR	1	1988-09-02	14 CFR § 29.1093 Induction System Icing Protection
FAR	1	1983-01-31	14 CFR § 29.1419 Ice Protection
FAR	1	1993-04-09	14 CFR § 23.1419 Ice Protection
FAR	1	1990-07-20	14 CFR § 25.1419 Ice Protection
FAR	1	1990-07-20	14 CFR § 25.1093 Induction System Icing Protection
FAR	1	1977-07-18	14 CFR § 27.1325 Static Pressure Systems
FAR	1	1984-11-06	14 CFR § 29.1325 Static Pressure and Pressure Altimeter Systems
FAR	1	1996-06-19	14 CFR § 33.67 Fuel System
FAR	1	1984-02-23	14 CFR § 33.68 Induction System Icing
FAR	4	1996-12-02	14 CFR § 61.A Appendix A to Part 61 — Practical Test Requirements for Airplane Airline Transport Pilot Certificates and Associated Class and Type Ratings (For Parts 121 and 135 Use Only)
FAR	5	1972-05-17	14 CFR § 63.C Appendix C to Part 63 — Flight Engineer Training Course Requirements
FAR	12	1989-09-25	14 CFR § 121.C Appendix C to Part 121 — C-46 Nontransport Category Airplanes
FAR	2	1988-09-27	14 CFR § 121.E Appendix E to Part 121 — Flight Training Requirements
FAR	4	1977-08-29	14 CFR § 121.F Appendix F to Part 121 — Proficiency Check Requirements
FAR	5	1982-08-02	14 CFR § 145.A
FAR	16	1970-01-28	SFAR SFAR No. 23
FAR	1	1964-12-24	14 CFR § 25.929 Propeller Deicing
FAR	3	1983-01-31	14 CFR § 27.B Appendix B Part 27 — Airworthiness Criteria for Helicopter Instrument Flight
FAR	1	1984-02-23	14 CFR § 33.66 Bleed Air System
FAR	1	1964-04-23	14 CFR § 43.D Appendix D — Scope and Detail of Items (as Applicable to the Particular Aircraft) to Be Included in Annual and 100-Hour Inspections
FAR	17	1978-10-10	14 CFR § 135.A Appendix A to Part 135 — Additional Airworthiness Standards for 10 or More–Passenger Airplanes
FAR	1	1965-01-09	14 CFR § 23.1095 Carburetor Deicing Fluid Flow Rate
FAR	1	1965-01-09	14 CFR § 23.1097 Carburetor Deicing Fluid System Capacity
FAR	1	1965-01-09	14 CFR § 23.1099 Carburetor Deicing Fluid System Detail Design

Doc. Type	Est. Pg.	Date	Title
FAR	1	1996-02-09	14 CFR § 23.1323 Airspeed Indicating System
FAR	1	1996-02-09	14 CFR § 23.1325 Static Pressure System
FAR	1	1976-12-20	14 CFR § 25.1403 Wing Icing Detection Lights
FAR	3	1996-06-13	14 CFR § 29.B Appendix B to Part 29 — Airworthiness Criteria for Helicopter Instrument Flight
FAR	1	1984-02-23	14 CFR § 33.77 Foreign Object Ingestion
FAR	4	1996-05-01	14 CFR § 43.A Appendix A — Major Alterations, Major Repairs, and Preventive Maintenance
FAR	1	1964-12-31	14 CFR § 121.225 Propeller Deicing Fluid
FAR	1	1996-01-29	14 CFR § 121.419 Pilots and Flight Engineers: Initial, Transition, and Upgrade Ground Training
FAR	1	1980-10-09	14 CFR § 125.123 Propeller Deicing Fluid
FAR	1	1988-09-27	14 CFR § 135.293 Initial and Recurrent Pilot Testing Requirements
FAR	1	1996-02-09	14 CFR § 23.775 Windshields and Windows
FAR	1	1996-02-09	14 CFR § 23.929 Engine Installation Ice Protection
FAR	1	1993-04-09	14 CFR § 23.951 General
FAR	1	1993-04-09	14 CFR § 23.1189 Shutoff Means
FAR	1	1993-08-06	14 CFR § 23.1525 Kinds of Operation
FAR	1	1992-06-29	14 CFR § 25.629 Aeroelastic Stability Requirements
FAR	1	1990-07-20	14 CFR § 25.773 Pilot Compartment View
FAR	1	1990-08-28	14 CFR § 25.951 General
FAR	1	1984-02-23	14 CFR § 25.1323 Airspeed Indicating System
FAR	1	1974-07-18	14 CFR § 25.1325 Static Pressure Systems
FAR	1	1965-04-29	14 CFR § 25.D Appendix D to Part 25
FAR	1	1974-10-01	14 CFR § 27.951 General
FAR	1	1984-11-06	14 CFR § 27.1525 Kinds of Operations
FAR	1	1984-11-06	14 CFR § 27.1559 Limitations Placard
FAR	1	1968-01-26	14 CFR § 29.773 Pilot Compartment View
FAR	1	1976-12-20	14 CFR § 29.951 General
FAR	1	1988-09-02	14 CFR § 29.1189 Shutoff Means
FAR	1	1996-06-13	14 CFR § 29.1323 Airspeed Indicating System
FAR	1	1984-11-06	14 CFR § 29.1525 Kinds of Operations
FAR	1	1984-11-06	14 CFR § 29.1559 Limitations Placard
FAR	1	1989-08-18	14 CFR § 61.153 Airplane Rating: Aeronautical Knowledge
FAR	4	1989-09-25	14 CFR § 63.B Appendix B to Part 63 — Flight Navigator Training Course Requirements
FAR	1	1971-07-28	14 CFR § 65.55 Knowledge Requirements
FAR	4	1970-09-04	14 CFR § 65.A Appendix A to Part 65 — Aircraft Dispatcher Courses
FAR	4	1989-08-18	14 CFR § 91.A Appendix A to Part 91 — Category II Operations: Manual, Instruments, Equipment, and Maintenance
FAR	1	1997-03-19	14 CFR § 121.305 Flight and Navigational Equipment

Doc. Type	Est. Pg.	Date	Title
FAR	1	1995-12-20	14 CFR § 121.323 Instruments and Equipment for Operations at Night
FAR	1	1964-12-31	14 CFR § 121.325 Instruments and Equipment for Operations Under IFR or Over-the-top
FAR	1	1964-12-31	14 CFR § 121.539 Operations Notices
FAR	1	1995-05-20	14 CFR § 121.703 Mechanical Reliability Reports
FAR	5	1996-06-17	14 CFR § 121.H Appendix H to Part 121 — Advanced Simulation Plan
FAR	1	1980-10-09	14 CFR § 125.205 Equipment Requirements: Airplanes Under IFR
FAR	1	1980-10-09	14 CFR § 125.C Appendix C to Part 125 — Ice Protection
FAR	1	1990-10-26	14 CFR § 135.149 Equipment Requirements: General
FAR	1	1993-12-30	14 CFR § 135.351 Recurrent Training
FAR	1	1978-10-10	14 CFR § 135.415 Mechanical Reliability Reports
FAR	1	1987-11-18	14 CFR § 139.305 Paved Areas
FAR	1	1988-02-12	14 CFR § 139.313 Snow and Ice Control
FAR	1	1986-09-18	14 CFR § 171.309 General Requirements
FR	44	1996-05-07	61 FR 20646 Airworthiness Directives; Aerospatiale Model ATR-42 and ATR-72 Series Airplanes
FR	43	1996-05-07	61 FR 20615 Airworthiness Directives; de Havilland, Inc. DHC-6 Series Airplanes
NPRM	8	1995-10-18	60 FR 53888 Airworthiness Directives; Aerospatiale Model ATR-42 and ATR-72 Series Airplanes
FR	5	1996-01-25	61 FR 2147 Airworthiness Directives; Aerospatiale Model ATR-42 and ATR-72 Series Airplanes
FR	2	1996-04-02	61 FR 14593 International Conference on Aircraft Inflight Icing
NPRM	4	1996-01-25	61 FR 2163 Airworthiness Directives; Empresa Brasileira de Aeronautica, S.A. (EMBRAER) Model EMB-120 Series Airplanes
NPRM	4	1996-01-25	61 FR 2189 Airworthiness Directives; Fairchild Aircraft SA226 and SA227 Series Airplanes
NPRM	4	1996-01-25	61 FR 2183 Airworthiness Directives; Empresa Brasileiro de Aeronautico, S.A. Models EMB-110P1 and EMB-110P2 Airplanes
NPRM	4	1996-01-25	61 FR 2180 Airworthiness Directives; Beech Aircraft Corporation Models 99, 99A, A99A, B99, C99, B200, B200C, 1900, 1900C, and 1900D Airplanes
NPRM	4	1996-01-25	61 FR 2178 Airworthiness Directives; Cessna Aircraft Company Models 208 and 208B Airplanes
NPRM	4	1996-01-25	61 FR 2175 Airworthiness Directives; de Havilland, Inc. DHC-6 Series Airplanes
NPRM	4	1996-01-25	61 FR 2172 Airworthiness Directives; Dornier 228 Series Airplanes
NPRM	4	1996-01-25	61 FR 2169 Airworthiness Directives; Saab Model SAAB SF340A, SAAB 340B, and SAAB 2000 Series Airplanes
NPRM	4	1996-01-25	61 FR 2166 Airworthiness Directives; Construcciones Aeronauticas, S.A. (CASA) Model C-212 and CN-235 Series Airplanes
NPRM	4	1996-01-25	61 FR 2160 Airworthiness Directives; Fokker Model F27 Mark 100, 200, 300, 400, 500, 600, and 700 Series Airplanes, and Model F27 Mark 050 Series Airplanes
NPRM	4	1996-01-25	61 FR 2157 Airworthiness Directives; Dornier Model 328-100 Series Airplanes
NPRM	4	1996-01-25	61 FR 2154 Airworthiness Directives; de Havilland Model DHC-7 and DHC-8 Series Airplanes

Doc. Type	Est. Pg.	Date	Title
NPRM	4	1996-01-25	61 FR 2151 Airworthiness Directives; Short Brothers Model SD3-30, SD3-60, and SD3-SHERPA Series Airplanes
NPRM	4	1996-01-25	61 FR 2144 Airworthiness Directives; Jetstream Model BAe ATP Airplanes
NPRM	4	1996-01-25	61 FR 2142 Airworthiness Directives; Jetstream Model 4101 Airplanes
NPRM	4	1996-01-25	61 FR 2139 Airworthiness Directives; British Aerospace Model HS 748 Series Airplanes
NPRM	57	1996-07-1 6	61 FR 37143 Revisions to Digital Flight Data Recorder Rules
FR	245	1995-12-20	60 FR 65831 Commuter Operations and General Certification and Operations Requirements
FR	3	1995-03-22	60 FR 15037 Airworthiness Directives; Dornier Model 328-100 Series Airplanes
FR	6	1995-02-21	60 FR 9616 Airworthiness Directives; Aerospatiale Model ATR-42 and ATR-72 Series Airplanes
NPRM	4	1997-02-26	62 FR 8648 Airworthiness Directives; Mitsubishi Model MU-300 Airplanes
FR	2	1996-12-04	61 FR 64270 Airworthiness Directives; Mitsubishi Heavy Industries, LTD. Models MU-2B-10, -15, -20, -25, -26, -26A, -30, -35, -36, -36A, -40, and -60 Airplanes
FR	3	1996-09-16	61 FR 48619 Airworthiness Directives; Saab Model SAAB 2000 Series Airplanes
FR	2	1994-12-13	59 FR 64112 Airworthiness Directives, Beech Model 400, 400A, 400T, and MU-300-10 Airplanes, and Mitsubishi Model MU-300 Airplanes
FR	3	1996-01-29	61 FR 2705 Airworthiness Directives; General Dynamics (Convair) Model 240 Series Airplanes, Including Model T-29 (Military) Airplanes; Model 340 and 440 Series Airplanes; and Model C-131 (Military) Airplanes; Including Those M …
FR	4	1996-07-17	61 FR 37199 Airworthiness Directives; British Aerospace Model BAe 146-l00A, -200A, and -300A Series Airplanes
NPRM	4	1997-05-13	62 FR 26258 Airworthiness Directives; Empresa Brasileira de Aeronautica, S.A. (EMBRAER) Model EMB-120 Series Airplanes
NPRM	3	1996-07-12	61 FR 36667 Airworthiness Directives; Short Brothers Model SD3-60 SHERPA Series Airplanes
FR	3	1996-01-08	61 FR 511 Airworthiness Directives; Saab Model SAAB SF340A and SAAB 340B Series Airplanes
FR	3	1994-12-06	59 FR 62563 Airworthiness Directives; Fokker Model F28 Series Airplanes
FR	3	1996-04-25	61 FR 18242 Airworthiness Directives; Saab Model SAAB SF340A and SAAB 340B Series Airplanes
NPRM	3	1997-02-26	62 FR 8650 Airworthiness Directives; Raytheon (Beech) Model 400, 400A, 400T, and MU-300-10 Airplanes
FR	1	1995-10-24	60 FR 54415 Airworthiness Directives; Beech Aircraft Corporation Models 60 and A60 Airplanes
FR	2	1996-05-07	61 FR 20682 Airworthiness Directives; Short Brothers Model SD3-30, SD3-60, and SD3-SHERPA Series Airplanes
FR	2	1996-05-07	61 FR 20681 Airworthiness Directives; Fokker Model F27 Mark 100, 200, 300, 400, 500, 600, and 700 Series Airplanes, and Model F27 Mark 050 Series Airplanes
FR	2	1996-05-07	61 FR 20679 Airworthiness Directives; de Havilland Model DHC-7 and DHC-8 Series Airplanes
FR	2	1996-05-07	61 FR 20677 Airworthiness Directives; Empresa Brasileira de Aeronautica, S.A. (EMBRAER) Model EMB-120 Series Airplanes
FR	2	1996-05-07	61 FR 20676 Airworthiness Directives; Dornier Model 328-100 Series Airplanes

Doc. Type	Est. Pg.	Date	Title
FR	2	1996-05-07	61 FR 20674 Airworthiness Directives; Construcciones Aeronauticas, S.A. (CASA) Model C-212 and CN-235 Series Airplanes
FR	2	1996-05-07	61 FR 20672 Airworthiness Directives; Saab Model SAAB SF340A, SAAB 340B, and SAAB 2000 Series Airplanes
FR	1	1996-05-07	61 FR 20671 Airworthiness Directives; British Aerospace Model HS 748 Series Airplanes
FR	2	1996-05-07	61 FR 20669 Airworthiness Directives; Jetstream Model 4101 Airplanes
FR	2	1996-05-07	61 FR 20668 Airworthiness Directives; Jetstream Model BAe ATP Airplanes
FR	2	1996-07-03	61 FR 34921 Notice of Intent to Request Renewal from the Office of Management and Budget (OMB) of Current Public Collections of Information
NPRM	15	1996-08-09	61 FR 41687 Airworthiness Standards; Rain and Hail Ingestion Standards Proposed Rule
FR	1	1996-10-18	61 FR 54331 Airworthiness Directives; Short Brothers Model SD3-60 SHERPA Series Airplanes
NPRM	3	1996-10-03	61 FR 51618 Airworthiness Directives; AlliedSignal Inc. TPE331 Series Turboprop Engines
FR	3	1996-11-20	61 FR 59038 Airworthiness Directives; Jetstream Model 4101 Airplanes
FR	3	1994-03-31	59 FR 15042 Airworthiness Directives; British Aerospace Model BAe 146-l00A, -200A, and -300A Series Airplanes
FR	2	1994-03-04	59 FR 10279 Airworthiness Directives; McDonnell Douglas Model DC-9-10 Series Airplanes
FR	4	1997-02-03	62 FR 4944 Airworthiness Directives; Fokker Model F28 Mark 0070 and 0100 Series Airplanes
FR	29	1996-01-26	61 FR 2607 Operating Requirements: Domestic, Flag, Supplemental, Commuter, and On-Demand Operations: Editorial and Terminology Changes
FR	2	1996-05-07	61 FR 20644 Airworthiness Directives; Jetstream Aircraft Limited Jetstream Models 3101 and 3201 Airplanes
FR	2	1996-05-07	61 FR 20643 Airworthiness Directives; Fairchild Aircraft SA226 and SA227 Series Airplanes
FR	2	1996-05-07	61 FR 20641 Airworthiness Directives; Cessna Aircraft Company Models 208 and 208B Airplanes
FR	2	1996-05-07	61 FR 20639 Airworthiness Directives; Dornier 228 Series Airplanes
FR	2	1996-05-07	61 FR 20638 Airworthiness Directives; Beech Aircraft Corporation Models 99, 99A, A99A, B99, C99, B200, B200C, 1900, 1900C, and 1900D Airplanes
FR	2	1996-05-07	61 FR 20636 Airworthiness Directives; Empresa Brasileiro de Aeronautico, S.A. Models EMB-110P1 and EMB-110P2 Airplanes
FR	3	1996-12-05	61 FR 64456 Airworthiness Directives; Cessna Model 560 Series Airplanes
FR	2	1995-01-05	60 FR 1712 Airworthiness Directives; Boeing Model 757 Equipped with Pratt & Whitney Model PW2000 Series Engines
FR	4	1994-05-16	59 FR 25290 Airworthiness Directives; British Aerospace Model ATP Airplanes
FR	1	1997-02-19	62 FR 7339A Airworthiness Directives; Jetstream Model 4101 Airplanes
FR	2	1997-02-07	62 FR 5743 Airworthiness Directives; Jetstream Model 4101 Airplanes
FR	4	1997-02-06	62 FR 5552 Special Conditions; Ballistic Recovery Systems Cirrus SR-20 Installation
NPRM	3	1997-05-13	62 FR 26261 Airworthiness Directives; Raytheon Aircraft Company (formerly Beech Aircraft Corporation) 90, 100, 200 and 300 Series Airplanes

Doc. Type	Est. Pg.	Date	Title
FR	3	1996-01-04	61 FR 254 Special Conditions; Hamilton Standard Model 568F Propeller
FR	45	1996-02-09	61 FR 5151 Airworthiness Standards; Systems and Equipment Rules Based on European Joint Aviation Requirements
FR	1	1996-05-28	61 FR 26427 Airworthiness Directives; Empresa Brasileiro de Aeronautico, S.A. Models EMB-110P1 and EMB-110P2 Airplanes; Correction
FR	1	1996-05-28	61 FR 26426 Airworthiness Directives; Beech Aircraft Corporation Models 99, 99A, A99A, B99, C99, B200, B200C, 1900, 1900C, and 1900D Airplanes; Correction
FR	1	1996-05-28	61 FR 26425 Airworthiness Directives; de Havilland, Inc. DHC-6 Series Airplane, Correction
FR	1	1996-05-28	61 FR 26425b Airworthiness Directives; Cessna Aircraft Company Models 208 and 208B Airplanes; Correction
FR	1	1996-05-28	61 FR 26424 Airworthiness Directives; Jetstream Aircraft Limited Jetstream Models 3101 and 3201 Airplanes, Correction
FR	1	1996-05-28	61 FR 26424b Airworthiness Directives; Fairchild Aircraft SA226 and SA227 Series Airplanes; Correction
FR	6	1996-11-21	61 FR 59272 Notice of Passenger Facility Charge (PFC) Approvals and Disapprovals
FR	337	1997-04-04	62 FR 16219 Pilot, Flight Instructor, Ground Instructor, and Pilot School Certification Rules; Final Rule
FR	3	1996-02-23	61 FR 6935 Airworthiness Directives; Boeing Model 757-200 Series Airplanes Equipped With Rolls-Royce Model RB2 11-535E4/E4B Engines
FR	28	1996-06-05	61 FR 28683 Standards for Approval for High Altitude Operation of Subsonic Transport Airplanes
FR	2	1996-08-20	61 FR 42997 Airworthiness Directives; Raytheon Aircraft Corporation Model 1900D Airplanes
FR	4	1996-11-04	61 FR 56642 Airworthiness Directives; Fairchild Aircraft SA226 and SA227 Series Airplanes
FR	4	1995-08-11	60 FR 41146 Notice of Passenger Facility Charge (PC) Approvals and Disapprovals
FR	2	1994-10-27	59 FR 53931 Airworthiness Directives; McDonnell Douglas Model DC-10 Series Airplanes
FR	3	1997-01-13	62 FR 1799 Notice of Passenger Facility Charge (PFC) Approvals and Disapprovals
FR	8	1997-02-19	62 FR 7335 Special Conditions; Soloy Corporation, Soloy Dual Pac Engine (Formally Soloy Dual Pac, Inc.)
FR	2	1997-02-03	62 FR 4899 Airworthiness Directives; Rolls-Royce plc RB211-535E4 and -535E4-B Series Turbofan Engines
FR	29	1997-02-21	62 FR 7950 Special Conditions; Sino Swearingen Model SJ30-2 Airplane
FR	6	1997-02-14	62 FR 7082 Notice of Passenger Facility Charge (PFC) Approvals and Disapprovals
NPRM	32	1997-02-03	62 FR 5075 Operating Requirements: Domestic, Flag, Supplemental, Commuter, and On-Demand Operations; Editorial and Other Changes; Proposed Rule and On-Demand Operations: Editorial and Other Changes
FR	1	1997-03-25	62 FR 14181 Notice of Intent to Rule on Application (97-10-C-00-CH0) to Impose and Use the Revenue from a Passenger Facility Charge (PFC) at the Charlottesville-Albermarle Airport, Charlottesville, Virginia
FR	18	1996-02-09	61 FR 5129 Airworthiness Standards; Powerplant Rules Based on European Joint Aviation Requirements
NPRM	2	1996-02-21	61 FR 6583 Airworthiness Directives; Jetstream Aircraft Limited Jetstream Models 3101 and 3201 Airplanes

Doc. Type	Est. Pg.	Date	Title
FR	1	1996-02-06	61 FR 4509b Intent to Rule on Application to Impose a Passenger Facility Charge (PFC) at Chicago O'Hare International Airport, Chicago, Illinois and Use PFC Revenue at Gary Regional Airport, Gary, IN
FR	9	1996-03-20	61 FR 11491 Flight Crewmember Duty Period Limitations, Flight Time Limitations, and Rest Requirements
FR	14	1996-04-03	61 FR 14608 Airworthiness Directives; Boeing Model 747-400, 757, and 767 Series Airplanes
FR	4	1996-05-28	61 FR 26429 Airworthiness Directives; Robinson Helicopter Company Model R22 Helicopters
FR	1	1996-05-29	61 FR 26947 Notice of Airport Capital Improvement Program National Priority System; Opportunity to Comment
FR	1	1996-05-22	61 FR 25731 Airport Capital Improvement Program National Priority System; Comment Request
FR	4	1996-05-13	61 FR 22080 Notice of Passenger Facility Charge (PFC) Approvals and Disapprovals
FR	15	1996-06-17	61 FR 30725 Advanced Simulation Plan Revisions; Final Rule
NPRM	3	1996-06-12	61 FR 29697 Airworthiness Directives; Rolls-Royce plc RB211-535E4 and -535E4-B Series Turbofan Engines
FR	1	1996-07-29	61 FR 39504 Notice of Intent to Rule on Application to Impose and Use the Revenue from a Passenger Facility Charge (PFC) at Altoona-Blair County Airport, Altoona, PA
FR	1	1996-08-07	61 FR 41199 Notice of Intent to Rule on Application to Use the Revenue from a Passenger Facility Charge (PFC) at James M. Cox-Dayton International Airport, Dayton, OH
FR	1	1996-08-07	61 FR 41198A Notice of Intent to Rule on Request to Amend an Approved Application to Impose a Passenger Facility Charge (PFC) at Dayton International Airport and Use PFC Revenue at Dayton International Airport and Dayt …
FR	1	1996-10-28	61 FR 55684A Notice of Intent to Rule on Application (96-02-C-00-SYR) to Impose and Use the Revenue from a Passenger Facility Charge (PFC) at Syracuse Hancock International Airport, Syracuse, New York
FR	1	1996-10-02	61 FR 51485A Intent to Rule on Application to Impose and Use the Revenue from a Passenger Facility Charge (PFC) at Indianapolis International Airport, Indianapolis, IN
FR	2	1995-02-14	60 FR 8290 Airworthiness Directives; Jetstream Aircraft Limited (formerly British Aerospace, Regional Aircraft Limited) Jetstream Model 3101 Airplanes
FR	2	1995-05-22	60 FR 27005 Airworthiness Directives; Airbus Model A300, A310, and A300-600 Series Airplanes
FR	1	1995-06-26	60 FR 32900 Airworthiness Directives; Jetstream Model ATP Airplanes
FR	2	1995-08-03	60 FR 39627 Airworthiness Directives; Jetstream Aircraft Limited (JAL) HP137 Mk1 and Jetstream Series 200 Airplanes
FR	3	1995-09-13	60 FR 47643 Notice of Passenger Facility Charge (PFC) Approvals and Disapprovals
FSF	7	1993-09-01	Airport Operations Incident Reports Highlight Problems Involving Air Carrier Ground Deicing/Anti-icing
FSF	3	1996-01-01	Flight Safety Digest Pilots Can Minimize the Likelihood of Aircraft Roll Upset in Severe Icing
FSF	10	1993-04-01	Accident Prevention U.S. Accident Report Blames Wing Ice and Airline Industry/FAA Failures in Fatal Fokker Crash

Doc. Type	Est. Pg.	Date	Title
FSF	3	1993-01-01	Airport Operations Communication and Coordination Keys to Safe and Effective Winter Operations
FSF	4	1993-11-01	Airport Operations Accidents Show Need for Comprehensive Ground Deicing Programs
FSF	11	1994-09-01	Accident Prevention Breakdown in Coordination by Commuter Crew During Unstabilized Approach Results in Controlled-flight-into-terrain Accident
FSF	8	1995-06-01	Accident Prevention Turboprop Freighter Crashes After Severe Icing Causes Multiple Engine Failures
FSF	8	1995-03-01	Flight Safety Digest Publications Received at FSF Jerry Lederer Aviation Safety Library
FSF	3	1994-09-01	Flight Safety Digest Publications Received at FSF Jerry Lederer Aviation Safety Library
FSF	15	1995-01-01	Accident Prevention Stall and Improper Recovery During ILS Approach Result in Commuter Airplane's Uncontrolled Collision with Terrain
FSF	10	1993-12-01	Accident Prevention Training, Deicing and Emergency Checklist Linked in MD-81 Accident Following Clear-ice Ingestion by Engines
FSF	1	1995-09-01	Aviation Mechanics Bulletin News & Tips
FSF	3	1993-02-01	Flight Safety Digest Publications Received at FSF Jerry Lederer Aviation Safety Library
FSF	6	1993-11-01	Helicopter Safety Operators Say Rule Changes Could Improve Helicopter IFR Safety
FSF	10	1995-05-01	Accident Prevention Rejected Takeoff in Icy Conditions Results in Runway Overrun
FSF	6	1993-09-01	Human Factors & Aviation Medicine 'Hurry-up' Syndrome Identified as a Causal Factor in Aviation Safety Incidents
FSF	16	1996-04-01	Accident Prevention Commuter Captain Fails to Follow Emergency Procedures After Suspected Engine Failure, Loses Control of the Aircraft During Instrument Approach
FSF	2	1995-09-01	Aviation Mechanics Bulletin New Products
FSF	3	1993-01-01	Flight Safety Digest Reports Received at FSF Jerry Lederer Aviation Safety Library
FSF	3	1993-02-01	Flight Safety Digest Accidents/lncidents
FSF	2	1996-03-01	Aviation Mechanics Bulletin Maintenance Alerts
FSF	1	1995-03-01	Aviation Mechanics Bulletin News & Tips
FSF	2	1995-05-01	Aviation Mechanics Bulletin New Products
FSF	4	1995-03-01	Flight Safety Digest Accident/lncident Briefs
FSF	10	1994-11-01	Accident Prevention Airframe Icing and Captain's Improper Use of Autoflight System Result in Stall and Loss of Control of Commuter Airplane
FSF	3	1993-01-01	Flight Safety Digest Accident/lncident Briefs
FSF	2	1993-09-01	Flight Safety Digest U.S. Air Carrier Accident Rate Lowered Significantly in 1989; Recently Released Report Compares Data to 1980–1988 Period
FSF	2	1995-03-01	Aviation Mechanics Bulletin New Products
FSF	7	1995-07-01	Accident Prevention Captain's Failure to Establish Stabilized Approach Results in Controlled-flight-into-terrain Commuter Accident
FSF	6	1996-01-01	Flight Safety Digest Publications Received at FSF Jerry Lederer Aviation Safety Library
FSF	25	1996-04-01	Flight Safety Digest An Analysis of Controlled-flight-into-terrain (CFIT) Accidents of Commercial Operators, 1988 Through 1994
FSF	3	1996-07-01	Flight Safety Digest Dubrovnik-bound Flight Crew's Improperly Flown Nonprecision Instrument Approach Results in Controlled-flight-into-terrain Accident
FSF	1	1996-09-01	Flight Safety Digest Appendix D — Examples of Incidents and Accidents Involving the Flightcrew-Automation Interface

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FSF	2	1996-09-01	Flight Safety Digest: The Interfaces Between Flight Crews and Modern Flight Deck Systems
FSF	11	1995-10-01	Accident Prevention Commuter Crew's Loss of Situational Awareness During Night Takeoff Results in Controlled Flight into Terrain
FSF	9	1995-01-01	Airport Operations Ultra-high-capacity Aircraft Will Intensify Airport Safely Issues
FSF	9	1995-11-01	Airport Operations Rapid Response of Airport Emergency Services Hindered by Weather and Other Factors
FSF	14	1994-02-01	Accident Prevention Captain Stops First Officer's Go-around, DC-9 Becomes Controlled-flight-into-terrain (CFIT) Accident
FSF	11	1994-04-01	Accident Prevention Inflight Loss of Propeller Blade on MU-2B Results in Uncontrolled Collision with Terrain
FSF	2	1994-03-01	Flight Safety Digest Limitations of See-and-Avoid Concept Cited in Fatal Midair Collision
FSF	3	1994-07-01	Flight Safety Digest Accident and Incident Reports Show Importance of 'Sterile Cockpit' Compliance
FSF	2	1993-11-01	Aviation Mechanics Bulletin New Products
FSF	9	1993-01-01	Accident Prevention Missing Screws Send Commuter Plummeting
FSF	3	1993-11-01	Accident Prevention Fatal Commuter Crash Blamed on Visual Illusion, Lack of Cockpit Coordination
FSF	15	1993-03-01	Flight Safety Digest Aviation Statistics
AD	3	1995-02-21	AD T95-04-51 Engine Air Inlet De-Icing System
AD	3	1995-04-06	AD 95-04-51 Engine Air Inlet De-Icing System
AD	2	1996-12-27	AD 96-25-02 Operating in Conditions That Are Beyond the Capability of the Icing Protection System
AD	3	1996-06-11	AD 96-09-28 Icing Conditions
AD	3	1995-01-03	AD T94-25-51 Icing Conditions
AD	1	1997-05-13	AD 97-NM-46 Flightcrew Ability to Recognize the Formation of Significant Ice Accretion
AD	1	1996-06-11	AD 96-09-24 Icing Conditions
AD	1	1984-03-02	AD 84-02-05 Engine Anti-Icing System
AD	2	1996-11-22	AD 96-21-10 Minimizing Potential Hazards Associated with Operating the Airplane in Severe Icing Conditions
AD	1	1996-07-31	AD 96-NM-122-AD Icing Conditions
AD	2	1996-06-11	AD 96-09-11 Icing Conditions
AD	2	1996-06-11	AD 96-09-12 Icing Conditions
AD	2	1996-06-11	AD 96-09-15 Icing Conditions
AD	2	1996-06-11	AD 96-09-17 Icing Conditions
AD	1	1996-06-11	AD 96-09-18 Icing Conditions
AD	1	1996-06-11	AD 96-09-19 Icing Conditions
AD	1	1996-06-11	AD 96-09-20 Icing Conditions
AD	2	1996-06-11	AD 96-09-21 Icing Conditions
AD	1	1996-06-11	AD 96-09-22 Icing Conditions
AD	1	1996-06-11	AD 96-09-23 Icing Conditions

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AD	1	1996-06-11	AD 96-09-25 Icing Conditions
AD	1	1996-06-11	AD 96-09-26 Icing Conditions
AD	1	1996-06-11	AD 96-09-27 Icing Conditions
AD	2	1996-06-11	AD 96-09-13 Icing Conditions
AD	2	1996-06-11	AD 96-09-14 Icing Conditions
AD	2	1996-06-11	AD 96-09-16 Icing Conditions
AD	3	1996-02-01	AD 95-NM-146-AD Icing Conditions
AD	1	1958-04-01	AD 57-03-04 Zone III Fire Protection
AD	1	1985-08-22	AD 85-15-03 Anti-Icing Systems
AD	1	1988-02-09	AD 87-24-07 POH/AFM Revision — Icing
AD	2	1996-02-01	AD 96-NM-19-AD Icing Conditions
AD	1	1986-12-31	AD 86-26-02 POH/AFM Appendix — Icing
AD	1	1986-12-15	AD 86-24-13 POH/AFM Appendix — Icing
AD	1	1986-12-15	AD 86-24-09 POH/AFM Appendix — Icing
AD	1	1986-12-15	AD 86-24-10 POH/AFM Appendix — Icing
AD	2	1997-02-26	AD 96-NM-210 Uncommanded Nose-Down Pitch at Certain Flap Settings During Icing Conditions
AD	2	1996-05-10	AD 96-01-04 Auto-Ignition System
AD	2	1996-02-01	AD 96-CE-01-AD Icing Conditions
AD	2	1996-02-01	AD 96-CE-02-AD Icing Conditions
AD	2	1996-02-01	AD 96-CE-03-AD Icing Conditions
AD	2	1996-02-01	AD 96-CE-04-AD Icing Conditions
AD	2	1996-02-01	AD 96-CE-05-AD Icing Conditions
AD	2	1996-02-01	AD 96-CE-06-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-13-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-14-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-15-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-16-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-17-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-18-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-20-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-21-AD Icing Conditions
AD	2	1996-02-01	AD 96-NM-22-AD Icing Conditions
AD	1	1960-01-06	AD 60-01-05 Propeller Deicing
AD	1	1987-07-13	AD 86-01-01 Placard Icing Condition
AD	1	1986-12-15	AD 86-24-11 POH/AFM Appendix — Icing
AD	1	1986-12-15	AD 86-25-04 POH/AFM Appendix — Icing
AD	2	1995-03-08	AD 95-02-51 Icing Conditions
AD	1	1979-04-30	AD 79-08-07 Anti-Icing Propeller Wiring
AD	1	1984-01-31	AD 84-02-02 Wing Anti-Icing System

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AD	1	1948-02-11	AD 48-11-01 Ungrounding Modification — Class B
AD	3	1982-02-16	AD 81-18-08 Revised AFM
AD	1	1980-08-18	AD 78-01-09 Pneumatic De-Icing System
AD	1	1989-12-15	AD 89-24-07 Anti-Icing Advisory System
AD	1	1948-01-01	AD 47-42-16 Combustion Chamber Inspection
AD	1	1947-10-15	AD 47-10-15 Recertification of Lockheed 49
AD	1	1948-02-01	AD 48-42-02 Fire Prevention Modification
AD	2	1952-01-01	AD 52-19-01 Powerplant Fire Protection
AD	1	1952-05-01	AD 52-04-08 Anti-Icing Heater Controls
AD	1	1962-01-16	AD 61-26-03 Fuel Vent Lines
AD	2	1962-05-22	AD 62-10-02 Fire Protection Modification
AD	1	1968-02-13	AD 68-04-01 Fuel Leakage
AD	1	1982-12-27	AD 82-26-06 Windscreen Washing/Deicing System
AD	1	1982-09-30	AD 82-20-02 Temporary Revision to POH/AFM
AD	1	1987-07-10	AD 86-25-52 AFM Change — Icing
AD	2	1994-12-21	AD 94-25-03 AFM Changes — Limitations
AD	1	1996-10-01	AD 96-19-08 Prevent Condensational Water from Collecting in the Tube of the De-icing System for the Horizontal Stabilizer
AD	1	1968-08-05	AD 68-16-01 Placard to Prevent Engine Flameout
AD	1	1973-04-12	AD 73-08-02 Operation in Icing Conditions
AD	1	1981-11-19	AD 81-24-04 Change to AFM ‘Icing Conditions’
AD	1	1983-03-31	AD 83-02-10 Icing Prevention
AD	1	1988-10-13	AD 88-20-04 AFM Changes — Icing
AD	2	1994-07-22	AD 93-11-01 AFM Limitations — Ice Accumulation
AD	1	1994-12-28	AD 94-25-10 AFM Changes — Icing Conditions
AD	1	1995-01-20	AD 95-01-05 AFM — Limitations
AD	1	1997-02-26	AD 96-NM-209 Uncommanded Nose-Down Pitch at Certain Flap Settings During Icing Conditions
AD	1	1952-10-15	AD 51-19-04 Modification Board Items
AD	1	1960-11-15	AD 60-21-02 Carburetor Preheat Modifications
AD	1	1971-07-16	AD 71-05-03 Known Icing Conditions
AD	1	1976-07-23	AD 76-14-09 Inspection of Hollow Steel Blades
AD	1	1982-11-23	AD 82-24-04 De-Icing System
AD	1	1982-05-03	AD 82-05-05 Placard on Icing Conditions
AD	1	1985-07-31	AD 85-11-05 AFM Placard — Icing Condition
AD	1	1986-02-24	AD 85-24-04 AFM Revision Placard — Icing
AD	1	1986-02-11	AD 85-25-10 Placard Icing Conditions
AD	1	1988-06-17	AD 85-26-51 AFM — Ice Ingestion
AD	1	1987-09-01	AD 87-16-11 Placard — Icing
AD	1	1991-08-22	AD 91-16-01 Wing De-Icer System

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AD	1	1992-09-18	AD 92-19-01 AFM Changes — Icing
AD	1	1993-01-22	AD 93-01-02 Tailplane De-Icing System
AD	1	1994-11-16	AD T94-24-51 Autopilot
AD	1	1995-12-12	AD 95-22-03 Icing Conditions
AD	1	1996-02-28	AD 96-03-04 Ice Contaminated Tailplane Stall (ICTS) Conditions
AD	2	1948-02-11	AD 48-10-01 Ungrounding Modification — Class A
AD	1	1951-08-16	AD 51-11-01 Modification Board Items
AD	1	1952-07-01	AD 52-04-07 Heater Control Modification
AD	2	1956-08-01	AD 56-19-02 Steel Propeller Blades
AD	1	1959-01-01	AD 59-05-03 Deicer Valves
AD	1	1966-01-01	AD 66-18-03 Induction System Icing
AD	1	1970-02-22	AD 70-03-02 Fuselage Pressure Shell
AD	1	1976-06-23	AD 76-12-10 Wing Deicing
AD	1	1981-02-27	AD 81-01-01 Propeller Deice Relay
AD	1	1986-10-06	AD 86-20-01 Pilot System Modification
AD	1	1987-01-20	AD 87-01-03 Engine Oil Cooler System
AD	1	1992-04-13	AD 92-02-02 Ice Guards — Propeller
AD	1	1992-01-17	AD 92-03-02 AFM Limitations Revisions
AD	2	1995-04-07	AD 95-04-05 Passenger Door
AD	2	1996-11-19	AD 96-24-06 Uncommanded Roll of the Airplane During Approach and Landing When Residual Ice is Present or Can Be Expected
AD	1	1948-02-11	AD 48-11-02 Ungrounding Modifications — Class C
AD	1	1958-01-01	AD 58-26-03 Westinghouse Deicing Generator
AD	1	1966-11-22	AD 66-14-02 Windshield De-icing Systems
AD	1	1972-04-15	AD 72-07-04 Windscreen De-Icing Hand Pump
AD	1	1977-01-06	AD 76-26-03 Carburetor Icing
AD	1	1979-11-01	AD 79-18-03 Wing/Antenna Anti-Ice System
AD	1	1980-09-29	AD 80-19-10 Deicer Systems in Adverse Weather
AD	1	1982-04-15	AD 82-06-10 Vacuum-Driven-Attitude Instruments
AD	1	1983-10-11	AD 83-19-06 Engine Stall Conditions
AD	1	1983-11-10	AD 83-22-07 Placard — Icing Conditions
AD	1	1987-08-03	AD 84-24-51 AFM Change — Temperature
AD	1	1986-10-15	AD 86-20-02 AFM Changes/Placards/Labels — Icing
AD	1	1987-02-12	AD 87-03-02 Tail Deicing System
AD	1	1990-09-17	AD 90-17-14 Elevator Deicing System
AD	1	1991-11-29	AD 91-21-09 Air Induction System
AD	1	1994-04-15	AD 94-07-09 Prevent Engine Power Rollback During Flight in Icing Conditions
AD	1	1997-02-03	AD 95-NM-29 Icing of the No. 1 Pitot Tube
AD	1	1995-09-19	AD 95-15-12 Icing Conditions
AD	2	1995-07-26	AD 95-12-13 Icing Conditions

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AD	1	1995-04-21	AD 95-06-52 Engine Icing
AD	1	1996-11-20	AD 96-NM-97 Overheating of the Electrical Ground Posts
AD	1	1996-09-19	AD 96-15-01 Glare Shield in the Cockpit
AD	1	1996-07-22	AD 96-14-09 Icing Conditions
AD	1	1997-03-14	AD 97-03-12 Overheating of the Electrical Ground Posts (‘Earth Posts’)
AD	1	1948-03-02	AD 47-51-12 Carburetor Airscoop
AD	1	1947-01-01	AD 47-47-05 Stewart-Warner 921B Heaters
AD	1	1948-02-18	AD 48-52-01 Additional Modification Items
AD	1	1954-01-01	AD 54-09-01 Carburetor Hotspot Heater Assembly
AD	1	1957-07-01	AD 56-22-01 Aluminum Alloy Blades
AD	1	1957-12-01	AD 57-03-02 Fuel Strainer Screen
AD	1	1958-01-01	AD 58-24-04 Stall Warning System Switch
AD	1	1958-01-01	AD 58-05-03 Modifications and Inspections
AD	1	1959-01-01	AD 59-25-06 Carburetor Alternate Airsource
AD	1	1964-09-15	AD 64-17-05 Engine Breather Tube
AD	1	1965-03-13	AD 65-06-02 Fatigue Crack in Cuff Ring
AD	1	1966-09-13	AD 66-09-01 Replace Deicer Boots
AD	1	1968-10-17	AD 68-21-04 Ice Damage to Engine
AD	1	1975-02-21	AD 75-04-11 Ingestion of Ice and Snow into the Engine
AD	1	1976-10-01	AD 76-17-07 Static Port System
AD	1	1987-03-09	AD 79-12-05 Stall Warning Systems
AD	1	1980-07-25	AD 80-12-15 Pitot Static Probe
AD	1	1980-10-16	AD 80-21-06 Muffler Core and Body Assys
AD	1	1982-01-04	AD 81-25-03 Windshield Heat Generation
AD	1	1983-01-17	AD 81-21-51 Revision to AFM LR-25
AD	1	1982-01-11	AD 81-22-51 AFM Revision
AD	1	1983-04-04	AD 83-06-01 Ice Shields Installation
AD	1	1984-06-28	AD 84-12-04 Temporary Placard Anti-Ice System
AD	1	1984-12-15	AD 84-23-07 ‘D’ Type Oil Cooler Installation
AD	1	1986-03-19	AD 85-22-09 Placard — Icing Conditions
AD	1	1988-07-11	AD 88-13-07 Pitot Tubes
AD	1	1988-09-07	AD 88-18-05 Pitot Tubes
AD	1	1989-07-10	AD 89-12-07 Wing Cavity
AD	1	1989-12-04	AD 89-23-10 Bulletin — Icing
AD	1	1990-11-13	AD 90-21-08 Fuel Tank Bladder
AD	1	1990-12-03	AD 90-23-03 Main Rotor Servo Control
AD	1	1991-06-10	AD 91-08-01 Placard — Max. Flap Ext. Speed
AD	1	1993-03-18	AD 92-08-51 Power Reductions of Engines
AD	1	1993-08-09	AD 93-14-21 AFM — Hydraulic System
AD	1	1994-11-28	AD 94-22-01 Ingestion of Ice or Snow

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AD	2	1994-06-15	AD 94-08-01 Prevent Loss of Multiple Engine Power During Flight in Freezing Precipitation
AD	2	1996-11-04	AD 95-CE-34 Failure of Both Generators During Critical Phases of Flight
AD	1	1996-03-01	AD 95-CE-18-AD Icing Conditions
AD	3	1995-09-13	AD 95-17-04 Loss of Engine Power During Flight in Freezing Precipitation
AD	1	1995-06-21	AD 95-10-14 Electrical and Mechanical Inspection
AD	1	1995-03-10	AD 95-02-06 Flap Extension Speed
AD	1	1996-06-07	AD 96-09-09 Icing Conditions
AD	1	1996-05-03	AD 96-07-09 Contaminated Airplane Fuel System
AD	1	1997-05-13	AD 97-CE-05 Loss of Vacuum to Depressurize the Airplane Cabin
AC	19	1994-05-19	AC 120-60 Ground Deicing and Anti-Icing Program
AC	29	1994-12-14	AC 135-17 Pilot Guide: Small Aircraft Ground Deicing
AC	22	1992-09-30	AC 120-58 Pilot Guide Large Aircraft Ground Deicing
AC	18	1993-08-23	AC 150/5300-14 Design of Aircraft Deicing Facilities
AC	561	1995-06-01	AC 29-2A Certification of Transport Category Rotorcraft
AC	11	1994-12-12	AC 135-16 Ground Deicing and Anti-icing Training and Checking
AC	27	1982-12-17	AC 20-117 Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing
AC	29	1971-04-21	AC 20-73 Aircraft Ice Protection
AC	436	1987-09-16	AC 27-1 Certification of Normal Category Rotorcraft
AC	509	1976-01-01	AC 65-15A Airframe and Powerplant Mechanics Airframe Handbook
AC	119	1975-01-01	AC 00-6A Aviation Weather for Pilots and Flight Operations Personnel
AC	38	1991-10-01	AC 150/5200-30A Airport Winter Safety and Operations
AC	24	1992-01-03	AC 23.1419-2 Certification of Part 23 Airplanes for Flight in Icing Conditions
AC	11	1996-07-17	AC 91-51A Effect of Icing on Aircraft Control and Airplane Deice and Anti-lce Systems
AC	29	1991-02-11	AC 150/5390-15 Management of Airport Industrial Waste
AC	449	1976-01-01	AC 65-12A Airframe and Powerplant Mechanics Powerplant Handbook
AC	5	1981-10-22	AC 20-113 Pilot Precautions and Procedures to be Taken in Preventing Aircraft Reciprocating Engine Induction System and Fuel System Icing Problems
AC	168	1996-08-15	AC 00-2.10 Advisory Circular Checklist and Status of Other FAA Publications for Sale by the U.S. Government Printing Office (GPO)
AC	88	1995-01-01	AC 00-45D Aviation Weather Services
AC	253	1980-01-01	AC 61-23B Pilot's Handbook of Aeronautical Knowledge
AC	79	1993-06-30	AC 33-2B Aircraft Engine Type Certification Handbook
AC	2	1981-05-30	AC 135-9 FAR Part 135 Icing Limitations
AC	236	1994-09-06	AC 91-70 Oceanic Operations
AC	476	1976-01-01	AC 65-9A Airframe and Powerplant Mechanics General Handbook
AC	159	1989-02-09	AC 23-8A Flight Test Guide for Certification of Part 23 Airplanes
AC	226	1980-01-01	AC 61-27C Instrument Flying Handbook
AC	31	1996-12-19	AC 120-57A Surface Movement Guidance and Control System
AC	2	1972-01-18	AC 20-29B Use of Aircraft Fuel Anti-lcing Additives

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AC	38	1978-04-01	AC 20-106 Aircraft Inspection for the General Aviation Aircraft Owner
AC	85	1990-02-14	AC 21-16C Radio Technical Commission for Aeronautics Document No. DO-160C
AC	3	1985-12-15	AC 43-16 General Aviation Airworthiness Alerts, Special Issue
AC	52	1976-01-01	AC 65-2D Airframe and Powerplant Mechanics Certification Guide
AC	10	1987-11-01	AC 43-16 General Aviation Airworthiness Alerts No. 112
AC	33	1985-02-11	AC 1 50/5000-4B Airport Research and Technical Reports
AC	11	1992-10-15	AC 150/5220--18 Buildings for Storage and Maintenance of Airport Snow and Ice Control Equipment and Materials
AC	5	1974-07-29	AC 00-34A Aircraft Ground Handling and Servicing
AC	10	1986-11-01	AC 43-16 General Aviation Airworthiness Alerts No. 100
AC	31	1996-03-28	AC 60-25 Reference Materials and Subject Matter Knowledge Codes for Airman Knowledge Testing
AC	85	1978-01-01	AC 61-13B Basic Helicopter Handbook
AC	12	1995-01-01	AC 61-113 Airline Transport Pilot, Aircraft Dispatcher, and Flight Navigator Knowledge Test Guide
AC	15	1995-01-01	AC 63-1 Flight Engineer Knowledge Test Guide
AC	7	1991-03-27	AC 150/5220-13B Runway Surface Condition Sensor Specification Guide
AC	32	1991-01-23	AC 61-107 Operations of Aircraft at Altitudes Above 25,000 Feet MSL and/or Mach Numbers (Mmo) Greater Than .75
AC	208	1972-01-01	AC 43.13-lA Acceptable Methods, Techniques, and Practices — Aircraft Inspection and Repair
AC	35	1993-03-29	AC 20-131A Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and MODE S Transponders
AC	4	1983-01-20	AC 00-24B Thunderstorms
AC	20	1997-05-01	AC 43-16 General Aviation Airworthiness Alerts No. 226
AC	19	1995-01-01	AC 61-114 Commercial Pilot Knowledge Test Guide
AC	52	1992-06-30	AC 150/5220-20 Airport Snow and Ice Control Equipment
AC	98	1992-12-02	AC 23-11 Type Certification of Very Light Airplanes with Power-Plants and Propellers Certificated to Parts 33 and 35 of the Federal Aviation Regulations
AC	11	1985-01-04	AC 25.629-1 Flutter Substantiation of Transport Category Airplanes
AC	27	1991-12-13	AC 60-22 Aeronautical Decision Making
AC	21	1978-03-27	AC 120-17A Maintenance Control by Reliability Methods
AC	54	1991-07-29	AC 120-40B Airplane Simulator Qualification
AC	71	1991-08-09	AC 120-54 The Advanced Qualification Program (AQP)
AC	44	1994-10-11	AC 120-63 Helicopter Simulator Qualification
AC	15	1973-06-26	AC 121-1A Standard Operations Specifications — Aircraft Maintenance Handbook
AC	19	1977-01-12	AC 121-22 Maintenance Review Board (MRB)
AC	44	1978-12-01	AC 135-3B Air Taxi Operators and Commercial Operators
AC	8	1985-09-30	AC 20-88A Guidelines on the Marking of Aircraft Powerplant Instruments (Displays)
AC	5	1993-09-30	AC 23-14 Type Certification Basis for Conversion from Reciprocating Engine to Turbine Engine-Powered Part 23 Airplanes

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AC	6	1995-03-02	AC 23.1521-lB Type Certification of Automobile Gasoline in Part 23 Airplanes with Reciprocating Engines
AC	35	1988-12-30	AC 120-42A Extended Range Operation with Two-Engine Airplanes (ETOPS)
AC	34	1995-06-14	AC 20-130A Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors
AC	23	1994-05-25	AC 20-138 Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR and IFR Supplemental Navigation System
AC	69	1986-04-09	AC 25-7 Flight Test Guide for Certification of Transport Category Airplanes
AC	8	1982-05-01	AC 43-16 General Aviation Airworthiness Alerts No. 46
AC	10	1982-11-01	AC 43-16 General Aviation Airworthiness Alerts No. 52
AC	10	1986-12-01	AC 43-16 General Aviation Airworthiness Alerts No. 101
AC	12	1975-01-01	AC 61-57a Flight Test Guide
AC	23	1991-02-21	AC 61-89D Pilot Certificates: Aircraft Type Ratings
AC	38	1995-11-29	AC 70/7460-1J Obstruction Marking and Lighting
AC	54	1992-02-05	AC 120-45A Airplane Flight Training Device Qualification
AC	15	1996-06-20	AC 1 50/5200-28B Notices to Airmen (NOTAMs) for Airport Operators
AC	17	1991-05-31	AC 150/5390-3 Vertiport Design
AC	2	1985-12-20	AC 20-24B Qualification of Fuels, Lubricants, and Additives for Aircraft Engines
AC	18	1988-09-12	AC 20-101C Airworthiness Approval of Omega/VLF Navigation Systems for Use in the National Airspace System (NAS) Alaska
AC	20	1988-08-24	AC 20-121A Airworthiness Approval of Loran-C Navigation Systems for Use in the U.S. National Airspace System (NAS) and Alaska
AC	11	1980-09-01	AC 43-16 General Aviation Airworthiness Alerts No. 26
AC	8	1982-02-01	AC 43-16 General Aviation Airworthiness Alerts No. 43
AC	10	1983-12-01	AC 43-16 General Aviation Airworthiness Alerts No. 65
AC	8	1987-06-01	AC 43-16 General Aviation Airworthiness Alerts No. 107
AC	10	1987-10-01	AC 43-16 General Aviation Airworthiness Alerts No. 111
AC	10	1991-11-01	AC 43-16 General Aviation Airworthiness Alerts No. 160
AC	15	1995-01-01	AC 43-16 General Aviation Airworthiness Alerts No. 198
AC	322	1980-01-01	AC 61-21A Flight Training Handbook
AC	14	1994-01-01	AC 61-112 Flight and Ground Instructor Knowledge Test Guide
AC	11	1995-01-01	AC 61-119 Instrument Rating Knowledge Test Guide
AC	73	1995-05-24	AC 90-89A Amateur-Built Aircraft and Ultralight Flight Testing Handbook
AC	42	1977-01-01	AC 91-23A Pilot’s Weight and Balance Handbook
AC	10	1994-03-09	AC 150/5210-17 Programs for Training of Aircraft Rescue and Firefighting Personnel
AC	33	1982-08-27	AC 150/5230-4 Aircraft Fuel Storage, Handling, and Dispensing on Airports
AC	363	1989-04-28	AC 150/5370-l0A Announcement of Availability — Standards for Specifying Construction of Airports
AC	31	1991-08-05	AC 23-10 Auxiliary Fuel Systems for Reciprocating and Turbine Powered Part 23 Airplanes
AC	9	1983-07-01	AC 43-16 General Aviation Airworthiness Alerts No. 60
AC	9	1984-08-01	AC 43-16 General Aviation Airworthiness Alerts No. 73

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AC	11	1985-10-01	AC 43-16 General Aviation Airworthiness Alerts No. 87
AC	11	1986-05-01	AC 43-16 General Aviation Airworthiness Alerts No. 94
AC	10	1990-07-01	AC 43-16 General Aviation Airworthiness Alerts No. 144
AC	12	1997-02-01	AC 43-16 General Aviation Airworthiness Alerts No. 223
AC	17	1997-04-01	AC 43-16 General Aviation Airworthiness Alerts No. 225
AC	6	1985-03-18	AC 61-84B Role of Preflight Preparation
AC	2	1984-07-18	AC 91-33A Use of Alternate Grades of Aviation Gasoline for Grade 80/87 and Use of Automotive Gasoline
AC	4	1996-02-09	AC 120-50A Guidelines for Operational Approval of Windshear Training Programs
AC	48	1981-01-22	AC 125-1 Operations of Large Airplanes Subject to Federal Aviation Regulations Part 125
AC	90	1989-01-27	AC 150/5200-31 Airport Emergency Plan
AC	43	1995-11-13	AC 150/5220-16B Automated Weather Observing Systems (AWOS) for Non-Federal Applications
AC	39	1969-05-01	AC 00-25 Forming and Operating a Flying Club
AC	15	1990-06-22	AC 20-27D Certification and Operation of Amateur-Built Aircraft
AC	5	1976-10-20	AC 20-43C Aircraft Fuel Control
AC	2	1980-11-20	AC 20-105A Engine Power-Loss Accident Prevention
AC	136	1995-09-06	AC 21-2H Export Airworthiness Approval Procedures
AC	24	1985-10-23	AC 23.629-1A Means of Compliance with Section 23.629, Flutter
AC	13	1993-01-21	AC 23.1521-2 Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines
AC	35	1986-05-02	AC 25-8 Auxiliary Fuel System Installations
AC	9	1986-03-19	AC 25.939-1 Evaluating Turbine Engine Operating Characteristics
AC	6	1993-02-02	AC 25.1523-1 Minimum Flightcrew
AC	4	1988-06-27	AC 33.47-1 Detonation Testing in Reciprocating Aircraft Engines
AC	10	1979-10-01	AC 43-16 General Aviation Airworthiness Alerts No. 15
AC	9	1984-11-01	AC 43-16 General Aviation Airworthiness Alerts No. 76
AC	10	1985-04-01	AC 43-16 General Aviation Airworthiness Alerts No. 81
AC	11	1989-01-01	AC 43-16 General Aviation Airworthiness Alerts No. 126
AC	11	1989-12-01	AC 43-16 General Aviation Airworthiness Alerts No. 137
AC	1	1991-01-21	AC 43-16 General Aviation Airworthiness Alerts, Special Issue
AC	10	1991-03-01	AC 43-16 General Aviation Airworthiness Alerts No. 152
AC	10	1991-04-01	AC 43-16 General Aviation Airworthiness Alerts No. 153
AC	9	1992-06-01	AC 43-16 General Aviation Airworthiness Alerts No. 167
AC	18	1994-02-01	AC 43-16 General Aviation Airworthiness Alerts No. 187
AC	13	1995-09-01	AC 43-16 General Aviation Airworthiness Alerts No. 206
AC	15	1996-09-01	AC 43-16 General Aviation Airworthiness Alerts No. 218
AC	14	1996-11-01	AC 43-16 General Aviation Airworthiness Alerts No. 220
AC	17	1996-12-01	AC 43-16 General Aviation Airworthiness Alerts No. 221
AC	115	1977-01-01	AC 60-14 Aviation Instructor's Handbook

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AC	16	1972-01-01	AC 61-10A Refresher Courses for Private and Commercial Pilots
AC	16	1995-01-01	AC 61-117 Recreational Pilot and Private Pilot Knowledge Test Guide
AC	24	1975-03-25	AC 67-2 Announcement of Availability of ‘Medical Handbook for Pilots’ May 1974
AC	3	1979-07-24	AC 91-13C Cold Weather Operation of Aircraft
AC	1	1975-06-26	AC 91-43 Unreliable Airspeed Indications
AC	26	1991-06-28	AC 91-67 Minimum Equipment Requirements for General Aviation Operations Under FAR Part 91
AC	13	1995-11-07	AC 120-27C Aircraft Weight and Balance Control
AC	19	1988-11-23	AC 120-49 Certification of Air Carriers
AC	17	1997-02-25	AC 120-51B Crew Resource Management Training
AC	6	1994-09-12	AC 120-62 Takeoff Safety Training Aid: Announcement of Availability
AC	14	1990-11-19	AC 135-15 Emergency Medical Services/Airplane (EMS/A)
AC	29	1988-07-15	AC 139.201-1 Airport Certification Manual (ACM) & Airport Certification Specifications (ACS)
AC	60	1993-02-18	AC 141-lA Pilot School Certification
AC	42	1989-01-06	AC 150/5050-3B Planning the State Aviation System
AC	118	1989-09-29	AC 150/5300-13 Airport Design
AC	44	1982-12-03	AC 150/5380-6 Guidelines and Procedures for Maintenance of Airport Pavements
TCD	56	1994-10-15	TCD Type Certificate Data Sheet No. 3A10
TCD	20	1996-08-15	TCD Type Certificate Data Sheet No. A22CE
TCD	32	1996-05-31	TCD Type Certificate Data Sheet No. A53EU
TCD	26	1969-02-28	TCD Aircraft Specification No. A-781
TCD	46	1990-01-01	TCD Type Certificate Data Sheet No. 2A4
TCD	31	1997-02-10	TCD Type Certificate Data Sheet No. A-793
TCD	22	1973-09-01	TCD Aircraft Specification No. A-812
TCD	16	1994-07-27	TCD Type Certificate Data Sheet No. E8NE
TCD	7	1988-10-12	TCD Type Certificate Data Sheet No. E10EU
TCD	42	1995-06-15	TCD Type Certificate Data Sheet No. A10CE
TCD	5	1980-04-22	TCD Type Certificate Data Sheet No. E3WE
TCD	37	1969-09-30	TCD Aircraft Specification No. 6A3
TCD	37	1971-07-21	TCD Aircraft Specification No. 6A4
TCD	5	1975-12-04	TCD Type Certificate Data Sheet No. E16EU
TCD	66	1994-10-15	TCD Type Certificate Data Sheet No. A6CE
TCD	13	1963-02-27	TCD Aircraft Specification No. A-795
TCD	4	1973-03-30	TCD Type Certificate Data Sheet No. E2WE
TCD	9	1994-11-15	TCD Type Certificate Data Sheet No. E3GL
TCD	19	1990-08-01	TCD Type Certificate Data Sheet No. A15EU
TCD	13	1995-04-15	TCD Type Certificate Data Sheet No. A16SW
TCD	32	1993-10-21	TCD Type Certificate Data Sheet No. H3WE
TCD	5	1987-05-29	TCD Type Certificate Data Sheet No. P22EA

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TCD	21	1985-10-01	TCD Type Certificate Data Sheet No. A5SW
TCD	156	1995-07-15	TCD Aircraft Specification No. 3A16
TCD	16	1997-02-06	TCD Type Certificate Data Sheet A8SW
TCD	36	1971-12-02	TCD Aircraft Specification No. 4A10
TCD	6	1968-08-29	TCD Type Certificate Data Sheet No. E7EU
TCD	5	1978-06-19	TCD Type Certificate Data Sheet No. E8EU
TCD	32	1992-01-24	TCD Type Certificate Data Sheet No. E12EU
TCD	53	1996-04-15	TCD Type Certificate Data Sheet No. A17SW
TCD	25	1996-06-14	TCD Type Certificate Data Sheet No. A19SW
TCD	12	1990-10-23	TCD Type Certificate Data Sheet No. A16EU
TCD	25	1980-04-17	TCD Type Certificate Data Sheet No. A2SW
TCD	12	1990-10-23	TCD Type Certificate Data Sheet No. A16EU
TCD	10	1959-04-06	TCD Type Certificate Data Sheet No. 4A27
TCD	7	1992-01-17	TCD Type Certificate Data Sheet No. H8EU
TCD	4	1977-02-01	TCD Type Certificate Data Sheet No. P-911
TCD	10	1996-08-15	TCD Type Certificate Data Sheet No. A37CE
TCD	49	1985-08-02	TCD Aircraft Specification No. 1A10
TCD	19	1996-09-16	TCD Type Certificate Data Sheet No. A46EU
TCD	12	1993-01-07	TCD Type Certificate Data Sheet No. H1SW
TCD	8	1996-12-16	TCD Type Certificate Data Sheet No. E00054EN
TCD	5	1975-10-15	TCD Type Certificate Data Sheet No. E7EA
TCD	4	1969-06-16	TCD Type Certificate Data Sheet No. E9EU
TCD	6	1996-01-02	TCD Type Certificate Data Sheet No. E18NE
TCD	10	1995-12-18	TCD Type Certificate Data Sheet No. P25EA
TCD	6	1995-08-31	TCD Type Certificate Data Sheet No. lE16
TCD	21	1995-08-01	TCD Type Certification Data Sheet No. A16WE
TCD	5	1978-06-01	TCD Aircraft Specification No. 1A7
TCD	13	1992-01-22	TCD Type Certificate Data Sheet No. H4EU
TCD	11	1996-09-18	TCD Type Certificate Data Sheet No. H6SO
TCD	9	1987-04-14	TCD Type Certificate Data Sheet No. E1IN
TCD	9	1986-10-16	TCD Type Certificate Data Sheet No. E2EU
TCD	13	1994-04-14	TCD Type Certificate Data Sheet No. E4WE
TCD	13	1988-10-28	TCD Type Certificate Data Sheet No. E5NE
TCD	6	1967-09-06	TCD Type Certificate Data Sheet No. E-290
TCD	4	1966-02-15	TCD Type Certificate Data Sheet No. E-306
TCD	5	1984-07-23	TCD Type Certificate Data Sheet No. P5EA
TCD	3	1945-08-01	TCD Type Certificate Data Sheet No. 2-572
TCD	24	1994-12-15	TCD Type Certificate Data Sheet No. A51EU
TCD	45	1996-10-15	TCD Type Certificate Data Sheet No. 3A13
TCD	11	1991-02-20	TCD Type Certificate Data Sheet No. A3WE

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TCD	19	1992-03-13	TCD Type Certificate Data Sheet No. A21NM
TCD	11	1975-05-30	TCD Type Certificate Data Sheet No. A40EU
TCD	11	1979-01-09	TCD Type Certificate Data Sheet No. A45EU
TCD	14	1969-11-14	TCD Type Certificate Data Sheet No. 4A30
TCD	8	1972-01-21	TCD Type Certificate Data Sheet No. H6EU
TCD	9	1971-07-19	TCD Type Certificate Data Sheet No. E21N
TCD	4	1976-09-21	TCD Type Certificate Data Sheet No. E4EU
TCD	3	1964-05-11	TCD Type Certificate Data Sheet No. E6CE
TCD	8	1975-05-29	TCD Type Certificate Data Sheet No. E14EU
TCD	15	1994-06-10	TCD Type Certificate Data Sheet No. E19EU
TCD	5	1992-08-31	TCD Type Certificate Data Sheet No. 1E9
TCD	40	1994-10-15	TCD Type Certificate Data Sheet No. A4CE
TCD	17	1993-06-04	TCD Type Certificate Data Sheet No. A4EU
TCD	34	1996-09-15	TCD Type Certificate Data Sheet No. 3A12
TCD	21	1989-03-31	TCD Type Certificate Data Sheet No. A7PC
TCD	20	1989-11-01	TCD Type Certificate Data Sheet No. A1SO
TCD	12	1993-09-14	TCD Type Certificate Data Sheet No. A19SW
TCD	3	1972-10-02	TCD Type Certificate Data Sheet No. H5WE
TCD	4	1995-07-13	TCD Type Certificate Data Sheet No. E1NM
TCD	5	1970-08-10	TCD Type Certificate Data Sheet No. E1PC
TCD	5	1994-10-28	TCD Type Certificate Data Sheet No. E6WE
TCD	3	1972-08-17	TCD Type Certificate Data Sheet No. E15EU
TCD	24	1994-08-15	TCD Type Certificate Data Sheet No. 3A17
TCD	56	1996-08-15	TCD Type Certificate Data Sheet No. 3A21
TCD	29	1978-05-22	TCD Type Certificate Data Sheet No. A23EU
TCD	117	1985-04-15	TCD Aircraft Specification No. A-765
TCD	38	1996-01-15	TCD Type Certificate Data Sheet No. 3A20
TCD	34	1994-08-15	TCD Type Certificate Data Sheet No. 3A25
TCD	10	1968-04-01	TCD Type Certificate Data Sheet No. A2SO
TCD	42	1996-04-19	TCD Type Certificate Data Sheet No. A41EU
TCD	25	1969-09-30	TCD Aircraft Specification No. A-618
TCD	35	1974-02-08	TCD Aircraft Specification No. A-669
TCD	2	1992-01-16	TCD Type Certificate Data Sheet No. H1EU
TCD	4	1981-10-23	TCD Type Certificate Data Sheet No. E1NE
TCD	4	1979-01-24	TCD Type Certificate Data Sheet No. E3EA
TCD	13	1996-07-19	TCD Type Certificate Data Sheet No. E6NE
TCD	3	1986-07-16	TCD Type Certificate Data Sheet No. E13EA
TCD	5	1994-08-11	TCD Type Certificate Data Sheet No. E15EA
TCD	7	1995-05-31	TCD Type Certificate Data Sheet No. E15NE
TCD	7	1993-02-01	TCD Type Certificate Data Sheet No. E33NE

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TCD	4	1972-04-24	TCD Type Certificate Data Sheet No. E-311
TCD	7	1985-04-17	TCD Type Certificate Data Sheet No. 1E3
TCD	7	1989-06-16	TCD Type Certificate Data Sheet No. 1E8
TCD	19	1987-02-25	TCD Type Certificate Data Sheet No. A13EU
TCD	14	1992-10-13	TCD Type Certificate Data Sheet No. A18EU
TCD	4	1994-10-15	TCD Type Certificate Data Sheet No. A34CE
TCD	62	1994-01-l5	TCD Aircraft Specification No. 3A15
TCD	25	1996-08-15	TCD Type Certificate Data Sheet No. 3A19
TCD	33	1994-10-15	TCD Type Certificate Data Sheet No. 3A24
TCD	31	1996-10-15	TCD Type Certificate Data Sheet No. A7CE
TCD	6	1995-06-15	TCD Type Certificate Data Sheet No. A25CE
TCD	16	1995-06-15	TCD Type Certificate Data Sheet No. A9NM
TCD	6	1996-11-14	TCD Type Certificate Data Sheet A18SW
TCD	34	1997-02-06	TCD Type Certificate Data Sheet No. A21EA
TCD	5	1996-05-31	TCD Type Certificate Data Sheet No. A35EU
TCD	6	1980-03-27	TCD Type Certificate Data Sheet No. A37EU
TCD	7	1996-11-15	TCD Type Certificate Data Sheet No. T00007WI
TCD	26	1973-05-01	TCD Type Certificate Data Sheet No. 4A21
TCD	12	1983-06-27	TCD Type Certificate Data Sheet No. 4A22
TCD	85	1996-12-03	TCD Type Certificate Data Sheet No. 4A25
TCD	24	1984-07-30	TCD Type Certificate Data Sheet No. 4A26
TCD	19	1973-05-01	TCD Type Certificate Data Sheet No. 4A28
TCD	11	1992-02-03	TCD Type Certificate Data Sheet No. H1IN
TCD	14	1996-06-19	TCD Type Certificate Data Sheet No. H1NE
TCD	22	1996-11-18	TCD Type Certificate Data Sheet No. H2SW
TCD	14	1979-04-30	TCD Type Certificate Data Sheet No. H9SW
TCD	2	1994-08-30	TCD Type Certificate Data Sheet No. TR7BO
TCD	19	1990-04-20	TCD Type Certificate Data Sheet No. E4CE
TCD	3	1967-05-09	TCD Type Certificate Data Sheet No. E6EU
TCD	10	1988-09-30	TCD Type Certificate Data Sheet No. E10CE
TCD	5	1981-07-27	TCD Type Certificate Data Sheet No. E13EU
TCD	4	1967-09-15	TCD Type Certificate Data Sheet No. E-291
TCD	7	1987-05-05	TCD Type Certificate Data Sheet No. P6EA
TCD	3	1994-07-25	TCD Type Certificate Data Sheet No. P15NE
TCD	5	1984-05-31	TCD Type Certificate Data Sheet No. P16EA
TCD	7	1982-09-15	TCD Type Certificate Data Sheet No. P24EA
TCD	4	1982-09-15	TCD Type Certificate Data Sheet No. P28EA
TCD	4	1984-05-31	TCD Type Certificate Data Sheet No. P29EA
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TCD	6	1994-03-23	TCD Type Certificate Data Sheet No. P33EA

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TCD	6	1989-08-21	TCD Type Certificate Data Sheet No. P39EA
TCD	3	1994-03-11	TCD Type Certificate Data Sheet No. P41EA
TCD	6	1989-08-21	TCD Type Certificate Data Sheet No. P42GL
TCD	6	1989-08-21	TCD Type Certificate Data Sheet No. P43GL
TCD	5	1987-04-30	TCD Type Certificate Data Sheet No. P52GL
TCD	4	1988-07-28	TCD Type Certificate Data Sheet No. P53GL
TCD	3	1994-03-11	TCD Type Certificate Data Sheet No. P55GL
TCD	3	1982-07-13	TCD Type Certificate Data Sheet No. P59GL
TCD	3	1971-01-07	TCD Type Certificate Data Sheet No. P-871
TCD	2	1971-01-05	TCD Type Certificate Data Sheet No. P-887
TCD	5	1981-03-06	TCD Type Certificate Data Sheet No. P-892
TCD	8	1981-03-06	TCD Type Certificate Data Sheet No. P-908
TCD	8	1996-04-25	TCD Type Certificate Data Sheet No. P-920
TCD	11	1978-12-20	TCD Type Certificate Data Sheet No. A42EU
TCD	34	1995-06-15	TCD Type Certificate Data Sheet No. 5A6
TCD	19	1995-11-02	TCD Type Certificate Data Sheet No. A17WE
TCD	27	1985-09-15	TCD Aircraft Specification No. 5A4
TCD	4	1986-03-31	TCD Type Certificate Data Sheet No. A14SW
TCD	5	1975-12-04	TCD Type Certificate Data Sheet No. A39EU
TCD	8	1995-03-23	TCD Type Certificate Data Sheet No. A45NM
TCD	7	1963-11-01	TCD Aircraft Specification No. 2A5
TCD	12	1965-02-01	TCD Aircraft Specification No. 3A2
TCD	11	1956-09-14	TCD Aircraft Specification No. 6A2
TCD	17	1975-03-20	TCD Aircraft Specification No. 6A6
TCD	5	1975-04-15	TCD Type Certificate Data Sheet No. E2NE
TCD	34	1995-01-05	TCD Type Certificate Data Sheet No. E4EA
TCD	5	1982-05-28	TCD Type Certificate Data Sheet No. E7WE
TCD	8	1995-11-30	TCD Type Certificate Data Sheet No. E22EA
TCD	13	1993-06-09	TCD Type Certificate Data Sheet No. E25NE
TCD	3	1960-09-01	TCD Type Certificate Data Sheet No. E-265
TCD	3	1982-09-15	TCD Type Certificate Data Sheet No. P2EA
TCD	4	1982-09-15	TCD Type Certificate Data Sheet No. P14EA
TCD	5	1994-05-18	TCD Type Certificate Data Sheet No. P15EA
TCD	5	1982-09-15	TCD Type Certificate Data Sheet No. P23EA
TCD	4	1995-07-21	TCD Type Certificate Data Sheet No. P57GL
TCD	3	1969-08-05	TCD Type Certificate Data Sheet No. P-736
TCD	4	1981-01-12	TCD Type Certificate Data Sheet No. P-851

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TCD	2	1971-01-06	TCD Type Certificate Data Sheet No. P-856
TCD	7	1981-03-06	TCD Type Certificate Data Sheet No. P-878
TCD	2	1970-12-07	TCD Type Certificate Data Sheet No. P-881
TCD	4	1981-03-06	TCD Type Certificate Data Sheet No. P-884
TCD	3	1981-03-06	TCD Type Certificate Data Sheet No. P-891
TCD	6	1984-05-31	TCD Type Certificate Data Sheet No. P-913
TCD	22	1995-10-15	TCD Type Certificate Data Sheet No. A9CE
TCD	12	1994-10-15	TCD Type Certificate Data Sheet No. A13CE
TCD	16	1994-10-15	TCD Type Certificate Data Sheet No. A16CE
TCD	56	1997-01-10	TCD Aircraft Specification No. 2A3
TCD	10	1996-08-01	TCD Type Certificate Data Sheet No. A1NM
TCD	4	1967-05-15	TCD Type Certificate Data Sheet No. A5SO
TCD	5	1990-07-16	TCD Type Certificate Data Sheet No. A15NM
TCD	4	1993-02-18	TCD Type Certificate Data Sheet No. A30NM
TCD	4	1990-01-31	TCD Type Certificate Data Sheet No. A31NM
TCD	3	1990-05-15	TCD Type Certificate Data Sheet No. A32NM
TCD	5	1990-03-30	TCD Type Certificate Data Sheet No. A34SO
TCD	5	1996-05-31	TCD Type Certificate Data Sheet No. A35NM
TCD	6	1996-08-15	TCD Type Certificate Data Sheet No. A39CE
TCD	6	1994-01-31	TCD Type Certificate Data Sheet No. TQ3CH
TCD	3	1995-09-06	TCD Type Certificate Data Sheet No. E1EA
TCD	5	1964-05-15	TCD Type Certificate Data Sheet No. E1EU
TCD	13	1996-08-20	TCD Type Certificate Data Sheet No. E2EA
TCD	13	1993-06-17	TCD Type Certificate Data Sheet No. E3NE
TCD	5	1987-11-30	TCD Type Certificate Data Sheet No. E4NE
TCD	5	1980-12-01	TCD Type Certificate Data Sheet No. E4NE
TCD	5	1974-10-18	TCD Type Certificate Data Sheet No. E5EU
TCD	4	1980-08-22	TCD Type Certificate Data Sheet No. E7NE
TCD	2	1969-05-15	TCD Type Certificate Data Sheet No. E8EA
TCD	7	1996-08-20	TCD Type Certificate Data Sheet No. E9NE
TCD	1	1983-12-15	TCD Type Certificate Data Sheet No. E13CE
TCD	5	1996-07-19	TCD Type Certificate Data Sheet No. E17EA
TCD	8	1995-01-11	TCD Type Certificate Data Sheet No. E24NE
TCD	18	1992-06-05	TCD Type Certificate Data Sheet No. E30NE
TCD	7	1996-07-31	TCD Type Certificate Data Sheet No. F34NE
TCD	9	1996-08-21	TCD Type Certificate Data Sheet No. E40NE
TCD	5	1996-08-30	TCD Type Certificate Data Sheet No. E44NE
TCD	1	1983-12-28	TCD Aircraft Engine Specification No. E-288
TCD	4	1968-08-28	TCD Type Certificate Data Sheet No. E-300
TCD	2	1958-04-14	TCD Type Certificate Data Sheet No. E-301

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TCD	3	1962-05-09	TCD Type Certificate Data Sheet No. E-305
TCD	3	1967-01-15	TCD Type Certificate Data Sheet No. E-308
TCD	3	1996-02-02	TCD Type Certificate Data Sheet No. P10NE
TCD	2	1989-08-21	TCD Type Certificate Data Sheet No. P18NE
TCD	2	1977-09-30	TCD Type Certificate Data Sheet No. P19EA
TCD	2	1997-01-21	TCD Type Certificate Data Sheet P44GL
TCD	3	1970-12-01	TCD Type Certificate Data Sheet No. P-206
TCD	3	1970-12-04	TCD Type Certificate Data Sheet No. P-785
TCD	3	1971-01-06	TCD Type Certificate Data Sheet No. P-853
TCD	3	1971-01-07	TCD Type Certificate Data Sheet No. P-870
TCD	2	1956-07-29	TCD Type Certificate Data Sheet No. P-906
TCD	4	1976-05-01	TCD Type Certificate Data Sheet No. 1E5
TCD	2	1960-09-29	TCD Type Certificate Data Sheet No. 1E6
TCD	2	1966-08-08	TCD Type Certificate Data Sheet No. 3E2
TCD	14	1983-01-01	TCD Type Certificate Data Sheet No. ATC 540
TCD	15	1996-04-22	TCD Type Certificate Data Sheet No. A9SW
TCD	7	1994-10-15	TCD Type Certificate Data Sheet No. A20CE
TCD	3	1996-01-15	TCD Type Certificate Data Sheet No. A26CE
TCD	3	1994-06-14	TCD Type Certificate Data Sheet No. A49NM
TCD	5	1995-06-16	TCD Type Certificate Data Sheet No. A86EU
TCD	3	1986-04-11	TCD Type Certificate Data Sheet No. H9NM
TCD	10	1987-07-14	TCD Type Certificate Data Sheet No. 3A18
TCD	11	1995-08-15	TCD Type Certificate Data Sheet No. A1EA
TCD	4	1995-06-15	TCD Type Certificate Data Sheet No. A1WI
TCD	3	1994-10-15	TCD Type Certificate Data Sheet No. A2CE
TCD	19	1996-12-18	TCD Type Certificate Data Sheet No. A7SO
TCD	20	1996-05-23	TCD Type Certificate Data Sheet No. A9EA
TCD	4	1984-09-15	TCD Type Certificate Data Sheet No. A12CE
TCD	4	1994-10-15	TCD Type Certificate Data Sheet No. A28CE
TCD	5	1989-01-20	TCD Type Certificate Data Sheet No. A54EU
TCD	7	1990-10-04	TCD Type Certificate Data Sheet No. A61EU
TCD	4	1993-07-19	TCD Type Certificate Data Sheet No. A68EU
TCD	84	1995-07-28	TCD Type Certificate Data Sheet No. A3EU
TCD	6	1986-07-02	TCD Type Certificate Data Sheet No. A6EU
TCD	45	1981-09-19	TCD Type Certificate Data Sheet No. A7EU
TCD	42	1995-05-30	TCD Type Certificate Data Sheet No. A20EU
TCD	37	1996-08-01	TCD Type Certificate Data Sheet No. A20WE
TCD	42	1995-02-10	TCD Type Certificate Data Sheet No. A22WE
TCD	6	1988-07-26	TCD Type Certificate Data Sheet No. A32EU
TCD	6	1993-08-15	TCD Type Certificate Data Sheet No. A38CE

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TCD	7	1995-12-19	TCD Type Certificate Data Sheet No. A50NM
TCD	4	1954-03-01	TCD Aircraft Specification No. A-593
TCD	17	1981-02-12	TCD Aircraft Specification No. A-814
TCD	9	1987-04-15	TCD Type Certificate Data Sheet No. 1A17
TCD	3	1996-07-27	TCD Type Certificate Data Sheet No. AS1GL
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TCD	5	1993-05-05	TCD Type Certificate Data Sheet No. H6NE
TCD	3	1979-03-01	TCD Type Certificate Data Sheet No. H6SW
TCD	3	1985-02-04	TCD Type Certificate Data Sheet No. H8NM
TCD	4	1994-05-03	TCD Type Certificate Data Sheet No. H9EA
TCD	3	1985-02-08	TCD Type Certificate Data Sheet No. H10SW
TCD	4	1994-12-02	TCD Type Certificate Data Sheet No. H19NM
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TCD	4	1970-08-14	TCD Type Certificate Data Sheet No. E5WE
TCD	3	1983-09-09	TCD Type Certificate Data Sheet No. E14NE
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TCD	6	1994-05-27	TCD Type Certificate Data Sheet No. E36NE
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TCD	7	1996-08-08	TCD Type Certificate Data Sheet No. P3NE
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TCD	5	1996-08-12	TCD Type Certificate Data Sheet No. P7NE
TCD	7	1987-04-30	TCD Type Certificate Data Sheet No. P9EA
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TCD	3	1996-08-12	TCD Type Certificate Data Sheet No. P11NE
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TCD	7	1994-06-30	TCD Type Certificate Data Sheet No. P27EA
TCD	4	1992-10-15	TCD Type Certificate Data Sheet No. P30NE
TCD	4	1992-10-15	TCD Type Certificate Data Sheet No. P31NE
TCD	3	1995-11-10	TCD Type Certificate Data Sheet No. P40EA
TCD	2	1979-09-28	TCD Type Certificate Data Sheet No. P45GL
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TCD	3	1970-12-04	TCD Type Certificate Data Sheet No. P-786
TCD	5	1981-03-06	TCD Type Certificate Data Sheet No. P-907
TCD	1	1961-06-09	TCD Type Certificate Data Sheet No. P-912
TCD	3	1994-04-30	TCD Type Certificate Data Sheet No. TP5BO
TCD	14	1980-08-01	TCD Type Certificate Data Sheet No. A3SW
TCD	36	1993-12-08	TCD Type Certificate Data Sheet No. A4SW
TCD	8	1995-06-07	TCD Type Certificate Data Sheet No. A11EA
TCD	6	1993-02-10	TCD Type Certificate Data Sheet No. A15EA
TCD	11	1993-08-25	TCD Type Certificate Data Sheet No. A16EA
TCD	27	1979-06-14	TCD Type Certificate Data Sheet No. 7A14
TCD	3	1990-07-15	TCD Type Certificate Data Sheet No. A5CE
TCD	3	1992-10-22	TCD Type Certificate Data Sheet No. A11WE
TCD	10	1992-12-15	TCD Type Certificate Data Sheet No. A27CE
TCD	7	1991-07-15	TCD Aircraft Specification No. A-684
TCD	10	1997-02-20	TCD Type Certificate Data Sheet No. A41NM
TCD	8	1950-07-10	TCD Aircraft Specification No. A-726
TCD	30	1969-08-20	TCD Aircraft Specification No. A-762
TCD	32	1995-09-21	TCD Aircraft Specification No. A-763
TCD	25	1995-05-15	TCD Type Certificate Data Sheet No. A-817
TCD	48	1963-07-01	TCD Aircraft Specification No. 6A5
TCD	5	1988-11-07	TCD Type Certificate Data Sheet No. G1NE
TCD	4	1995-03-01	TCD Type Certificate Data Sheet No. H15EU
TCD	15	1996-03-08	TCD Type Certificate Data Sheet No. 1H15
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TCD	7	1993-01-22	TCD Type Certificate Data Sheet No. E2GL
TCD	4	1968-05-15	TCD Type Certificate Data Sheet No. E3EU
TCD	2	1988-10-18	TCD Type Certificate Data Sheet No. E6SO
TCD	6	1992-03-17	TCD Type Certificate Data Sheet No. E12NE
TCD	13	1996-11-18	TCD Type Certificate Data Sheet No. E20NE
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TCD	5	1994-05-16	TCD Type Certificate Data Sheet No. E21NE
TCD	13	1993-10-05	TCD Type Certificate Data Sheet No. E25EA
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TCD	5	1996-05-03	TCD Type Certificate Data Sheet No. E42NE
TCD	4	1993-05-28	TCD Type Certificate Data Sheet No. E43NE
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TCD	2	1984-09-11	TCD Type Certificate Data Sheet No. P8NE
TCD	3	1989-12-14	TCD Type Certificate Data Sheet No. P12NE
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TCD	3	1970-05-01	TCD Type Certificate Data Sheet No. P-825
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TCD	2	1963-08-14	TCD Type Certificate Data Sheet No. P-887
TCD	1	1974-03-01	TCD Type Certificate Data Sheet No. P-898
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TCD	2	1963-08-14	TCD Type Certificate Data Sheet No. P-915
TCD	1	1963-08-14	TCD Type Certificate Data Sheet No. P-916
TCD	3	1993-09-10	TCD Type Certificate Data Sheet No. TE2CH
TCD	1	1963-08-14	TCD Type Certificate Data Sheet No. 7P3
TCD	4	1983-01-01	TCD Type Certificate Data Sheet No. 710
TCD	4	1947-06-03	TCD Type Certificate Data Sheet No. 770
TCD	3	1983-01-01	TCD Type Certificate Data Sheet No. 719
TCD	3	1944-11-27	TCD Type Certificate Data Sheet No. 756
TCD	5	1983-01-01	TCD Type Certificate Data Sheet No. 2-577
TCD	5	1983-01-01	TCD Type Certificate Data Sheet No. 2-576
TCD	9	1983-01-01	TCD Type Certificate Data Sheet No. 785
TCD	2	1943-07-14	TCD Type Certificate Data Sheet No. 752
TCD	26	1996-01-16	TCD Type Certificate Data Sheet No. A3SO
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TCD	3	1980-01-01	TCD Type Certificate Data Sheet No. A7SW
TCD	4	1983-11-30	TCD Type Certificate Data Sheet No. A9PC

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TCD	5	1973-11-21	TCD Type Certificate Data Sheet No. A26EU
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TCD	9	1996-12-20	TCD Type Certificate Data Sheet No. A67EU
TCD	4	1994-04-07	TCD Type Certificate Data Sheet No. A74EU
TCD	6	1996-07-31	TCD Type Certificate Data Sheet No. A78EU
TCD	4	1983-02-16	TCD Aircraft Specification No. A-754
TCD	24	1987-07-15	TCD Aircraft Specification No. A-777
TCD	17	1994-10-15	TCD Aircraft Specification No. A-790
TCD	17	1994-08-11	TCD Type Certificate Data Sheet No. 1A8
TCD	8	1989-03-15	TCD Type Certificate Data Sheet No. 1A13
TCD	50	1994-12-12	TCD Type Certificate Data Sheet No. 3A23
TCD	9	1979-01-22	TCD Aircraft Specification No. 4A12
TCD	9	1990-08-15	TCD Aircraft Specification No. 5A3
TCD	15	1996-07-01	TCD Type Certificate Data Sheet No. 7A15
TCD	6	1980-05-29	TCD Type Certificate Data Sheet No. A8PC
TCD	4	1979-06-19	TCD Type Certificate Data Sheet No. A11EU
TCD	20	1992-03-15	TCD Type Certificate Data Sheet No. A14CE
TCD	37	1996-01-03	TCD Type Certificate Data Sheet No. A17EU
TCD	8	1983-12-15	TCD Type Certificate Data Sheet No. A23CE
TCD	10	1996-11-04	TCD Type Certificate Data Sheet No. A23SO
TCD	4	1996-01-29	TCD Type Certificate Data Sheet No. A32SO
TCD	3	1975-05-14	TCD Type Certificate Data Sheet No. A38EU
TCD	5	1995-08-21	TCD Type Certificate Data Sheet No. A62EU
TCD	12	1985-09-15	TCD Aircraft Specification No. A-757
TCD	8	1977-12-01	TCD Type Certificate Data Sheet No. A14EA
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TCD	4	1989-01-31	TCD Type Certificate Data Sheet No. A23NM
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TCD	12	1989-07-06	TCD Type Certificate Data Sheet No. A28NM
TCD	2	1985-08-01	TCD Type Certificate Data Sheet No. A28SO
TCD	4	1996-01-29	TCD Type Certificate Data Sheet No. A32SO
TCD	7	1987-09-03	TCD Type Certificate Data Sheet No. A33EU
TCD	5	1995-01-23	TCD Type Certificate Data Sheet No. A33SO
TCD	6	1993-09-21	TCD Type Certificate Data Sheet No. A56EU

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TCD	9	1960-04-04	TCD Aircraft Specification No. A-772
TCD	3	1981-04-01	TCD Aircraft Specification No. A-783
TCD	5	1959-04-10	TCD Aircraft Specification No. A-786
TCD	9	1960-09-23	TCD Aircraft Specification No. A-789
TCD	6	1959-04-10	TCD Aircraft Specification No. A-808
TCD	13	1980-02-01	TCD Type Certificate Data Sheet No. 2A15
TCD	10	1963-01-30	TCD Aircraft Specification No. 4A17
TCD	3	1959-04-06	TCD Type Certificate Data Sheet No. 4A23
TCD	6	1973-10-18	TCD Type Certificate Data Sheet No. 7A10
TCD	1	1988-11-07	TCD Type Certificate Data Sheet No. G1NM
TCD	6	1982-02-09	TCD Type Certificate Data Sheet No. H2WE
TCD	3	1986-02-05	TCD Type Certificate Data Sheet No. H8EA
TCD	11	1995-08-07	TCD Type Certificate Data Sheet No. H13WE
TCD	4	1994-11-25	TCD Type Certificate Data Sheet No. H80EU
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TCD	7	1997-01-08	TCD Type Certificate Data Sheet E00049EN
TCD	29	1995-06-12	TCD Type Certificate Data Sheet No. E13NE
TCD	5	1993-11-01	TCD Type Certificate Data Sheet No. E31NE
TCD	3	1994-01-12	TCD Type Certificate Data Sheet No. E35NE
TCD	6	1994-05-20	TCD Type Certificate Data Sheet No. E41NE
TCD	5	1993-12-16	TCD Type Certificate Data Sheet No. E45NE
TCD	3	1969-10-27	TCD Type Certificate Data Sheet No. E-283
TCD	10	1986-07-12	TCD Type Certificate Data Sheet No. E-295
TCD	3	1959-05-11	TCD Type Certificate Data Sheet No. E-296
TCD	8	1987-05-11	TCD Type Certificate Data Sheet No. E-297
TCD	3	1965-12-22	TCD Type Certificate Data Sheet No. E-302
TCD	5	1981-02-06	TCD Type Certificate Data Sheet No. E-307
TCD	2	1994-09-22	TCD Type Certificate Data Sheet No. P2BO
TCD	2	1975-04-25	TCD Type Certificate Data Sheet No. P4EU
TCD	2	1983-09-01	TCD Type Certificate Data Sheet No. P4NE
TCD	2	1983-03-01	TCD Type Certificate Data Sheet No. P5EU
TCD	2	1982-11-26	TCD Type Certificate Data Sheet No. P6EU
TCD	2	1981-01-23	TCD Type Certificate Data Sheet No. P9EU
TCD	2	1982-09-15	TCD Type Certificate Data Sheet No. P10EA
TCD	1	1981-01-23	TCD Type Certificate Data Sheet No. P10EU
TCD	2	1991-01-15	TCD Type Certificate Data Sheet No. P23NE
TCD	4	1989-12-01	TCD Type Certificate Data Sheet No. P24NE
TCD	3	1987-04-30	TCD Type Certificate Data Sheet No. P46GL
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TCD	2	1977-03-01	TCD Type Certificate Data Sheet No. P48GL
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TCD	2	1996-02-23	TCD Type Certificate Data Sheet No. P54GL
TCD	2	1995-03-22	TCD Type Certificate Data Sheet No. P60GL
TCD	6	1977-01-01	TCD Type Certificate Data Sheet No. P-845
TCD	1	1957-03-07	TCD Type Certificate Data Sheet No. P-877
TCD	1	1957-03-07	TCD Type Certificate Data Sheet No. P-879
TCD	4	1985-07-15	TCD Type Certificate Data Sheet No. P-880
TCD	2	1955-05-04	TCD Type Certificate Data Sheet No. P-885
TCD	4	1982-09-15	TCD Type Certificate Data Sheet No. P-917
TCD	4	1983-01-01	TCD Type Certificate Data Sheet No. (Army OA-10A) 2-548
TCD	7	1983-01-01	TCD Type Certificate Data Sheet No. ATC 657
TCD	1	1983-01-01	TCD Type Certificate Data Sheet No. 791
TCD	1	1983-01-01	TCD Type Certificate Data Sheet No. 246
TCD	1	1983-01-01	TCD Type Certificate Data Sheet No. 764
FO	9	1988-08-23	8400.10 Air Transportation Operations Inspector’s Handbook Vol. 4 Chap. 8 Sec. 1 General
FO	8	1988-08-23	8400.10 Air Transportation Operations Inspector’s Handbook Vol. 4 Chap. 8 Sec. 2 Approval of Far Parts 121 and 135 Procedures
FO	3	1988-08-23	8400.10 Air Transportation Operations Inspector’s Handbook Vol. 6 Chap. 2 Sec. 10 Ground Deicing/Anti-Icing Inspections
FO	14	1997-03-17	8400.10 Air Transportation Operations Inspector’s Handbook Append. 4 Chap. FSAT 97-03 In-Flight Icing Operations and Training Recommendations
FO	7	1996-09-20	8400.10 Air Transportation Operations Inspector’s Handbook Append. 4 Chap. FSAT 96-13 FAA-Approved Deicing Program Updates, Winter 1996–97
FO	44	1995-07-20	AIM Aeronautical Information Manual Chap. 7 Sec. 1 Meteorology
FO	2	1995-10-17	8400.10 Air Transportation Operations Inspector’s Handbook Append 4 Chap. FSAT 95-29 Operations During Freezing Drizzle and Light Freezing Rain
FO	2	1996-09-09	8400.10 Air Transportation Operations Inspector’s Handbook Append. 4 Chap. FSAT 96-14 Operations During Freezing Drizzle and Light Freezing Rain
FO	6	1996-07-01	7110.10L Flight Services Chap. 9 Sec. 2 Pilot Weather Report (UA/UUA)
FO	40	1996-11-06	7110.65J Air Traffic Control Explanation of Changes 5 Bg 5 BRIEFING GUIDE
FO	103	1995-07-20	AIM Aeronautical Information Manual Pge Pilot/Controller Glossary
FO	102	1996-06-20	7210.3M Facility Operation and Administration Part 6 Chap. 20 Explanation of Changes 1 Bg 1 Briefing Guide
FO	18	1988-08-23	8400.10 Air Transportation Operations Inspector’s Handbook Vol. 3 Chap. 15 Sec. 3 General Operations Manuals
FO	6	1996-02-29	7210.3M Facility Operation and Administration Part 3 Chap. 12 Sec. 1 General
FO	14	1973-11-01	8340.1A Maintenance Bulletins Chap. 3 Sec. 1 Safety Practices
FO	3	1996-07-01	7110.10L Flight Services Chap. Briefing Guide — Change 2
FO	1	1993-06-09	8300.10 Airworthiness Inspector’s Handbook Append. 4 Chap. FSAW 93-35 System Enhancements (Version 4.1) for Operation Specifications Subsystem (OPSS)

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FO	2	1995-01-11	8300.10 Airworthiness Inspector's Handbook Append. 4 Chap. FSAW 95-01 ATR-42 and ATR-72 Airworthiness Directive T-95-02-51 Compliance Procedures
FO	9	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 5 Chap. 2 Sec. 3 Conduct of Flight Tests in Airplane Flight Simulators and Training Devices
FO	2	1995-01-11	8400.10 Air Transportation Operations Inspector's Handbook Append. 4 Chap. FSAT 95-01 ATR-42 and ATR-72 Airworthiness Directive T-95-02-51 Compliance Procedures
FO	5	1996-07-01	7110.10L Flight Services Append. A Sec. 1
FO	5	1995-07-20	7110.65J Air Traffic Control Glossary Sec. 1
FO	1	1996-06-06	8400.10 Air Transportation Operations Inspector's Handbook Append. 4 Chap. FSAT 96-08 Relief of Icing Fuel Penalties Associated with Critical Fuel Calculations for ETOPS
FO	12	1996-07-01	7110.10L Flight Services Chap. 7 Sec. 1 Messages and Formats
FO	9	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 5 Chap. 2 Sec. 5 Oral and Flight Test Events in Helicopters
FO	1	1994-11-02	8400.10 Air Transportation Operations Inspector's Handbook Explanation of Changes 9
FO	4	1996-06-01	NAIGAOM North Atlantic International General Aviation Operations Manual Chap. 3 Equipment
FO	5	1995-07-20	7110.65J Air Traffic Control Chap. 2 Sec. 6 Weather Information
FO	1	1973-11-01	8340.1A Maintenance Bulletins Chap. 3 Sec. 2 Append. 10 Ice and Rain Protection (ATA Code 3000)
FO	7	1973-11-01	8340.1A Maintenance Bulletins Chap. 3 Sec. 2 Append. 30 Engines (ATA Code 7200) (T = Turbine/Turboprop R = Reciprocating)
FO	4	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 4 Chap. 3 Sec. 5 Selected Practices
FO	1	1996-11-06	7110.65J Air Traffic Control Explanation of Changes 5
FO	17	1995-03-02	8110.4A Type Certification Process Chap. 3 Type Certificates
FO	1	1973-11-01	8340.1A Maintenance Bulletins Chap. 3 Sec. 2 Tools and Test Equipment
FO	9	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 3 Chap. 2 Sec. 5 Flightcrew Aircraft Ground Training Curriculum Segments
FO	5	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 3 Chap. 7 Sec. 2 Parts 121/135 Weather Information Systems
FO	1	1994-01-11	8400.10 Air Transportation Operations Inspector's Handbook Append. 3 Chap. HBAT 94-03 Operations Specifications (OpSpecs) Revision: Part 135 Operations in Ground Icing Conditions
FO	30	1988-10-01	8700.1 General Aviation Operations Inspector's Handbook Vol. 2 Chap. 148 Sec. 2 Procedures
FO	5	1996-06-01	NAIGAOM North Atlantic International General Aviation Operations Manual Chap. 2 Environment
FO	27	1996-07-01	7110.10L Flight Services Chap. 14 Sec. 1 General
FO	1	1995-10-17	8300.10 Airworthiness Inspector's Handbook Append. 4 Chap. FSAW 94-46 Internal Freezing of Pneumatic Deicers Due to Accumulated Moisture
FO	32	1996-01-19	8300.10 Airworthiness Inspector's Handbook Append. 4 Chap. FSAW 96-02 General Certification and Operations Requirements for Air Carriers Transitioning from Part 135 to Part 121

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FO	31	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 3 Chap. 2 Sec. 6 Flight Training Curriculum Segments
FO	16	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 5 Chap. 2 Sec. 2 Flight Test Events in Airplanes
FO	5	1995-05-11	8400.10 Air Transportation Operations Inspector's Handbook Append. 3 Chap. HBAT 95-04 Air Ambulance Operations Specifications Revised
FO	31	1996-01-19	8400.10 Air Transportation Operations Inspector's Handbook Append. 4 Chap. FSAT 96-09 General Certification and Operations Requirements for Air Carriers Transitioning from Part 135 to Part 121
FO	2	1988-10-01	8700.1 General Aviation Operations Inspectors Handbook Vol. 2 Chap. 80 Sec. 2 Procedures
FO	4	1990-10-02	7610.4H Special Military Operations Chap. 12 Sec. 10 USAF Undergraduate Flying Training (UFT)/Pilot Instructor Training (PIT)
FO	2	1988-11-01	8300.10 Airworthiness Inspector's Handbook Vol. 2 Chap. 221 Sec. 2 Procedures
FO	3	1988-11-01	8300.10 Airworthiness Inspector's Handbook Vol. 3 Chap. 131 Sec. 2 Procedures
FO	4	1973-11-01	8340.1A Maintenance Bulletins Chap. Foreword
FO	5	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 6 Chap. 2 Sec. 2 Ramp Inspections
FO	3	1997-05-09	8400.10 Air Transportation Operations Inspector's Handbook Append. 4 Chap. FSAT INDEX Flight Standards Information Bulletins for Air Transportation (FSAT)
FO	1	1996-06-01	NAIGAOM North Atlantic International General Aviation Operations Manual Chap. 4 Route Planning
FO	2	1996-07-01	7110.10L Flight Services Chap. 2 Sec. 4 Pilots Automatic Telephone Weather Answering Service (PATWAS) for Nonautomated Flight Service Stations (FSS)
FO	3	1996-07-01	7110.10L Flight Services Chap. 3 Sec. 2 Preflight Pilot Briefing
FO	24	1996-02-29	7110.65J Air Traffic Control Explanation of Changes 2 Bg 2 BRIEFING GUIDE
FO	102	1996-06-20	7210.3M Facility Operation and Administration Part 6 Chap. 20 Explanation of Changes 1 Explanation of Changes 1
FO	3	1988-11-01	8300.10 Airworthiness Inspector's Handbook Vol. 2 Chap. 76 Sec. 2 Procedures
FO	2	1969-04-10	8310-6 Airworthiness Compliance Check Sheet Handbook Chap. 2 Sec. 22 Airworthiness Compliance Check Sheet #22
FO	5	1988-08-23	8400.10 Air Transportation Operations Inspector's Handbook Vol. 3 Chap. 7 Sec. 1 General Background Information
FO	25	1995-07-20	AIM Aeronautical Information Manual Chap. 4 Sec. 3 Airport Operations
FO	15	1995-07-20	AIM Aeronautical Information Manual Chap. 5 Sec. 3 En Route Procedures
FO	1	1996-06-01	NAIGAOM North Atlantic International General Aviation Operations Manual Chap. 5 Flight Planning
FO	4	1989-10-24	5100.38A Airport Improvement Program (AIP) Handbook Chap. 5 Sec. 7 Safety, Security, and Support Equipment
FO	2	1996-07-01	7110.10L Flight Services Chap. 2 Sec. 2 Transcribed Weather Broadcasts (TWEB)
FO	1	1996-07-01	7110.10L Flight Services Chap. 2 Sec. 3 VOR TWEB
FO	3	1996-07-01	7110.10L Flight Services Chap. 4 Sec. 6 En Route Flight Advisory Service (EFAS)
FO	8	1996-07-01	7110.10L Flight Services Chap. 6 Sec. 4 Flight Plan Handling
FO	1	1996-07-01	7110.10L Flight Services Chap. 9 Sec. 6 Aviation Area Forecast (FA)

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FO	1	1996-07-01	7110.10L Flight Services Chap. 9 Sec. 10 Meteorological Impact Statement (MIS)
FO	1	1996-07-01	7110.10L Flight Services Chap. 9 Sec. 11 Center Weather Advisory (CWA)
FO	18	1996-07-01	7110.10L Flight Services Append. A Sec. A
FO	8	1996-07-01	7110.10L Flight Services Append. A Sec. S
FO	1	1996-11-04	7110.10L Flight Services Chap. EXPCHG
FO	17	1995-07-20	7110.65J Air Traffic Control Chap. 1 Sec. 2 Terms of reference
FO	18	1995-07-20	7110.65J Air Traffic Control Glossary Sec. A
FO	8	1995-07-20	7110.65J Air Traffic Control Glossary Sec. S
FO	2	1996-02-29	7210.3M Facility Operation and Administration Part 2 Chap. 8 Sec. 3 Operations
FO	1	1987-09-03	8000.45C Aircraft Certification National Resource Specialists Append. 1 Listing of National Resource Specialists
FO	3	1991-08-02	8020.11A Aircraft Accident and Incident Notification, Investigation, and Reporting Chap. 6 Sec. 4 FAA Form 8020-5, Aircraft Incident Record
FO	24	1995-03-02	8110.4A Type Certification Process Chap. 2 Type Certification Process
FO	29	1994-06-13	8130.2C Airworthiness Certification of Aircraft and Related Products Chap. 4 Sec. 6 Experimental Airworthiness Certifications
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Further Reading from FSF Publications

Dow, J.P., Sr. "Icing — Detection and Countermeasures for Corporate and Regional Aircraft." In *Aviation Safety: Challenges and Solutions*: *Proceedings of the 8th Annual European Aviation Safety Seminar*. 1996.

A discussion of present and future systems for detecting ice. Symptoms covered include vibrations, control force changes, instrument indications and aural and visual cues. Also presented are ice countermeasures that can be taken during all phases of flight from pre-takeoff to landing.

Hellyer, K. "Safe Winter Operations." In *Managing Safety: Proceedings of 48th Annual International Air Safety Seminar*. Seattle, Washington, United States: Flight Safety Foundation, 1995.

An overview of the history of deicing and anti-icing; the properties of Type I and Type II deicing/anti-icing fluids; methods of deicing/anti-icing; and discussions of holdover time (how long an application of deicing/anti-icing fluid will remain effective), deicing vehicles, and cold wings, which are caused by recent flight operations at very low temperatures or the taking on of super-chilled fuel.

"Turboprop Freighter Crashes After Severe Icing Causes Multiple Engine Failures." *Accident Prevention* Volume 52 (June 1995): 1–6.

A detailed account of a Vickers Viscount accident caused by severe icing at altitude. Ice-caused failure of engines no. 2 and no. 3, ice on the vertical stabilizer, and questionable decision-making on the part of the two-pilot flight crew led to controlled flight into trees while approaching the airport at Birmingham, England and the death of the aircraft captain.

Lawton, R. "Airframe Icing and Captain's Improper Use of Autoflight System Result in Stall and Loss of Control of Commuter Airplane." *Accident Prevention* Volume 51 (November 1994): 1–8.

An account of an actual accident which occurred while an Embraer-120 RT was climbing to altitude on autopilot. Moderate icing of the wing and commensurate loss of lift went unnoticed by the flight crew until the aircraft stalled and began a spin to the left. The crew regained control of the aircraft at 1,678 meters (5,500 feet). The aircraft was substantially damaged, but there were no injuries.

Briot, R. "Icing Operations: Facing the Facts." *Flight Safety Digest* Special Supplement: "Proceedings of the 6th Annual European Corporate and Regional Aircraft Operators Safety Seminar" (May 1994): 261–295.

An illustrated discussion of the precise effects of wing icing. Charts and graphs show the relationship between ice accrual and loss in angle of attack margin, the effects of flaps and gear on performance when wings are iced, and a comparison between the lift generated by a clean airfoil and the lift generated by the same airfoil with an accumulation of rough ice. Photographs show examples of the appearance of ice accretion on leading edges and on the full wing surface.

Perkins, P.J. "Tailplane Stall Caused by Ice." In *Safe Application of Technology in Corporate Aviation: Proceedings of the 39th Corporate Aviation Safety Seminar.* 1994.

An examination of the causes, effects and remedies associated with ice on the tailplane of the aircraft — a subject that gets much less coverage than wing ice. Presented are actual occurrences in which the aircraft nose either could not be raised or suddenly pitched down when the landing flaps were extended. Also discussed are runback ice (ice which forms aft of the area protected by deicing equipment); the symptoms of a tailplane stall; and pilot action to be taken if evidence of severe tailplane ice appears.

"Training, Deicing and Emergency Checklist Linked in MD-81 Accident Following Clear-ice Ingestion by Engines." *Accident Prevention* Volume 50 (December 1993): 1–8.

An account of an accident caused by incomplete ground deicing. The aircraft took off with clear ice remaining on the wings. On initial climb, chunks of ice shed from the wings were ingested by the two Pratt & Whitney JT8D turbofan engines, effectively destroying them. The flight crew guided the powerless aircraft to a successful emergency landing about 10 kilometers (6.2 miles) northeast of the airport.

MacIntosh, R.M. "Accidents Show Need for Comprehensive Ground Deicing Programs." *Airport Operations* Volume 19 (November/December 1993): 1–4.

A study of ground icing, which is easier to counteract than icing encountered in flight, yet continues to take its toll, particularly among nonslatted turbojet transports. Minute amounts of ice contamination on the leading edges of wings can cause a significant reduction in the stall angle-of-attack. Many pilots lack the training to respond effectively or respect for the dangers of ground icing.

Sumwalt, R. III. "Incident Reports Highlight Problems Involving Air Carrier Ground Deicing/Anti-icing." *Airport Operations* Volume 19 (September/October 1993): 1–6.

A discussion of the psychological and physiological factors that affect a pilot's ability to properly detect ice, remove ice, and ensure that the aircraft's critical surfaces are free of ice before takeoff. The psychological factors include judgment, perception and motivation. Physical factors include difficulties in inspecting wings and other aerodynamic surfaces from the cockpit, or from the ground if the surfaces are highly elevated.

Eloranta, Capt. J.T. "Confirming Airworthiness Prior to Takeoff in Icing Conditions — Pilot Options." *Flight Safety Digest* Special Supplement: Proceedings of the 5th annual European Corporate and Regional Aircraft Operators Safety Seminar (August 1993): 118–121.

A presentation outlining actions that the pilot can take to ensure that the components of his aircraft are free of frozen contaminants before takeoff is attempted. These include, where possible, an inspection of aerodynamic surfaces by hand, which is the only sure way; knowledge of the deicing fluids available; awareness of the deicing holding period for current weather and traffic conditions; understanding that a "representative" surface may not be truly representative of ice accretion; and verification that proper deicing procedures are used.

Pope, J.A. "U.S. Accident Report Blames Wing Ice and Airline Industry/FAA Failures in Fatal Fokker Crash." *Accident Prevention* Volume 50 (April 1993): 1–8.

A look at an accident in which the Fokker F-28-4000 flight crew exceeded the holdover time for the Type I deicing fluid by more than 200 percent, tried (unsuccessfully) to determine the extent of wing ice contamination from the cockpit at night and used a speed of rotation for takeoff (V_R) that was 9.3 kilometers per hour (five knots) below the prescribed speed. The angle-of-attack stall margin was eliminated, and the aircraft rolled to the left and crashed immediately after takeoff, fatally injuring one cabin crew member and 25 passengers.

"Unstabilized Approach, Icing Conditions Lead to Commuter Tragedy." *Accident Prevention* Volume 49 (December 1992): 1–6.

An account of a tailplane stall caused by 1.3 centimeters to 2.5 centimeters (0.5 inch to one inch) of mixed rime and clear ice which, characteristically, caused the Jetstream commuter to roll up and enter an uncontrolled descent when the landing flaps were lowered to 50 degrees. The pilot had earlier refused several offers to have the aircraft deiced while it was on the ground at its previous stop.

"Rapid High-altitude Icing Linked to Series of Fatal Accidents." *Accident Prevention* Volume 49 (November 1992): 1–8.

In the accident described herein, a Mitsubishi MU-2, a twin turboprop utility transport, was cruising at 6,405 meters (21,000 feet) when, without warning, it rolled sharply to the left and entered a spin. Less than a minute later, the aircraft impacted the ground in uncontrolled flight, killing the pilot and passenger. An investigation attributed this and similar accidents at altitudes above 4.575 meters (15,000 feet) in instrument meteorological conditions to airframe icing. The reduced lift and increased drag lowered airspeed to the point of stall.♦

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