UNITED STATES DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

FAA
INFLIGHT AIRCRAFT
ICING PLAN

April 1997

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 (SLD).

The Conference included the following working groups: (1) Icing Environmental 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 recommendations and consensus items are listed in Appendix I. Appendix II is a table that indicates how the recommendations and consensus items relate to various tasks in the 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 In-Flight Icing Product Development Plan: FY97 & FY98," 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 of icing activities.

This report contains five appendices:

(1) Appendix I: May 1996, International Conference on Aircraft Inflight Icing Working Group Recommendations, Consensus Items, and Non-Consensus Items.

(2) Appendix II: FAA Inflight Aircraft Icing Plan Tasks and Associated May 1996, International Conference on Aircraft Inflight Icing Recommendations, Consensus Items, and Non-Consensus Items.

(3) Appendix III: Significant Recommendations and Consensus Items Not Incorporated into the FAA Inflight Aircraft Icing Plan.

(4) Appendix IV: Glossary of Acronyms.

(5) Appendix V: List of Contributors to the FAA Inflight Aircraft Icing Plan.

FLIGHT STANDARDS REGULATIONS AND GUIDANCE MATERIAL

<u>Task 1</u>. Improve training and operation regulations and guidance material related to icing.

A. The FAA will require Principal Operations Inspectors to ensure that training programs for persons operating aircraft under parts 121 and 135 of the Federal Aviation Regulations (14 CFR parts 121 and 135) include information about flight into freezing rain/freezing drizzle conditions as well as conventional icing conditions.

<u>PLAN DETAILS, TASK 1.A.</u>:

Responsible Party: Flight Standards Service.

Schedule:

- March 1997: Completed Flight Standards Handbook (Information) Bulletin requiring POI's to ensure that training programs include information about all icing conditions including flight into freezing drizzle and freezing rain.

B. 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) 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 Federal Aviation Regulations (14 CFR part 91), since section 91.527 does not apply to most general aviation aircraft.**

- **Direct Principal Operations Inspectors to ensure that all air carriers that operate aircraft under part 121 of the Federal Aviation Regulations (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 1.B.:

The review includes, but is not limited to, the following documents:

a. Aeronautical Information Manual (AIM)
b. Advisory Circular 91-51
c. ATC Handbooks 7110.65 and 7110.10
d. Advisory Circular 135-9
e. Winter Operations Guide
f. Sections 91.527, 135.227, and 121.341 of parts 91, 135, and 121, respectively, of the Federal Aviation Regulations (14 CFR 91.527, 135.227, and 121.341)
g. FAA Order 8400.10
h. 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.)

a. International Civil Aviation Organization's Manual of Aeronautical and Meteorological Practice (Document 8896-AN/893/4)
b. 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.

C. The FAA will explore the feasibility of incorporating icing performance and handling characteristics in airplane training simulators.

PLAN DETAILS, TASK 1.C.:

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.

D. The FAA will participate with appropriate organizations to encourage coordination among manufacturers, operators, associations, and 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 1.D.:

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.

A. 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 to improve the ability to forecast inflight icing, including icing due to SLD.

PLAN DETAILS, TASK 2.A.:

The FAA sponsors icing forecasting research though the AWR program under FAA Aviation Weather Research Program, AUA-460. Inflight icing is currently AWR's highest priority. Present work continues a seven-year history of FAA research in icing. Activities described under paragraphs A. and B. of this task are described in greater detail in "FAA In-Flight Icing Product Development Plan: FY97 & FY98," 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 underway 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 2D 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.

(See also Tasks 13.E. and 13.H. of this plan.)

Responsible party: FAA Aviation Weather Research Program, AUA-460.

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 AWC and Alaska AWC forecasters.
- FY99 and beyond:
    - Complete combined sensor-model icing algorithm and implement at AWC and Alaska AWC.
    - Develop higher resolution icing guidance product (down to 10 km horizontal scale) commensurate with the National Centers for Environmental Prediction (NCEP) capability improvement.

B. 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 2.B.:

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.

(See also Task 3 of this plan.)

Responsible Party: FAA Aviation Weather Research Program, AUA-460.

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 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 AWC and Alaska AWC.
- November 1997 - 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 Party: 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

<u>Task 4</u>. Ensure that aircraft having unpowered ailerons and pneumatic deicing boots do not have roll control anomalies if exposed to certain SLD conditions.

A. The FAA will develop and publish interim procedures for aircraft receiving new, amended, or supplemental type certificates.

<u>PLAN DETAILS, TASK 4A:</u>

In 1994, an accident occurred in which severe icing conditions outside of the icing certification envelope contributed to uncommanded roll. 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 non-powered 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 large supercooled droplets. The procedures that 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.

B. The FAA will issue Notices of Proposed Rulemaking (NPRM) to require that certain aircraft exit icing conditions when specific visual icing cues are observed. The NPRMs will be applicable to those aircraft (1) that have pneumatic deicing boots and unpowered ailerons and (2) that were not addressed by the icing AD's issued on April 24, 1996.

PLAN DETAILS, TASK 4B:

In April 1996, the FAA issued 18 Airworthiness Directives (AD) to require revising the FAA-approved Airplane Flight Manual to provide the flight crew with recognition cues for, and procedures for exiting from, severe icing conditions. The AD's were written because flight crews were not provided with the information necessary to determine:

- when the airplane is operating in icing conditions that have been shown to be unsafe; or
- what action to take when such conditions are encountered.

The AD's applied primarily to parts 23 and 25 airplanes that have unpowered primary roll controls, pneumatic deicing boots, and 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 AD's. The part 23 NPRM's 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 NPRM's will include:

a. All single and multi-engine turbopropeller powered airplanes.
b. All multi-engine piston powered airplanes.
c. 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 NPRM's.
- February 1998: Publish Final Rules.

Task 5. Task 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 Federal Aviation Regulations (14 CFR part 25). However, service experience has shown that airplanes may encounter icing conditions exceeding Appendix C, which may have catastrophic consequences. This 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.

A. The FAA will review, revise, and develop the following guidance material:

1) Review and revise Advisory Circular (AC) 20-73, Aircraft Ice Protection.
2) Review and revise AC 23.1419A, Certification of Part 23 Airplanes for Flight in Icing Conditions.
3) Develop AC 25.1419, Certification of Part 25 Airplanes for Flight in Icing Conditions.

PLAN DETAILS, TASK 6.A.1, 6.A.2, and 6.A.3:

A review of existing advisory material indicates that improvements can be made and additional new information incorporated to benefit all users. The AC's 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 Appendix C (see Task 5 of this plan).

Responsible Party: Aircraft Certification Service.

Schedule:

September 1998: Issue proposed AC's.

4) Review and update FAA Icing Handbook.

PLAN DETAILS, TASK 6.A.4:

The FAA Icing Handbook is a compendium of technical information pertaining to design, analysis, test, 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:

a. Airfoil and aircraft aerodynamics, performance, and stability and control with ice accretions.
b. Characterization of supercooled large droplet icing conditions.
c. Analytical icing accretion and performance codes.
d. Ice protection systems.

Responsible Party: FAA Technical Center.

Schedule:

December 1997: Complete update of the FAA Icing Handbook.

5) Develop an engine and propulsion icing AC.

PLAN DETAILS, TASK 6.A.5:

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:

a. Ice shed damage conditions
b. Power loss instability conditions (e.g., rollback, flameout, surge/stall, etc.)
c. Acceptance criteria (acceptable damage, acceptable power loss, etc.)
d. Natural icing flight tests [part 25 of the Federal Aviation Regulations (14 CFR part 25)]

Responsible Parties: Engine and Propeller Directorate, Transport Airplane Directorate.

Schedule:

September 1998: Issue final AC.

6) Develop an advisory circular to provide guidance on how to evaluate the susceptibility of a horizontal tail to stall.

PLAN DETAILS, TASK 6.A.6:

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 phenomen 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. The 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.

B. The FAA will coordinate an evaluation of a reformatted Appendix C, which could provide a presentation more easily used in certification and for other purposes and which could be incorporated in an AC.

PLAN DETAILS, TASK 6.B.:

Dr. Richard Jeck's AIAA-94-0482 paper, "Other Ways to Characterize the Icing Atmosphere," 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.

C. Task an Aviation Rulemaking Advisory Committee (ARAC) working group to harmonize the requirements of Section 23.1419 ("Ice protection") of part 23 of the Federal Aviation Regulations (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

Federal Aviation Regulations (14 CFR part 25.1419, 25.929, and 25.1093) and of part 25 of the Joint Airworthiness Regulations, and to produce appropriate advisory material.

PLAN DETAILS, TASK 6.C.:

Responsible Parties: Small and Transport Airplane Directorates.

Schedule:

October 2001: Publish Final Rule.

<u>Task 7.</u> 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.

<u>PLAN DETAILS, TASK 7</u>:

Section 25.1419 of part 25 of the Federal Aviation Regulations (14 CFR part 25) and Section 25.1419 of the Joint Airworthiness Regulations 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.

<u>Task 8</u>. (This task is left blank intentionally.)

<u>Task 9</u>. 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.

<u>PLAN DETAILS, TASK 9</u>:

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 FAA-sponsored 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 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 of this plan).

Responsible Party: FAA Icing Steering Committee.

Schedule:

June 2003: If appropriate, the FAA will propose a change to the envelope.

<u>Task 10</u>. The FAA Human Factors Team will review the design philosophy of automatic autopilot disconnection due to an external disturbance.

<u>PLAN DETAILS, TASK 10</u>:

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 the ensuing roll and pitch excursions has resulted during 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

<u>Task 11</u>. 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.

A. *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.

<u>PLAN DETAILS, TASK 11.A.</u>:

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:

- August1997: Develop interim recommendations on validation criteria.
- June 2001: Develop final recommendations on validation criteria.

B. *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 11.B.:

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, $C_{l,max}$, and stall angles.

C. *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 11.C.:

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.

A. 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 12.A.:

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):

1) "Sandpaper" ice (a thin layer of ice composed of roughness elements);
2) Residual ice (ice remaining after a deicer cycle);
3) Rime ice;
4) Glaze ice;
5) Large-droplet ice (spanwise step accretions beyond the "normal" impingement zone);
6) Beak ice (single horn ice shape on the upper surface); and
7) Intercycle ice (ice accumulated between deicer cycles).

These categories of ice would be considered during various phases of flight such as takeoff, landing, climb, hold, etc., for:

1) Operational ice protection systems;
2) Failed ice protections systems; and
3) Unprotected surfaces.

Responsible Parties: Aircraft Certification Service, FAA Technical Center, NASA LeRC, Industry, Academia.

Schedule:

December 1997: Publish a plan.

B. 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 12.B.:

Responsible Party: Aircraft Certification Service.

Schedule:

- October 1997: Complete visits to manufacturers.
- December 1997: Report findings.

C. 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: (1) the NASA LeRC/FAA Tailplane Icing Program and (2) the University of Illinois/FAA Study of Effect of Large Droplet Ice Accretions on Airfoil and Wing Aerodynamics and Control.

The NASA Lewis Research Center (LeRC)/FAA Tailplane Icing Program:

PLAN DETAILS, TASK 12.C.:

This program encompasses a study of tailplane icing using icing tunnel, wind tunnel, computational methods, and flight test. 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.

University of Illinois/FAA Study of Effect of Large-Droplet Ice Accretions on Airfoil and Wing Aerodynamics and Control:

PLAN DETAILS, TASK 12.C.:

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 large droplet icing conditions (freezing rain and drizzle) as well as in smaller droplet clouds at 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 deflection. 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.

D. 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 12.D.:

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.

A. The FAA will circulate "trial" SLD dropsize distributions to participating research organizations to assess differences in LWC and dropsize processing methods.

PLAN DETAILS, TASK 13.A.:

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 (MVD) 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.

B. The FAA will collect, consolidate, and analyze affordable and accessible existing SLD data. The FAA will recommend that individual Civil Aviation Authorities (CAA's) 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 13.B.:

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.

C. The FAA will conduct a study to determine the magnitude of the safety threat that is posed by mixed phase conditions.

PLAN DETAILS, TASK 13.C.:

Responsible party: FAA Technical Center.

Schedule:

February 1998: Report on the findings and recommendations for possible further action.

D. (This subtask is left blank intentionally.)

E. The FAA will support basic research on the formation mechanism of freezing drizzle aloft and at ground level.

PLAN DETAILS, TASK 13.E.:

Through the FAA Aviation Weather Research Program, the FAA has supported ongoing work in this area since fiscal year (FY) 1990. The "FAA Inflight Icing Product Development Plan: FY97 & FY98" 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.

F. 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 13.F.:

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 characterization (SLD, 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 air traffic use areas, wind tunnel and numerical simulation requirements, and operational requirements.

Responsible parties: FAA Technical Center, Canada [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.

G. The FAA supported 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 13.G.:

Responsible Parties: NASA LeRC, AES, FAA Technical Center.

Schedule:

September 1996: Completed NASA LeRC and Canada (AES/NRC/TC) tunnel testing.
July 1997: Report on the tunnel testing.

H. 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 13.H.:

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 the following 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, NOAA'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 $1,800,000.

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 (AUA-460), Canada (AES/NRC/TC), Joint Airworthiness Authorities (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.

I. 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 13.I.:

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

<u>Task 14</u>. The FAA Icing Steering Committee will coordinate inflight icing activities, including recommendations from the FAA International Conference on Aircraft Inflight Icing.

<u>PLAN DETAILS, TASK 14</u>:

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 if the Icing Plan tasks 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.

Appendix I

May 1996, International Conference on Aircraft Inflight Icing Working Group Recommendations, Consensus Items, and Non-Consensus Items

Working Group on Requirements for and Means of Compliance in Icing Conditions (Including Icing Simulation Methods)

RECOMMENDATIONS

CS_R1. Create an ad-hoc working group to identify validation requirements as guidance material for computer codes, icing tankers, and icing tunnels in the harmonization activities. Develop and publish guidance material, including
limitations for validating prediction tools/simulation facilities, through a coordinated effort between research/industry/regulatory authorities.

CS_R2. Set up a steering committee for coordination of in-flight icing activities, including recommendations from this conference.

CS_R3. Industry recommends that future harmonized rules provide sufficient details and guidance to allow consistent certification practices (some areas of NPA 219 are currently subject to interpretation):

The following topics should be addressed accurately:

- Critical ice shape assessment.
- Validation of simulation tools.
- Flight test techniques.
- Instrumentation issues.

CS_R4. Recommend standard terminology and definitions for icing conditions. Harmonize language between operational and certification areas, for example, the severity level of icing conditions.

CS_R5. Require in certification a means to detect icing conditions that exceed the 14 CFR part 25 Appendix C icing envelope and require appropriate Airplane Flight Manual /Airplane Operating Manual information, including exit procedures.

CS_R6. Require handling and performance adequate for recognition of and exit from the exceedance envelope.

CS_R7. Recommend that the FAA not make compliance with FAR 25.1419 mandatory because some manufacturers postpone icing certification until after type certification due to seasonal constraints for natural icing testing.

CS_R8. Prior to considering the expansion of Appendix C:

- Characterize the Supercooled Large Droplet (SLD) environment.
- Provide a means to detect SLD.
- SLD environment treated like flight into thunderstorms; avoid if possible, exit if encountered.
- Develop improved meteorological prediction capabilities.
- Use uplinking/nowcasting for weather updating.
- ATC take an active role in transmission and dissemination of SLD weather information.
- International research community develop validated SLD computational capability and accurate prediction tools/simulation facilities for near-freezing temperatures. Make international comparison between all improved codes.
- Provide educational/training information on SLD to support safe operations.
- Add appropriate language to Airplane Flight Manual/Airplane Operating Manual.

CS_R9. FAA/Industry should review data from the FAA Phase II icing tests to determine if there are significant correlations which can be shared for future use and to identify realistic ice shapes due to SLD. Look at parameters such as airfoils, pressure distribution, aileron design, etc. Manufacturers indicated a willingness to contribute data.

CS_R10. Long-Term Activity - Recommend review of the design philosophy of automatic autopilot disconnection (e.g., is it acceptable to have the autopilot disconnect based on external disturbances?).

CS_R11. Recommend Appendix C be reevaluated, modernized, and made more user friendly; no change to the icing environment defined by Appendix C is required. (See the work of Dr. Richard Jeck, FAA Technical Center.)

CS_R12. Harmonize Part 23.1419 and Part 25.1419 (except for the 61 knot stall speed requirement).

CS_R13. Recommend the development of reliable ice detectors that indicate the icing severity.

CS_R14. Recommend development of predictive sensing of icing conditions.

CS_R15. Provide a publicly available icing tanker.

CS_R16. 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.

CS_R17. Develop and validate propeller icing performance code.

NON-CONSENSUS ITEMS

CS_N1. If tests are needed to show adequate handling qualities, recommend use of SLD ice shapes replicated from tanker or icing tunnel tests in short term (code outputs currently in question).

CS_N2. Recommend a common definition of when the airframe anti-ice systems must be activated.

CS_N3. Require essentially unchanged controllability and performance in Appendix C environment.

CS_N4. Consider Part 33, 35 for exceedance icing conditions.

CS_N5. All aircraft should meet the same requirements; recommend ADs similar to the recently issued icing ADs also be issued for all airplanes.

CS_N6. Recommend ADs not be issued on large jet transports because of the absence of adverse service history.

CS_N7. Address SLD issues with a priority on airplanes with unpowered flight controls that were not covered by Phase II.

CS_N8. Recommend that the NASA Lewis Icing Research Tunnel (IRT) be able to simulate the entire Appendix C envelope, including low liquid water content.

Working Group on Icing Environmental Characterization

RECOMMENDATIONS

EC_R1. Circulate "trial" SLD dropsize distributions to PMS probe users to assess differences in LWC and dropsize processing methods.
- FAA Tech Center coordinate effort.
- Short-term urgency.

EC_R2. Consolidate all available data (esp. airborne) on ZR and ZL.
- Organized by AES of Canada and FAA Tech Center.
- Data to include:
  > Final dropsize distributions.
  > Other (tbd).
- Suggested sponsor: FAA.
- Urgency: Within 1 year.

EC_R3. Reach agreement on standard instruments LWC meter(s), reliable in SLD droplet range (50 to 2000 microns).
- Test and compare in NASA IRT.
- Urgency: This summer.

EC_R4. Compile a global ZR and ZL climatology.
- Cooperative effort of many individual countries.
- Coordination?
- Completed within 2 years.

EC_R5. Convene a workshop for SLD characterization.
- Sponsor: ICAO, WMO, AMS, EC, or FAA (or some combination).
- Within 2 years.

EC_R6. Need to conduct field projects to obtain SLD data.
- In Great Lakes Region because high frequency of ZL, ZR, and lack of measurements aloft.
  > Sponsors: FAA, NASA, AES/NRC.
- In Europe.
  > Sponsor: EC.

EC_R7. Encourage basic research on formation mechanisms for ZL.
- Will yield information on likely locations and frequencies of occurrence.
- Vital to forecasting community.
- Long term research effort.

EC_R8. Characterize SLD environment for operations:

- Solicit cooperation of operational aircraft in carrying probes (LWC and droplet); possibilities include:
  > Canada: DFO, DND, TC, etc.
  > U.S.: Coast Guard, etc.
- Solicit cooperation of designated pilots in reporting of visual cues.

EC_R9. If the Appendix C envelope is to be revised or supplemented to encompass SLD, a special committee should be formed to address a number of issues, including:
- Should there be a separated, independent envelope for SLD?
- What variables should be used:
  > MVD, 80% VD, dropsize distribution (5 bins).
  > LWC.
  > Altitude.
  > Temperature.
  > Horizontal extent.
- Should mixed phase conditions be included in a revision?
- Should it be tied to a severity index?
- Can it incorporate terminology common to operations?

CONSENSUS ITEMS

EC_C1. International cooperation needed (e.g., EURICE).

EC_C2. Global climatology of ZR and ZL (starting point).

EC_C3. Definition of SLD - "any droplets larger than 50 microns diameter."
"SLD LWC" - LWC in dropsizes larger than 50 microns diameter.

EC_C4. Need common language/definitions for:
- Certification, operations, forecasting, PIREPs.

EC_C5. Formation of ZL not well understood (nor horizontal extent).

EC_C6. Characterization of SLD environment needed to support:
- Flight operations and forecasting.
- Test and simulation.
- Design.

EC_C7. Need a standard instrument for:
- LWC (esp. SLD).
- Dropsize distribution.

EC_C8. Need a consistent procedure for calibrating, processing, and reporting drop size and LWC data.

EC_C9. Develop remote sensing devices for SLD (ground-based, airborne, and satellite).

- Microwave radiometers.
- Multiparameter radars.
- Lidars.

EC_C10. Manufacturers need better information for design purposes information on probe selection/installation.

EC_C11. If there is a need to revise or supplement the Appendix C envelope to include SLD, WE NEED MORE DATA!

EC_C12. Mixed-phase (solid and liquid) conditions not yet discussed.

NON-CONSENSUS ITEMS

EC_N1. Revise Appendix C Envelope (SLD and <50 microns).

EC_N2. Need for compact instrument package.

Working Group on Forecasting and Avoidance

RECOMMENDATIONS

FA_R1. FAA should encourage rapid prototyping of experimental products for limited operational use.

FA_R2. The FAA should endorse efforts in numerical weather forecast model development in the areas of prediction of cloud, cloud water, supercooled water, and eventually droplet size distribution with emphasis on a rapid implementation path and distribution mechanism.

FA_R3. FAA should fund technology transfer activities to foster development of operational sensors.

FA_R4. FAA needs a system-level analysis of operational forecast needs in order to focus research, define effective implementation strategies, and develop system architecture.

FA_R5. ASOS program should continue the development and implementation of freezing rain and freezing drizzle sensors, and stations that augment ASOS reports should routinely report this information.

FA_R6. The dispatcher should be provided with products that will permit full compliance with FAR 121.601c.

FA_R7. The recommendations from this conference should be shared with international aviation community through ICAO and other international agencies and forums.

FA_R8. The FAA should convene another working group meeting to address, specifically, icing severity definitions and icing severity index issues.

FA_R9. Standard terminology for large droplet icing should be developed and applied.

FA_R10. Ice accretion when reported by an aircraft should be confirmed with ATC as “Magic Words:”

- “Trace” and “Light” always should be reported to the controller,
- “Moderate” reports require action by ATC, and
- “Severe” represents emergency action needed.

FA_R11. Review and clarify ground observer reporting rules for precipitation type, especially freezing precipitation.

FA_R12 . The FAA should continue funding basic research to develop accurate icing detection and forecasting products.

FA_R13. Conduct one or more intensive field programs to collect comprehensive data sets to verify icing forecast and detection methods.

CONSENSUS ITEMS

FA_C1. The current PIREP system is flawed. It needs and deserves improvements. There are several issues:

- Stress to pilots the importance of accurate reporting, including null reports.
- Enable a more efficient insertion of PIREPs into the system so they may be distributed in near real-time and archived for later use.
- Make in-house PIREPs collected by airlines available to researchers and AWC forecasters, after de-identification.
- There exists a fear of reporting weather conditions for which aircraft are not legally certified.
- Develop special collection programs in cooperation with pilots.

FA_C2. Verification is vital for model and sensor outputs and for icing end-products to evaluate quality and enable improvements.

FA_C3. The aviation community must be made aware of all severe icing conditions (such as icing associated with high LWC and ambient temperatures near freezing) as being as significant as icing associated with supercooled large droplets.

FA_C4. Icing severity should be revisited:

- User needs.
- Definitions for pilot reporting.
- Meteorological definitions (i.e., ICAO).

FA_C5. Ensure that recommendations coming from this conference are integrated with user requirements.

NON-CONSENSUS ITEMS

FA_N1. Centralize all aviation weather forecasting activities within the National Weather Service's Aviation Weather Center.

RECOMMENDATIONS

Weather Reports and Forecasts

OT_R1. Need accurate depiction of icing location for preflight planning, avoidance, and exit procedures.

- Need plain language terminology for icing reports.
- Need new products for accurate forecasts of severe conditions and predictions of severe ice.
- Need accurate information to include emphasis on vertical distribution (temperature).

ATC

OT_R2. Emphasize severe icing in recurrent training for controllers.

OT_R3. Priority handling should be applicable to all aircraft requesting diversion for severe icing.

OT_R4. Clear, concise information in PIREPs must be passed to/from flight crews and dispatchers.

Dispatch

OT_R5. Recognize that dispatch includes both preflight and inflight decisions.

OT_R6. Need accurate forecasts and timely pilot reports in order to make real time, informed decisions regarding the safety of flight.

Flight Crew

OT_R7. Use manufacturer recommendations for operation of ice protection equipment. Research the ice bridging issue.

Training

OT_R8. Educate all pilots and dispatchers on weather conducive to severe icing, icing certification, icing subjects.

OT_R9. Develop common terminology including “priority handling.”

OT_R10. Encourage coordination among manufacturers, operators, associations and organizations, research communities, pilots, and international community for development of training aids, pictorials, visual training aids, and advisory material.

OT_R11. Need recurrent winter operations training updated with new information and technology.

OT_R12. Update advisory circulars or guidance material on severe icing.

OT_R13. Develop FAA/industry training aid on in-flight icing.

Reporting/ PIREPs

OT_R14. Incorporate use of PIREPs and reporting procedures particular to icing into training programs.

OT_R15. Develop company procedures for requesting PIREPs information in icing conditions.

OT_R16. Improve PIREPs coordination between ATC and FSS and company/one call for all.

OT_R17. Modify NASA's ASRS program to include severe icing/ support funding.

OT_R18. Support use of partnership programs such as ASAP to capture icing data. Forward pertinent data to the ASRS system.

OT_R19. Update PIREPs icing information to include precipitation type and altitude.

Technology

OT_R20. Need reactive ice detection equipment that identifies ice accretion aft of protected surfaces.

OT_R21. Support the development of predictive onboard/airborne ice systems.

OT_R22. Aircraft manufacturers should provide data to simulator manufacturers to help replicate the icing environment.

OT_R23. Fund NASA to expand capabilities to keep pace with manufacturing/ industry needs.

OT_R24. Encourage use of ASD (aircraft situational display) for dispatch.

OT_R25. FAA to fund research for the characterization of the icing environment.

OT_R26. Emphasize communication and cooperation in the international research community to define, resolve, and disseminate severe icing findings to industry in an established time frame.

Aircraft Certification

OT_R27. Review MMEL restrictions in ADs.

Regulations and Guidance Materials

OT_R28. Modify severe icing definition to include ice accretion aft of protected areas.

OT_R29. Recommend review and harmonization of FAA regulations pertaining to icing conditions.

NON-CONSENSUS ITEMS

OT_N1. Icing severity index.

OT_N2. Prohibition of operations in severe icing as defined by the AIM and in freezing rain and freezing drizzle.

RECOMMENDATIONS

PD_R1. Characterize Supercooled Large Droplet (SLD) icing environment.

PD_R2. Accelerate development of technologies which remotely assess icing conditions (airborne, ground based, space based).

PD_R3. Improve the air transportation system to decrease the probability of a catastrophic icing event.

PD_R4. Establish cooperative research efforts and methodologies to define aircraft critical ice accretion characteristics.

PD_R5. Establish cooperative research efforts to characterize Part 25 Appendix C exceedance environment (includes SLD).

PD_R6. Promote the use of ice detection systems to provide icing information about critical surfaces. Visual cues, if adequate, should be considered as a solution.

PD_R7. It is essential that an icing environment severity index be developed as a generic scale.

PD_R8. Coordinate research activities internationally.

PD_R9. Aircraft manufacturers and users should investigate the feasibility/cost/operational benefits of installing a combination of ice detection, supplemental ice protection, and operational procedures for protection to safely exit from uncertified type icing conditions for their aircraft.

CONSENSUS ITEMS

PD_C1. There needs to be an international definition of SLD conditions.

PD_C2. Flight crews need to be notified when critical areas of their aircraft are abnormally* accreting ice.

*Icing severity index for exceedance.

PD_C3. The aircraft manufacturer or modifier needs to define aircraft specific critical areas for SLD.

PD_C4. Research needs to be carried out to determine realistic limits for exceedance to Part 25 Appendix C for all forms of precipitation.

PD_C5. Critical ice formations need to be defined which consider the effects of ice protection systems through a cooperative research effort.

PD_C6. Candidate technologies exist to directly and indirectly (aerodynamic performance monitors) sense in-situ ice accretions, including SLD accretions, as currently characterized.

PD_C7. Candidate ice protection technologies exist which can remove SLD ice accretions as characterized today.

PD_C8. Encourage development of cost effective helicopter ice protection technology.

NON-CONSENSUS ITEMS

PD_N1. Ice detection systems should be REQUIRED on all aircraft certified to Appendix C.

PD_N2. Flight crews need to be notified when they are operating in conditions for which their aircraft are not protected in critical areas.

PD_N3. Wide area ice detection is preferred over spot sensor in near freezing conditions.

PD_N4. It is essential that an icing environmental severity index be developed as a generic scale. Aircraft/helicopters could be certified to meet certain levels* on this scale dependent on aircraft type and its on-board devices.

*See recommendation #7 for severity index.

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Appendix II

FAA INFLIGHT AIRCRAFT ICING PLAN TASKS AND ASSOCIATED MAY 1996, INTERNATIONAL CONFERENCE ON AIRCRAFT INFLIGHT ICING RECOMMENDATIONS, CONSENSUS ITEMS, AND NON-CONSENSUS ITEMS[1]

	FAA INFLIGHT AIRCRAFT ICING PLAN TASKS													
Conference Rec's, Consensus, and Non-Consensus Items[1]	1	2	3	4	5	6	7	8 task # not used	9	10	11	12	13	14
CS_R1											X			
CS_R2														X
CS_R3						X	X				X			
CS_R4	X													
CS_R5					X									
CS_R6					X									
CS_R7						X								
CS_R8					X								X	
CS_R9												X		
CS_R10										X				
CS_R11						X								
CS_R12						X								
CS_R13					X									
CS_R14		X												
CS_R15[2]														
CS_R16[3]														
CS_R17[3]														
CS_N1					X									

	FAA INFLIGHT AIRCRAFT ICING PLAN TASKS													
Conference Rec's, Consensus, and Non-Consensus Items[1]	1	2	3	4	5	6	7	8 task # not used	9	10	11	12	13	14
CS_N2[4]														
CS_N3							X							
CS_N4						X								
CS_N5				X	X									
CS_N6				X										
CS_N7				X										
CS_N8														
EC_R1													X	
EC_R2													X	
EC_R3													X	
EC_R4	X												X	
EC_R5													X	
EC_R6													X	
EC_R7													X	
EC_R8[5]													X	
EC_R9					X								X	
EC_C1	X												X	
EC_C2													X	
EC_C3	X													
EC_C4	X												X	
EC_C5													X	
EC_C6													X	
EC_C7													X	
EC_C8													X	

	FAA INFLIGHT AIRCRAFT ICING PLAN TASKS													
Conference Rec's, Consensus, and Non-Consensus Items[1]	1	2	3	4	5	6	7	8 task # not used	9	10	11	12	13	14
EC_C9		X												
EC_C10						X								
EC_C11													X	
EC_C12													X	
EC_N1					X									
EC_N2													X	
FA_R1		X												
FA_R2		X												
FA_R3		X												
FA_R4		X												
FA_R5[3]														
FA_R6		X												
FA_R7									X					X
FA_R8	X													
FA_R9	X													
FA_R10	X													
FA_R11	X													
FA_R12		X											X	
FA_R13														
FA_C1	X													
FA_C2		X												
FA_C3					X									
FA_C4	X													X
FA_C5														X

	FAA INFLIGHT AIRCRAFT ICING PLAN TASKS													
Conference Rec's, Consensus, and Non-Consensus Items[1]	1	2	3	4	5	6	7	8 task # not used	9	10	11	12	13	14
FA_N1[6]														
OT_R1	X	X												
OT_R2	X													
OT_R3	X													
OT_R4	X													
OT_R5	X													
OT_R6		X												
OT_R7	X													
OT_R8	X													
OT_R9	X													
OT_R10	X													
OT_R11	X													
OT_R12	X													
OT_R13	X													
OT_R14	X													
OT_R15	X													
OT_R16	X													
OT_R17	X													
OT_R18	X													
OT_R19	X													
OT_R20					X									
OT_R21			X											
OT_R22	X													
OT_R23											X	X		

	FAA INFLIGHT AIRCRAFT ICING PLAN TASKS													
Conference Rec's, Consensus, and Non-Consensus Items[1]	1	2	3	4	5	6	7	8 task # not used	9	10	11	12	13	14
OT_R24	X													
OT_R25													X	
OT_R26	X												X	
OT_R27[3]														
OT_R28	X													
OT_R29	X					X								
OT_N1	X													
OT_N2					X									
PD_R1													X	
PD_R2			X											
PD_R3	X	X	X	X	X	X	X		X	X	X	X	X	X
PD_R4												X		
PD_R5													X	
PD_R6					X									
PD_R7[3]														
PD_R8	X												X	
PD_R9					X									
PD_C1	X													
PD_C2					X									
PD_C3				X										
PD_C4													X	
PD_C5												X		
PD_C6					X									
PD_C7					X									

	FAA INFLIGHT AIRCRAFT ICING PLAN TASKS													
Conference Rec's, Consensus, and Non-Consensus Items[1]	1	2	3	4	5	6	7	8 task # not used	9	10	11	12	13	14
PD_C8			X											
PD_N1					X									
PD_N2					X									
PD_N3					X									
PD_N4[6]														

[1] Listing of a conference item under a specific FAA Inflight Aircraft Icing Plan task does not imply endorsement of the item by the FAA. This table is only a listing of conference items that are related to various tasks in the Inflight Aircraft Icing Plan. The text of the International Conference on Aircraft Inflight Icing items is located in Appendix I.

[2] The FAA supports funding of an icing tanker by private industry.

[3] See Appendix III.

[4] The FAA does not plan any tasks related to this non-consensus item.

[5] NCAR plans to have a project where pilot reports of visual icing cues will be used to help verify the accuracy of icing forecasts. The FAA does not plan a separate program to solicit pilot reports of visual icing cues.

[6] All aviation forecasts are issued from the National Weather Service's Aviation Weather Center in Kansas City.

Appendix III

Significant Recommendations and Consensus Items Not Incorporated into the FAA Inflight Aircraft Icing Plan

- **PD_R7. 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.

- **CS_R16. 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.

- **CS_R17. 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.

- **FA_R5. 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.

- **OT_R27. Review Master Minimum Equipment List (MMEL) restrictions in 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 flighyt 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.

Appendix IV

GLOSSARY

AAWC	Alaska Aviation Weather Center
AC	Advisory circular
AD	Airworthiness Directive
AES	Atmospheric Environmental Service (Canada)
AFM	Airplane Flight Manual
AGATE	Advanced General Aviation Transportation Experiment
AIM	Aeronautical Information Manual
AOM	Airplane Operations Manual
AMS	American Meteorological Society
ARAC	Aviation Rulemaking Advisory Committee
ASAP	Aviation Safety Action Plan
ASOS	Aviation Surface Observation System
ASD	Aircraft Situational Display
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
AWC	Aviation Weather Center
AWR	Aviation Weather Research
BRAIT	Boeing Research Aerodynamic Icing Tunnel
CAA	Civil Aviation Authorities
CRREL	Cold Regions Research Engineering Laboratory (U.S. Army)
DFO	Department of Fisheries and Oceans (Canada)
DND	Department of National Defense (Canada)
DOD	Department of Defense (United States)
EC	European Commission
EFF	Experimental Forecast Facility
EURICE	European Research on Aircraft Ice Certification
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FSS	Flight Service Station
FY	Fiscal year
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IRT	Icing research tunnel
JAA	Joint Airworthiness Authorities
LWC	Liquid water content
MMEL	Master Minimum Equipment List
MVD	Median Volume Diameter
NASA	National Air and Space Administration
NASA LeRC	National Air and Space Administration Lewis Research Center

NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NEXRAD	Next Generation Weather Radar (WSR-88D)
NOAA	National Oceanic and Atmospheric Administration
NPRM	Notice of Proposed Rulemaking
NRC	National Research Council of Canada
NSF	National Science Foundation
NWS	National Weather Service
PIREPS	Pilot Reports
PMS	Particle Measuring Systems, Inc.
SAE	Society of Automotive Engineers
SLD	Supercooled large droplets
TC	Transport Canada
TDWR	Terminal Doppler Weather Radar
WISP	Winter Icing and Storms Projects
WMO	World Meteorological Organization
WSOM	Weather Service Operations Manual
ZR	Freezing rain
ZL	Freezing drizzle

Appendix V

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