

How to Properly Use an Icing Forecast

The official icing forecast is produced by the National Weather Service in the form of an AIRMET or SIGMET and these are based on requirements set down by the International Civil Aviation Organization (ICAO). These must be a fairly broad forecasts based on the ICAO standards. However, there are ways to enhance safety by using supplemental products that have a higher degree of resolution and timeliness.

These forecasts are found on the National Weather Service Aviation Digital Data Service (ADDs) (www.aviationweather.gov). What follows is a discussion of how to use these pages to extract the best information and to make flying through potential icing conditions safer. Included in the appendixes are regulatory backgrounds to include Chief Counsel rulings on areas of known icing.

Icing is a weather phenomenon, greatly dependent on variables outside a meteorologist's capability to forecast (airframe type, speed, proximity to clouds etc.). The ability to recognize potential icing hazards is important to a pilot's ability to safely navigate through these areas.

It is our desire to be able to discreetly forecast icing for each aircraft and each flight but that is currently impossible. It is the responsibility of the pilot to determine how each icing forecast will potentially affect their specific flight/airframe and then be watchful during the flight for possible accumulation and performance impact.

Contents

Predicting InFlight Aircraft Icing Intensity – A Surrogate for Severity

Appendix I

Letter from Chief Counsel to AOPA, Known Icing

Appendix II

Icing Regulatory Rules

Predicting InFlight Aircraft Icing Intensity – A Surrogate for Severity

**Marcia K. Politovich, National Center for Atmospheric Research
Lead, FAA Aviation Weather Research Program InFlight Icing Product
Development Team**

What we commonly refer to as icing severity is the effect that accreted ice has on the flight capability of an airplane. This is related to the amount, location, shape and texture of the accreted ice which, in turn, is related to the atmospheric environment and flight parameters. (would a diagram help?)

An icing product intended for general use cannot capture this complexity. Rather, the product has to combine these factors into a broad-brushed picture of the *intensity* of the icing condition based on knowledge or inference of liquid water content, drop size, and temperature. However, regulations demand that expected severity – again, the effect on the airplane – be depicted. Thus, human forecasters providing AIRMETs and SIGMETs, and the methods used in automated algorithms such as CIP and FIP have devised various means to estimate icing severity.

One step in assessing severity is to consider the accretion rate on an airplane's wing. This can be calculated using a relatively simple two-dimensional (along a chord) airfoil accretion model that allows the user to vary the atmospheric environment variables (temperature, pressure, liquid water content, some metric of drop size) and aircraft variables (airfoil type, airspeed and angle of attack). The accretion rate at the stagnation point (where the airflow splits to go over or under the wing) can be calculated. Or – given an aircraft condition (a term we'll use to describe the combination of the aircraft variables), the atmospheric parameters can be varied to reach a desired accretion rate. If we define icing severity via thresholds of this accretion rate, then combinations of LWC and drop size can be found to meet these thresholds for an aircraft. This can be repeated for more aircraft, an uncertainty analysis can be performed, and a set of thresholds of LWC and drop size obtained that describe a "broad brush" severity index.

Bear in mind, however, that this does not tell the entire story. The shape of the accreted ice, the extent of the ice aft of the leading edge, and its texture affect the performance of the aircraft at least as much as the actual thickness at the stagnation point. Ice also accretes differently along the span of the wing, and accretes on the tail, engine intakes, nose and other locations. Those effects are not small nor are they easy to calculate – models of accretion of ice on a full three-dimensional aircraft are still in an experimental stage. Considerable research has been done on the effect of ice on lift and drag, and to some extent on controllability (as in roll and pitch moment changes), but this is also in an early stage.

So, is this an intractable problem? Not really, it's just that it won't be solved for many years. In the meantime, the pilot's best solution is to understand that an all-purpose, all-aircraft severity index is *guidance at best*.

MORE ON ICE ACCRETION RATE AS A SEVERITY SURROGATE

A quarter inch of ice is approximately that thickness at which a pilot would notice the ice buildup on the surface of the aircraft. Dr. Richard Jeck of the FAA Tech Center proposed a definition whereby light, moderate and heavy levels would be those at which $\frac{1}{4}$ in of ice will build up in 60, 15, and 5 min. Dr. Marcia Politovich applied this idea to the set of airplanes/airfoils listed in Table 1. This spans a broad range of aircraft. The Lockheed P-3 Orion (P3) is a large, four-engine propeller aircraft flown in coastal surveillance and by the National Oceanic and Atmospheric Administration for hurricane and other weather research. The Beechcraft 1900 (B1900) is a 19-passenger twin-turboprop commuter aircraft. The slightly smaller Queen Air (QA) has two piston engines. The Convair 640 (C640) is a 40-50 passenger twin turboprop or piston engine aircraft, and the Cessna T-37B (CT37) is a twin-engine military jet trainer. The 3-in (0.0762 m) cylinder (CYL) is used as a comparison.

Table 1: Airplanes and Parameters Used in this Study

| Airplane | Acronym | Airfoil used in trajectory program | Chord (m) | Equivalent airfoil diameter (m) | Airspeed (m/s) | Angle of attack (deg) |
|----------------------|---------|------------------------------------|-----------|---------------------------------|----------------|-----------------------|
| 3-inch cylinder | CYL | Circle | 0.076 | 0.0762 | 89.4 | 0.0 |
| Beechcraft Queen Air | QA | NACA-23015 | 1.07 | 0.161 | 77.2 | 3.0 |
| Beechcraft 1900D | B1900 | NACA-23015 | 0.91 | 0.137 | 103.9 | 2.9 |
| Cessna T-37B | CT37 | NACA-2412 | 1.7 | 0.204 | 128.4 | 0.0 |
| Convair 640 | C640 | NACA 23015 | 1.4 | 0.210 | 128.4 | 1.3 |
| P-3 Orion | P3 | NACA-0012 | 2.31 | 0.277 | 128.4 | 2.1 |

The accretion rate on an airfoil can be expressed as

$$R_{ice} = W \beta V_a / \rho_i, \quad (1)$$

where W is the liquid water content, β is the collection efficiency of the airfoil, V_a is the aircraft's airspeed and ρ_i is the density of the accreted ice. The accretion rate R_{ice} is expressed as a thickness per unit time. For this study, the accretion rate at the

stagnation point is considered, so the appropriate β is β_{\max} . This relation can also be turned around to define a threshold liquid water content W_T required for a given rate of accretion:

$$W_T = R_{\text{ice}} \rho_i (\beta_{\max} V_a). \quad (2)$$

The collection efficiency β (or β_{\max}) depends upon characteristics of both the atmosphere and the aircraft. These effects were analyzed using an two-dimensional airfoil ice accretion calculation software program. The program calculates the impingement of cloud-sized (10 – 50 μm diameter) drops on single-element airfoils and uses a Lagrangian method to calculate a series of individual drop trajectories from five chord lengths upstream of the airfoil to impact with the surface. Only monodisperse drop size distributions are modeled in the program. However, it has been shown that the bulk collection efficiency for realistic cloud drop size distributions is well-represented by that of the median volume diameter of the distribution⁸.

The density of the accreted ice enters into the calculation. There are few measurements of this. The LEWICE accretion model uses a simplified ice density assumption: if the freezing fraction is 1 (rime condition, all water freezes upon impact), the density is 820 kg/m^3 , if 0 (glaze condition, water spreads before it freezes) the density is 917 kg/m^3 . These values were used in separate calculations for rime or glaze ice.

For this discussion, we'll begin with results for a Beech 1900. Calculations were conducted using (2) for realistic ranges of outside air temperature, pressure, impact velocity (as airspeed), and drop diameters. Variations in outside air temperature have little effect on W_T . There is a larger effect from impact velocity; drop size has the most significant effect other than impact ice density. W_T values decrease with increasing impacting drop diameter (Fig. 1) since the collection efficiency is higher for these larger drops.

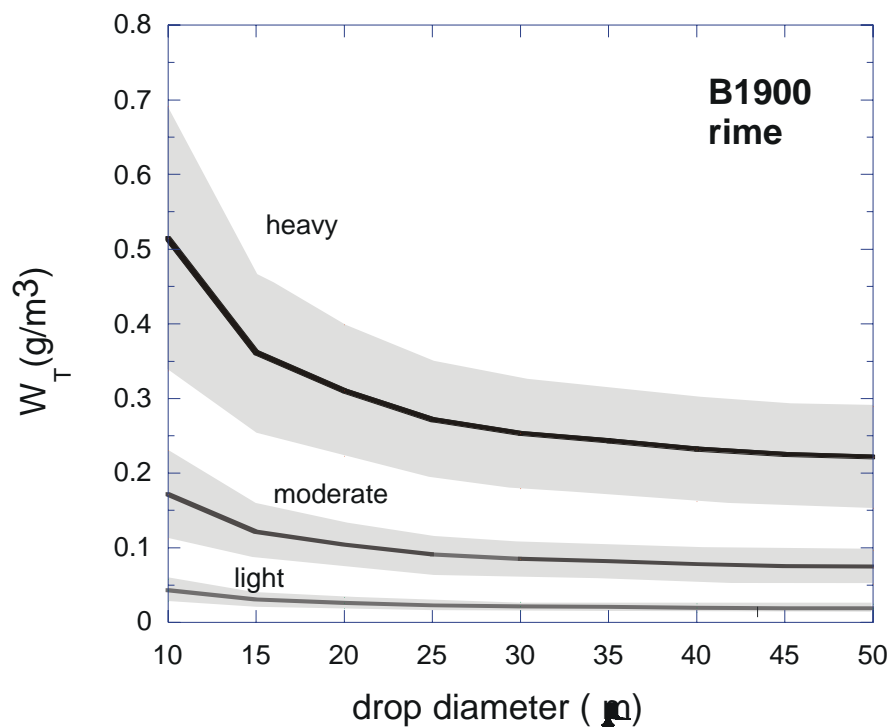


Figure 1: Dependence of threshold liquid water contents on drop diameter for rime ice on the B1900. The median volume diameter is assumed $15\text{ }\mu\text{m}$. The shaded areas represent uncertainty envelopes as listed in Table 2.

Table 2: β_{max} and Threshold Liquid Water Contents for Rime Icing at 700 hPa, -10°C . All calculations are for $15\text{ }\mu\text{m}$ drop diameter except where noted.

| Airplane | β_{max} | W_T (light) (g/m ³) | W_T (moderate) (g/m ³) | W_T (heavy) (g/m ³) | Uncertainty (%) |
|---|----------------------|---|--|---|--------------------|
| 3-inch cylinder | 0.54 | 0.032 | 0.13 | 0.38 | 36 |
| Beechcraft Queen Air | 0.43 | 0.046 | 0.019 | 0.55 | 33 |
| Beechcraft 1900D @ $10\text{ }\mu\text{m}$ | 0.36 | 0.041 | 0.16 | 0.41 | 34 |
| @ $15\text{ }\mu\text{m}$ | 0.51 | 0.029 | 0.11 | 0.34 | 30 |
| @ $25\text{ }\mu\text{m}$ | 0.68 | 0.021 | 0.086 | 0.26 | 29 |
| @ $50\text{ }\mu\text{m}$ | 0.84 | 0.018 | 0.070 | 0.21 | 31 |

| | | | | | |
|--------------|------|-------|-------|------|----|
| Cessna T-37B | 0.49 | 0.024 | 0.097 | 0.29 | 31 |
| Convair 640 | 0.45 | 0.027 | 0.11 | 0.32 | 31 |
| P-3 Orion | 0.33 | 0.036 | 0.15 | 0.43 | 44 |

Results for all airfoils are listed in Table 2 for atmospheric conditions of 700 hPa, -10°C, and a drop median volume diameter of 15 μm (with additional diameters for the B1900 as listed). Expected errors in the estimates are also listed and were determined using standard error propagation techniques. Uncertainties of 10 m/s for V and 10% in ρ_l were assumed; uncertainties in β for the various aircraft configurations of Table 1 (which include an expected uncertainty of 5 μm in drop diameter) were calculated for a realistic range of atmospheric temperatures and pressures and are carried through the calculations. The threshold icing rates R_{ice} were assumed constant. The final uncertainties in W_T range from 31% (25 μm drop, rime conditions) to 41% (10 μm drop, either rime or glaze) of the values. These W_T are for rime ice; for glaze ice (assuming no runoff) W_T would be increased by 12% due to the increase in impact ice density (and thus a lower accretion rate).

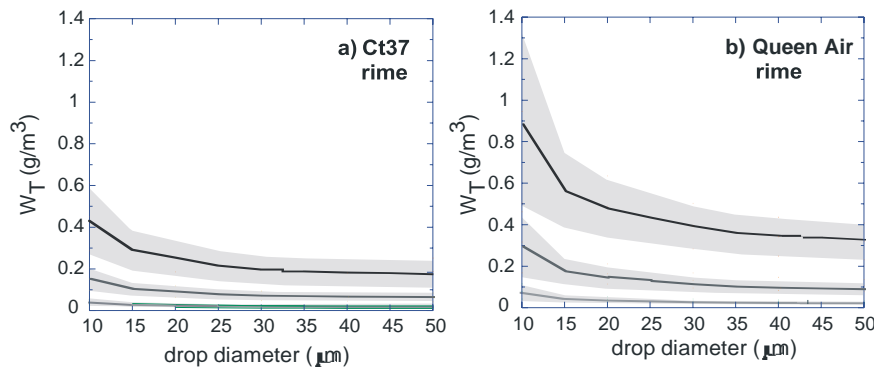


Figure 2: As for Fig. 1 except for a) CT37 and b) Queen Air.

The CT37 had the lowest W_T values of any of those shown in Table 2, while the QA had the highest (Fig. 2). The thresholds and their associated uncertainties can be combined to construct a set of intensity thresholds to apply to both aircraft as well as for those with W_T lying between. For those W_T curves that overlap, combined intensity categories such as trace-light, light-moderate, and moderate-heavy are assigned. For example, any liquid water content less than the lowest “light icing” W_T for the CT37 would be considered “trace icing” for all aircraft. Those with W_T above “heavy icing” for the QA will be heavy for all aircraft. There are points that lie above “heavy icing” for the CT37 and only indicate “moderate icing” for the QA and these would be considered “moderate to heavy” icing. The result is a chart of W_T versus drop size applicable to a wide range of aircraft, depicted as intensity definitions (Fig. 5).

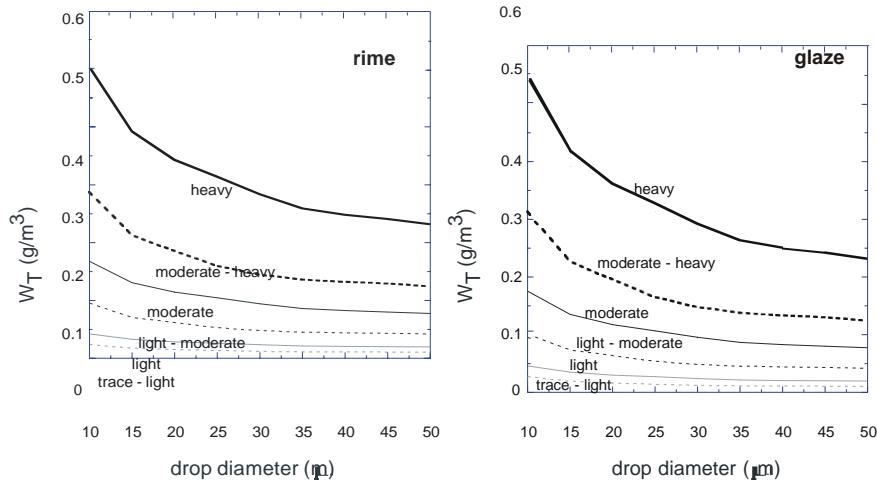


Figure 3: Expected icing intensity expressed as liquid water content threshold W_T versus drop diameter for rime and glaze icing of all collectors listed in Table 2.

The following caveats are associated with this method of defining an index.

- The index describes expected icing intensity, not severity. The relation between intensity and severity has not been established. It could be assumed that higher icing intensities correspond to more severe responses, but that has not been quantified.
- This index is not appropriate for supercooled large drop conditions (drop diameter > 50 μm); the calculations extend only to drop diameters of 50 μm .
- This index is not intended for rotorcraft, just fixed-wing aircraft.
- The accretion rate is dependent on just $\frac{1}{4}$ in of ice accumulation at the leading edge of an airfoil and does not take into account additional growth or effects of texture, horns, runback ice or ice ridging.
- The scale can be easily adjusted if the user decides to use different values for ice density, accretion time or accretion thickness.
- Currently there are no remote or *in situ* sensors that can reliably and routinely quantify liquid water content or drop size, and numerical weather prediction models are only just beginning to provide these values. However, the index can be applied to this information when it becomes available.
- The intensity index can provide meteorologists another tool which should be combined with other information such as current pilot reports, for true severity prediction. This is the basis for what is done in CIP and FIP.

Appendix I

Chief Counsel Ruling

U.S. Department
of Transportation
**Federal Aviation
Administration**

Office of the Chief Counsel

BOO Independence Ave., S.W.
Washington, D.C. 20591

JAN 16 2009

Ms. Leisha Bell
Manager, Regulatory Affairs

Aircraft Owners and Pilots Association
421 Aviation Way
Frederick, Maryland 21701-4798

Dear Ms. Bell:

In a letter dated November 21, 2006 to the FAA Office of the Chief Counsel, Mr. Luis M. Gutierrez of your association requested the rescission of a letter of interpretation regarding flight in known icing conditions issued on June 6, 2006. On September 22, 2008, I withdrew that letter in its entirety. After considering the points you and other stakeholders have raised to the June 6, 2006 letter and to our Notice of Draft Letter of Interpretation on Known Icing Conditions published in the Federal Register on April 3, 2007 (72 FR 15931), I am issuing this interpretation.

Our letter of June 6, 2006 responded to a request by Mr. Robert J. Miller for a legal interpretation of "known ice" as it relates to flight operations in the context of general aviation. While various FAA regulations contain limitations on flight in known icing conditions, the regulatory provisions that most commonly affect operators of general aviation aircraft not approved and equipped for such operations apply the term only indirectly. Flight into known ice is not directly referenced in part 91 and known icing conditions are only referenced in subpart F, which applies to large and turbine-powered multiengine airplanes and fractional ownership program aircraft. However, there are provisions in other subparts within part 91 that require a pilot to consider the consequences of flying in such conditions.

- 14 CFR § 91.9(a) states that "no person may operate a civil aircraft without complying with the operating limitations specified in the approved Airplane or Rotorcraft Flight Manual" These manuals may state that a particular aircraft type is not approved for flight in known icing conditions. We construe Mr. Miller's request as seeking clarification of the meaning of "known icing conditions" as that term appears in Airplane Flight Manuals (AFM) and Pilot Operating Handbooks for many general aviation aircraft.
- 14 CFR § 91.13(a) states that "[n]o person may operate an aircraft in a careless or reckless manner so as to endanger the life or property of another."

- 14 CFR § 91.103 specifies that "[e]ach pilot in command shall, before beginning a flight, become familiar with all available information concerning that flight. This information must include... "[f]or a flight under IFR or a flight not in the vicinity of the airport, weather reports and forecasts "

Rather than specifically defining "known ice," the FAA defines "known or observed or detected ice accretion" in the Aeronautical Information Manual (AIM). In paragraph 7-1-22 of that manual the agency defines "known or observed or detected ice accretion" as "[a]ctual ice observed visually to be on the aircraft by the flight crew or identified by on-board sensors." Actual adhesion to the aircraft, rather than the existence of potential icing conditions, is the determinative factor in this definition. The FAA believes the term "known or observed or detected ice accretion" to be synonymous with the term "known ice" and that the agency's definition of that term is non-controversial.

The formation of structural ice requires two elements: 1) the presence of visible moisture, and 2) an aircraft surface temperature at or below zero degrees Celsius. The FAA does not necessarily consider the mere presence of clouds (which may only contain ice crystals) or other forms of visible moisture at temperatures at or below freezing to be conducive to the formation of known ice or to constitute known icing conditions. There are many variables that influence whether ice will actually be detected or observed, or will form on and adhere to an aircraft. The size of the water droplets, the shape of the airfoil, and the speed of the aircraft, among other factors, can make a critical difference in the initiation and growth of structural ice.

Most flight manuals and other related documents use the term "known icing conditions" rather than "known ice," a similar concept that has a different regulatory effect. "Known ice" involves the situation where ice formation is actually detected or observed. "Known icing conditions" involve instead circumstances where a reasonable pilot would expect a substantial likelihood of ice formation on the aircraft based upon all information available to that pilot. While "known icing conditions" are not defined by regulation, the term has been used in legal proceedings involving violations of FAA safety regulations that relate to in-flight icing. The National Transportation Safety Board (NTSB) has held on a number of occasions that known icing conditions exist when a pilot knows or reasonably should know about weather reports in which icing conditions are reported or forecast. In those cases the pilots chose to continue their flights without implementing an icing exit strategy or an alternative course of action and the aircraft experienced heavy ice formation that validated the forecasted danger to the aircraft. The Board's decisions are consistent with the FAA's long-held position in enforcement actions that a pilot must consider the reasonable likelihood of encountering ice when operating an aircraft.

Notwithstanding the references to "weather forecasts" in various NTSB decisions, we emphasize that area forecasts alone are generally too broad to adequately inform a pilot of known icing conditions. Such forecasts may cover a large geographic area or represent too long a span of time to be particularly useful to a pilot. The forecasts in the cited decisions involved very specific information that alerted pilots to a substantial danger of severe icing.

Any assessment of known icing conditions is necessarily fact-specific. Permutations on the type, combination, and strength of meteorological elements that signify or negate the presence of known icing conditions are too numerous to describe exhaustively in this letter. Whether a pilot has operated into known icing conditions contrary to any limitation will depend upon the total information available to the pilot, and his or her proper analysis of that information in evaluating the risk of encountering known icing conditions during a particular operation. The pilot should consider factors such as the route of flight, flight altitude, and time of flight when making such an evaluation.

Pilots should also carefully evaluate all of the available meteorological information relevant to a proposed flight, including applicable surface observations, temperatures aloft, terminal and area forecasts, AIRMETs, SIGMETs, and pilot reports (PIREPs). As new technology becomes available, pilots should incorporate the use of that technology into their decision-making process. If the composite information indicates to a reasonable and prudent pilot that he or she will be operating the aircraft under conditions that will cause ice to adhere to the aircraft along the proposed route and altitude of flight, then known icing conditions likely exist. If the pilot operates the aircraft in known icing conditions contrary to the requirements of § 91.9(a), the FAA may take enforcement action.¹

Flight in known icing conditions by aircraft not approved and equipped for such operations presents a significant safety hazard because by the time the ice adheres to the aircraft, it may be too late for the pilot to take actions to assure the further safety of the flight. The agency's goal is to encourage proper flight planning in advance and to avoid unwarranted risk-taking based upon the possibility that forecasts and reports are in error.

As a result, flight which results in the formation of ice on an aircraft is not the sole factor the FAA will use in determining whether enforcement action is warranted in any particular case. In determining whether enforcement action is warranted, the FAA will evaluate those actions taken by the pilot (including both pre-flight actions and those taken during the flight) to determine if the pilot's actions were, in fact, reasonable in light of §§ 91.9(a), 91.13(a), and 91.103.² The FAA will specifically evaluate all weather information available to the pilot and determine whether the pilot's pre-flight planning took into account the possibility of ice formation, alternative courses of action to avoid known icing conditions and, if ice actually formed on the aircraft, what steps were taken by the pilot to exit those conditions.

In accordance with the discussion of "known icing conditions" contained in this interpretation, I also note that the definition of "known icing conditions" currently found in paragraph 7-1-22 of the AIM defines that term as "atmospheric conditions in which the

¹ Enforcement action could also be taken for operation of an aircraft into icing conditions that exceed the permissible icing certification limitations of the aircraft.

² Meteorological information that does not evidence known icing conditions, or the extent thereof, may regardless support a finding that a pilot's operation under the circumstances was careless if a reasonable and prudent pilot would not have operated the aircraft in those conditions under similar circumstances.

formation of ice is observed or detected in flight." That definition is not sufficiently broad to reflect the agency's position as set forth in this interpretation. The FAA will initiate action to revise the definition to reflect the interpretation articulated in this letter.

Pilots should not expose themselves or others to the risk associated with flying into conditions in which ice is likely to adhere to an aircraft. If ice is detected or observed along the route of flight, the pilot should have a viable exit strategy and immediately implement that strategy so that the flight may safely continue to its intended destination or terminate at an alternate landing facility. If icing is encountered by a pilot when operating an aircraft not approved or equipped for flight in known icing conditions, the FAA strongly encourages the submission of PIREPs and immediate requests to ATC for assistance. Such actions can significantly enhance safety, reduce accidents, and benefit the entire aviation community.

This response constitutes an interpretation of the Chief Counsel and was coordinated with the FAA's Flight Standards Service.

—

Kerry B. Long
Chief Counsel

Appendix II

Icing Regulations

14 CFR

The following regulations pertain to in-flight operations in icing conditions for fixed wing aircraft. § 91.527 falls in **Subpart F—Large and Turbine-Powered Multiengine Airplanes and Fractional Ownership Program Aircraft**. Therefore, it does not apply to many Part 91 aircraft, including the most common GA aircraft. §121.341 applies to all Part 121 aircraft, and §135.227 applies to all Part 135 aircraft. Additionally, there are General Counsel decisions that apply to Part 91 aircraft; in general the operator should avoid areas of “known icing”

§ 91.527 Operating in icing conditions.

(a) No pilot may take off an airplane that has frost, ice, or snow adhering to any propeller, windshield, stabilizing or control surface; to a power plant installation; or to an airspeed, altimeter, rate of climb, or flight attitude instrument system or wing, except that takeoffs may be made with frost under the wing in the area of the fuel tanks if authorized by the FAA.

(b) No pilot may fly under IFR into known or forecast light or moderate icing conditions or under Visual Flight Rules (VFR) into known light or moderate icing conditions, unless:

(1) The aircraft has functioning deicing or anti-icing equipment protecting each rotor blade, propeller, windshield, wing, stabilizing or control surface, and each airspeed, altimeter, rate of climb, or flight attitude instrument system;

(2) The airplane has ice protection provisions that meet section 34 of Special Federal Aviation Regulation No. 23; or

(3) The airplane meets transport category airplane type certification provisions, including the requirements for certification for flight in icing conditions.

(c) Except for an airplane that has ice protection provisions that meet the requirements in section 34 of Special Federal Aviation Regulation No. 23, or those for transport category airplane type certification, no pilot may fly an airplane into known or forecast severe icing conditions.

(d) If current weather reports and briefing information relied upon by the pilot in command indicate that the forecast icing conditions that would otherwise prohibit the flight will not be encountered during the flight because of changed weather conditions since the forecast, the restrictions in paragraphs (b) and (c) of this section based on forecast conditions do not apply.

[Doc. No. 18334, 54 FR 34314, Aug. 18, 1989, as amended by Amdt. 91–310, 74 FR 62696, Dec. 1, 2009]

§ 121.341 Equipment for operations in icing conditions.

(a) Except as permitted in paragraph (c)(2) of this section, unless an airplane is type certificated under the transport category airworthiness requirements relating to ice protection, or unless an airplane is a non-transport category airplane type certificated after December 31, 1964, that has the ice protection provisions that meet section 34 of appendix A of part 135 of this chapter, no person may operate an airplane in icing conditions unless it is equipped with means for the prevention or removal of ice on windshields, wings, empennage, propellers, and other parts of the airplane where ice formation will adversely affect the safety of the airplane.

(b) No person may operate an airplane in icing conditions at night unless means are provided for illuminating or otherwise determining the formation of ice on the parts of the wings that are critical from the standpoint of ice accumulation. Any illuminating that is used must be of a type that will not cause glare or reflection that would handicap crewmembers in the performance of their duties.

(c) *Non-transport category airplanes type certificated after December 31, 1964.* Except for an airplane that has ice protection provisions that meet section 34 of appendix A of part 135 of this chapter, or those for transport category airplane type certification, no person may operate:

(1) Under IFR into known or forecast light or moderate icing conditions;

(2) Under VFR into known light or moderate icing conditions; unless the airplane has functioning deicing anti-icing equipment protecting each propeller, windshield, wing, stabilizing or control surface, and each airspeed, altimeter, rate of climb, or flight attitude instrument system; or

(3) Into known or forecast severe icing conditions.

(d) If current weather reports and briefing information relied upon by the pilot in command indicate that the forecast icing condition that would otherwise prohibit the flight will not be encountered during the flight because of changed weather conditions since the forecast, the restrictions in paragraph (c) of this section based on forecast conditions do not apply.

[Doc. No. 6258, 29 FR 18205, Dec. 31, 1964, as amended by Amdt. 121–251, 60 FR 65929, Dec. 20, 1995]

§135.227 Icing conditions: Operating limitations.

(a) No pilot may take off an aircraft that has frost, ice, or snow adhering to any rotor blade, propeller, windshield, stabilizing or control surface; to a power plant installation; or to an airspeed, altimeter, rate of climb, flight attitude instrument system, or wing, except that takeoffs may be made with frost under the wing in the area of the fuel tanks if authorized by the FAA.

(b) No certificate holder may authorize an airplane to take off and no pilot may take off an airplane any time conditions are such that frost, ice, or snow may reasonably be expected to adhere to the airplane unless the pilot has completed all applicable training as required by §135.341 and unless one of the following requirements is met:

(1) A pre-takeoff contamination check, that has been established by the certificate holder and approved by the Administrator for the specific airplane type, has been completed within 5 minutes prior to beginning takeoff. A pre-takeoff contamination check is a check to make sure the wings and control surfaces are free of frost, ice, or snow.

(2) The certificate holder has an approved alternative procedure and under that procedure the airplane is determined to be free of frost, ice, or snow.

(3) The certificate holder has an approved deicing/anti-icing program that complies with §121.629(c) of this chapter and the takeoff complies with that program.

(c) No pilot may fly under IFR into known or forecast light or moderate icing conditions or under VFR into known light or moderate icing conditions, unless:

(1) The aircraft has functioning deicing or anti-icing equipment protecting each rotor blade, propeller, windshield, wing, stabilizing or control surface, and each airspeed, altimeter, rate of climb, or flight attitude instrument system;

(2) The airplane has ice protection provisions that meet section 34 of appendix A of this part; or

(3) The airplane meets transport category airplane type certification provisions, including the requirements for certification for flight in icing conditions.

(d) No pilot may fly a helicopter under IFR into known or forecast icing conditions or under VFR into known icing conditions unless it has been type certificated and appropriately equipped for operations in icing conditions.

(e) Except for an airplane that has ice protection provisions that meet section 34 of appendix A, or those for transport category airplane type certification, no pilot may fly an aircraft into known or forecast severe icing conditions.

(f) If current weather reports and briefing information relied upon by the pilot in command indicate that the forecast icing condition that would otherwise prohibit the flight will not be encountered during the flight because of changed weather conditions since the forecast, the restrictions in paragraphs (c), (d), and (e) of this section based on forecast conditions do not apply.

[Doc. No. 16097, 43 FR 46783, Oct. 10, 1978, as amended by Amdt. 133–20, 51 FR 40710, Nov. 7, 1986; Amdt. 135–46, 58 FR 69629, Dec. 30, 1993; Amdt. 135–60, 61 FR 2616, Jan. 26, 1996; Amdt. 135–119, 74 FR 62696, Dec. 1, 2009]

ICING INTENSITY FROM AIRMAN'S INFORMATION **MANUAL**

1. **Trace.** Ice becomes noticeable. The rate of accumulation is slightly greater than the rate of sublimation. A representative accretion rate for reference purposes is less than ¼ inch (6 mm) per hour on the outer wing. The pilot should consider exiting the icing conditions before they become worse.
2. **Light.** The rate of ice accumulation requires occasional cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is ¼ inch to 1 inch (0.6 to 2.5 cm) per hour on the unprotected part of the outer wing. The pilot should consider exiting the icing condition.
3. **Moderate.** The rate of ice accumulation requires frequent cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is 1 to 3 inches (2.5 to 7.5 cm) per hour on the unprotected part of the outer wing. The pilot should consider exiting the icing condition as soon as possible.
4. **Severe.** The rate of ice accumulation is such that ice protection systems fail to remove the accumulation of ice and ice accumulates in locations not normally prone to icing, such as areas aft of protected surfaces and any other areas identified by the manufacturer. A representative accretion rate for reference purposes is more than 3 inches (7.5 cm) per hour on the unprotected part of the outer wing. By regulation, immediate exit is required.

NOTE-

Severe icing is aircraft dependent, as are the other categories of icing intensity. Severe icing may occur at any ice accumulation rate when the icing rate or ice accumulations exceed the tolerance of the aircraft.

EXAMPLE-

Pilot report: give aircraft identification, location, time (UTC), intensity of type, altitude/FL, aircraft type, indicated air speed (IAS), and outside air temperature (OAT).

NOTE-

1. Rime ice. Rough, milky, opaque ice formed by the instantaneous freezing of small supercooled water droplets.
2. Clear ice. A glossy, clear, or translucent ice formed by the relatively slow freezing of large supercooled water droplets.
3. The OAT should be requested by the FSS or ATC if not included in the PIREP.

1. ~~**Trace.** Ice becomes perceptible. Rate of accumulation slightly greater than sublimation. Deicing/anti-icing equipment is not utilized unless encountered for an extended period of time (over 1 hour).~~

Commented [SJ(1): The current AIM definitions of Icing Intensity are in track change. Refer to the link below paragraph 7-1-19

AIM | ATPUBS | FAA |
Effective: December 2, 2021
Change: 1
FAA National Headquarters (FOB-10B), Mission
Support Services Policy (AJV-P)
United States Department of Transportation
Federal Aviation Administration
Subscription: <https://bookstore.gpo.gov>

Chapter 7 Section 1:
https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap7_section_1.html

Formatted: Font: 11 pt

Formatted: Indent: Left: -0.2"

Formatted: Font: Arial, 12 pt

Appendix II

Correspondence regarding “known icing” between AOPA and the FAA Chief Counsel

U.S. Department
of Transportation
**Federal Aviation
Administration**

Office of the Chief Counsel

800 Independence Ave., S.W.
Washington, D.C. 20591

JAN 16 2009

Ms. Leisha Bell
Manager, Regulatory Affairs

Aircraft Owners and Pilots Association
421 Aviation Way
Frederick, Maryland 21701-4798

Dear Ms. Bell:

In a letter dated November 21, 2006 to the FAA Office of the Chief Counsel, Mr. Luis M. Gutierrez of your association requested the rescission of a letter of interpretation regarding flight in known icing conditions issued on June 6, 2006. On September 22, 2008, I withdrew that letter in its entirety. After considering the points you and other stakeholders have raised to the June 6, 2006 letter and to our Notice of Draft Letter of Interpretation on Known Icing Conditions published in the Federal Register on April 3, 2007 (72 FR 15931), I am issuing this interpretation.

Our letter of June 6, 2006 responded to a request by Mr. Robert J. Miller for a legal interpretation of "known ice" as it relates to flight operations in the context of general aviation. While various FAA regulations contain limitations on flight in known icing conditions, the regulatory provisions that most commonly affect operators of general aviation aircraft not approved and equipped for such operations apply the term only indirectly. Flight into known ice is not directly referenced in part 91 and known icing conditions are only referenced in subpart F, which applies to large and turbine-powered multiengine airplanes and fractional ownership program aircraft. However, there are provisions in other subparts within part 91 that require a pilot to consider the consequences of flying in such conditions.

- 14 CFR § 91.9(a) states that "no person may operate a civil aircraft without complying with the operating limitations specified in the approved Airplane or Rotorcraft Flight Manual" These manuals may state that a particular aircraft type is not approved for flight in known icing conditions. We construe Mr. Miller's request as seeking clarification of the meaning of "known icing conditions" as that term appears in Airplane Flight Manuals (AFM) and Pilot Operating Handbooks for many general aviation aircraft.
- 14 CFR § 91.13(a) states that "[n]o person may operate an aircraft in a careless or reckless manner so as to endanger the life or property of another."

- 14 CFR § 91.103 specifies that "[e]ach pilot in command shall, before beginning a flight, become familiar with all available information concerning that flight. This information must include... "[f]or a flight under IFR or a flight not in the vicinity of the airport, weather reports and forecasts "

Rather than specifically defining "known ice," the FAA defines "known or observed or detected ice accretion" in the Aeronautical Information Manual (AIM). In paragraph 7-1-22 of that manual the agency defines "known or observed or detected ice accretion" as "[a]ctual ice observed visually to be on the aircraft by the flight crew or identified by on-board sensors." Actual adhesion to the aircraft, rather than the existence of potential icing conditions, is the determinative factor in this definition. The FAA believes the term "known or observed or detected ice accretion" to be synonymous with the term "known ice" and that the agency's definition of that term is non-controversial.

The formation of structural ice requires two elements: 1) the presence of visible moisture, and 2) an aircraft surface temperature at or below zero degrees Celsius. The FAA does not necessarily consider the mere presence of clouds (which may only contain ice crystals) or other forms of visible moisture at temperatures at or below freezing to be conducive to the formation of known ice or to constitute known icing conditions. There are many variables that influence whether ice will actually be detected or observed, or will form on and adhere to an aircraft. The size of the water droplets, the shape of the airfoil, and the speed of the aircraft, among other factors, can make a critical difference in the initiation and growth of structural ice.

Most flight manuals and other related documents use the term "known icing conditions" rather than "known ice," a similar concept that has a different regulatory effect. "Known ice" involves the situation where ice formation is actually detected or observed. "Known icing conditions" involve instead circumstances where a reasonable pilot would expect a substantial likelihood of ice formation on the aircraft based upon all information available to that pilot. While "known icing conditions" are not defined by regulation, the term has been used in legal proceedings involving violations of FAA safety regulations that relate to in-flight icing. The National Transportation Safety Board (NTSB) has held on a number of occasions that known icing conditions exist when a pilot knows or reasonably should know about weather reports in which icing conditions are reported or forecast. In those cases the pilots chose to continue their flights without implementing an icing exit strategy or an alternative course of action and the aircraft experienced heavy ice formation that validated the forecasted danger to the aircraft. The Board's decisions are consistent with the FAA's long-held position in enforcement actions that a pilot must consider the reasonable likelihood of encountering ice when operating an aircraft.

Notwithstanding the references to "weather forecasts" in various NTSB decisions, we emphasize that area forecasts alone are generally too broad to adequately inform a pilot of known icing conditions. Such forecasts may cover a large geographic area or represent too long a span of time to be particularly useful to a pilot. The forecasts in the cited decisions involved very specific information that alerted pilots to a substantial danger of severe icing.

Any assessment of known icing conditions is necessarily fact-specific. Permutations on the type, combination, and strength of meteorological elements that signify or negate the presence of known icing conditions are too numerous to describe exhaustively in this letter. Whether a pilot has operated into known icing conditions contrary to any limitation will depend upon the total information available to the pilot, and his or her proper analysis of that information in evaluating the risk of encountering known icing conditions during a particular operation. The pilot should consider factors such as the route of flight, flight altitude, and time of flight when making such an evaluation.

Pilots should also carefully evaluate all of the available meteorological information relevant to a proposed flight, including applicable surface observations, temperatures aloft, terminal and area forecasts, AIRMETs, SIGMETs, and pilot reports (PIREPs). As new technology becomes available, pilots should incorporate the use of that technology into their decision-making process. If the composite information indicates to a reasonable and prudent pilot that he or she will be operating the aircraft under conditions that will cause ice to adhere to the aircraft along the proposed route and altitude of flight, then known icing conditions likely exist. If the pilot operates the aircraft in known icing conditions contrary to the requirements of § 91.9(a), the FAA may take enforcement action.¹

Flight in known icing conditions by aircraft not approved and equipped for such operations presents a significant safety hazard because by the time the ice adheres to the aircraft, it may be too late for the pilot to take actions to assure the further safety of the flight. The agency's goal is to encourage proper flight planning in advance and to avoid unwarranted risk-taking based upon the possibility that forecasts and reports are in error.

As a result, flight which results in the formation of ice on an aircraft is not the sole factor the FAA will use in determining whether enforcement action is warranted in any particular case. In determining whether enforcement action is warranted, the FAA will evaluate those actions taken by the pilot (including both pre-flight actions and those taken during the flight) to determine if the pilot's actions were, in fact, reasonable in light of §§ 91.9(a), 91.13(a), and 91.103.² The FAA will specifically evaluate all weather information available to the pilot and determine whether the pilot's pre-flight planning took into account the possibility of ice formation, alternative courses of action to avoid known icing conditions and, if ice actually formed on the aircraft, what steps were taken by the pilot to exit those conditions.

In accordance with the discussion of "known icing conditions" contained in this interpretation, I also note that the definition of "known icing conditions" currently found in paragraph 7-1-22 of the AIM defines that term as "atmospheric conditions in which the

¹ Enforcement action could also be taken for operation of an aircraft into icing conditions that exceed the permissible icing certification limitations of the aircraft.

² Meteorological information that does not evidence known icing conditions, or the extent thereof, may regardless support a finding that a pilot's operation under the circumstances was careless if a reasonable and prudent pilot would not have operated the aircraft in those conditions under similar circumstances.

formation of ice is observed or detected in flight." That definition is not sufficiently broad to reflect the agency's position as set forth in this interpretation. The FAA will initiate action to revise the definition to reflect the interpretation articulated in this letter.

Pilots should not expose themselves or others to the risk associated with flying into conditions in which ice is likely to adhere to an aircraft. If ice is detected or observed along the route of flight, the pilot should have a viable exit strategy and immediately implement that strategy so that the flight may safely continue to its intended destination or terminate at an alternate landing facility. If icing is encountered by a pilot when operating an aircraft not approved or equipped for flight in known icing conditions, the FAA strongly encourages the submission of PIREPs and immediate requests to ATC for assistance. Such actions can significantly enhance safety, reduce accidents, and benefit the entire aviation community.

This response constitutes an interpretation of the Chief Counsel and was coordinated with the FAA's Flight Standards Service.

—
Kerry B. Long
Chief Counsel