AEROSPACE RECOMMENDED PRACTICE

ARP5905™

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Calibration and Acceptance of Icing Wind Tunnels

RATIONALE

ARP5905 has been reaffirmed to comply with the SAE five-year review policy.

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) document provides recommended practices for the calibration and acceptance of icing wind tunnels to be used in testing of aircraft components and systems and for the development of simulated ice shapes. This document is not applicable to air-breathing propulsion test facilities configured for the purposes of engine icing tests. Use of facilities as part of an aircraft's ice protection Certification Plan should be reviewed and accepted by the applicable regulatory agency prior to testing. Following acceptance of a test plan, data generated in these facilities may be submitted to regulatory agencies for use in the certification of aircraft ice protection systems and components. Certain types of tests may be appropriate in facilities with capabilities that are not as rigorously characterized as by the practices defined herein, and the acceptability of these tests should be coordinated with the applicable regulatory agency.

1.1 Background:

The U.S. Federal Aviation Administration established an icing plan in 1997 to respond to a need for a comprehensive program to create an awareness of inflight icing issues and to establish documents to provide training and guidance for regulatory authorities, aircraft operators, research organizations, and aircraft manufacturers. The FAA published a 14-task plan, entitled the "FAA Inflight Aircraft Icing Plan," and identified groups of people within the U.S. Government and throughout the aircraft industry to address the action items contained in this plan. Task 11 of this plan called for the development of "validation criteria and data for simulation methods used to determine ice shapes on aircraft." It also indicated that this task was to include data on "wind tunnel[s], ice accretion computer codes, and icing tankers." The FAA suggested "a coordinated effort among research organizations, industry, and regulatory authorities" and individuals were asked to participate in this work. Task 11 was divided into three subtasks and the people that participated in Subtask A were tasked with addressing criteria for the use of tankers, tunnels, and codes. Three documents were developed by the members of the Task 11.A Working Group and these three documents are being published as SAE ARPs. While each document follows a format that is appropriate to the topic, the three documents provide guidance for the application of codes (ARP5903), tankers (ARP5904), and tunnels (ARP5905) to the icing certification or qualification process.

1.2 Purpose:

The purpose of this ARP is to compile in one definitive source, commonly accepted calibration and acceptance criteria and procedures for icing wind tunnels. Wind tunnels that meet these criteria will have known icing conditions simulation capability. Each manufacturer is responsible for obtaining regulatory agency approval for using a specific facility to generate certification data in their specific certification program.

1.2 (Continued):

The reader is directed to the following: DOT/FAA/CT-88/8-2, “Aircraft Icing Handbook,” Volume 2, Chapter V, Section 4.0, Testing to Demonstrate Compliance, March 1991; “Aircraft Ice Protection,” U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular (AC) 20-73, April 21, 1971; “Certification of Transport Category Rotorcraft,” (AC 29-2C), September 30, 1999; and the advisory circulars for icing certification of airplanes (AC 23.1419-2A and AC 25.1419-1) for the myriad of considerations that are inherent in defining and conducting test programs for the purpose of obtaining certification for flight into known icing conditions. This ARP provides recommended practices for the calibration of icing wind tunnels. It is not intended to substitute for the regulatory agency’s latitude in selecting the combination of tests or inspections required to demonstrate compliance with regulations as described in the Aircraft Icing Handbook.

1.3 Facility/Site Qualification:

An icing facility that conforms to the recommended practices in this document provides an artificial icing test volume consistent with the capability provided by current wind tunnel technology. If results produced in a test facility are to be used in the certification process of aircraft components or ice protection systems, it should be substantiated that the facility calibration and supporting resources conform to this ARP. Also, a comparison between the facility icing condition envelopes that can be simulated and those defined by the regulatory authorities should be presented.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

2.1.1 AIR5504, Aircraft Inflight Icing Terminology

2.1.2 AIR5906, Ice Shape Measurement and Comparison Techniques Workshop

2.1.3 ARP5904, Airborne Icing Tankers

2.1.4 ARP5905, Calibration and Acceptance of Icing Wind Tunnels

2.1.5 AIR5320. Summary of Icing Simulation Test Facilities

2.1.6 AIR4906, Droplet Sizing Instrumentation Used in Icing Facilities

2.2 U.S. Government Publications:

FAA Reports: Documents with numbers such as DOT/FAA/AR-00/37 or DOT/FAA/CT-88/8-3 are available through the National Technical Information Service (NTIS), Springfield VA.

FAA regulations are available from: Superintendent of Documents, U.S. Government Printing Office, Mail Stop SSOP, Washington, DC 20402-0001.

FAA Advisory Circulars are available from: U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785.

2.2.1 “Aircraft Icing Handbook,” Volume 2, Chapter V, Section 4.0 Testing to Demonstrate Compliance, DOT/FAA/CT-88/8-2, March 1991.

2.2.2 Ide, R. F., “Liquid Water Content and Droplet Size Calibration of the NASA Lewis Icing Research Tunnel,” NASA Technical Memorandum TM-102447, Jan. 1990.

2.2.3 “Equations, Tables and Charts for Compressible Flow," NASA Ames Research Center, Moffett Field, California, Report No. NACA 1135, 1953.

2.2.4 Advisory Circular (AC) 20-73, “Aircraft Ice Protection,” U.S. Department of Transportation, Federal Aviation Administration, April 21, 1971.

2.2.5 Advisory Circular (AC) 23.1419-2A, “Certification of Part 23 Airplanes for Flight in Icing Conditions,” U.S. Department of Transportation, Federal Aviation Administration, August 19, 1998.

2.2.6 Advisory Circular (AC) 25.1419-1, “Certification of Transport Category Airplanes for Flight in Icing Conditions,” U.S. Department of Transportation, Federal Aviation Administration, August 18, 1999.

2.3 Non-U.S. Government Publications:

2.3.1 Jose C. Gonsalez and E. Allen Arrington, Monroe R. Curry, “Aero-Thermal Calibration of the NASA Glenn Icing Research Tunnel (2000 Tests),” American Institute of Aeronautics and Astronautics Paper # AIAA-2001-0233.

2.3.2 “Quality Assessment for Wind Tunnel Testing,” AGARD Advisory Report No. 304, July, 1994.

2.3.3 “Assessment of Wind Tunnel Data Uncertainty,” AIAA Standard S-071-1995, May, 1995.

2.3.4 Coleman, W.H and W.G. Steele, Jr., Experimentation and Uncertainty Analysis for Engineers, John Wiley & Sons, New York, 1989.

2.3.5 Wilbanks, C., Schultz, R., Analytical Study of Icing Simulation for Turbine Engines in Altitude Test Cells, AEDC-TR-73-144, November 1973.

2.3.6 George E. Cain, Roger F. Yurczyk, Dale L. Belter, and Seetharam H. Chintamani, “Boeing Research Aerodynamic/Icing Tunnel Capabilities and Calibration,” SAE Technical Paper 940114, February 21, 1994.

2.3.7 Seetharam Chintamani, Danny Delcarpio, Greg Langmeyer, “Development of Boeing Research Aerodynamic Icing Tunnel Circuit,” AGARD-CP-585, 1996.

2.3.8 “Certification of Transport Category Rotorcraft,” (AC 29-2C), September 30, 1999.

3. SYMBOLS:

α	Pitch angle, calibration probe
β	Yaw angle, calibration probe
Υ	Ratio of specific heats, (for air = 1.4)
μ_a	Dynamic viscosity of air
ρ_a	Freestream air density
ρ_{aU}	Uncorrected air density
ρ_{aSTP}	Density of air at standard temperature and pressure
ρ_{ice}	Density of ice
ρ_w	Density of water
τ_C	Thickness of the iced grid at the center location
τ_{grid}	Thickness of grid in the un-iced condition
τ_{ice}	Thickness of ice
$\tau_{ice\ R}$	Relative thickness of ice
$\tau_{(x,y)}$	Thickness of the iced grid at each (x,y) location

3. (Continued):

φ	Impingement parameter
ω_a	Air mass flow rate
ω_w	Water flow rate
ω_{wB}	Bulk water flow rate
A	Flow area
C_α	Pitch angle pressure coefficient
C_β	Yaw angle pressure coefficient
$C_{d\,a}$	Air discharge coefficient
$C_{d\,w}$	Water discharge coefficient
$C_{d\,w/a}$	Discharge coefficient based on difference of water and air pressures
C_{Pi}	Model pressure coefficient for port ”i”
C_0	Intercept constant
c_w	Specific heat capacity of water
D	Nozzle approach diameter
d_c	Rotating cylinder diameter
d_d	Droplet diameter
d_K	King probe wire diameter
d_o	Nozzle orifice diameter
e_b	Icing blade collection efficiency
e_c	Rotating cylinder collection efficiency
e_K	King Probe wire collection efficiency
gpm	Gallons per minute