STATEMENT OF

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BEFORE

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COMMITTEE ON TRANSPORTATION AND INFRASTRUCTURE

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AIRCRAFT ICING

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Mr. Chairman and members of the Subcommittee, I am Captain Rory Kay, Executive Air Safety Chairman of the Air Line Pilots Association, International ("ALPA") which represents the safety interest of over 53,000 professional pilots at 37 airlines in the United States and Canada. On behalf of our members, I thank you for this opportunity to testify before you on the issue of aircraft icing.

ALPA has long been an advocate for improvements to the way aircraft are operated in the presence of icing conditions, both on the ground and airborne. My focus today will primarily be on the impact of icing while airborne, however I do have concerns about the adequacy of the ground de-icing process which I have included in this statement.

ALPA brings a perspective to this discussion that no other organization can. Our members fly a vast range of aircraft types – everything from single-engine aircraft in airline service to wide-body, ultra-long range airliners – in all type of weather conditions, all around the globe. They have experienced first-hand the difficulties of determining the performance impacts, the uncertainties of knowing exactly what conditions are present and whether those conditions are compatible with the aircraft's design and equipment capability, and the acceptable courses of action available to them when they encounter icing.

We are all too familiar with the reasons why icing related accidents and incidents remain an important flight safety issue in the airline community. Historically pilots have been expected to decide when icing conditions exceed the capabilities of their aircraft and when it is acceptable to proceed into icing conditions. Such decisions would appear to be no different than the thousands of critical decisions made by professional airline pilots on every flight, every day, resulting in the extraordinary safety record we now enjoy. However, even the most cautious and experienced pilots have been involved in icing accidents or incidents. We must take note of this apparent disparity and continue to explore the reasons why. This is because the tools which pilots use to make these critical decisions have yet to be fully developed. In nearly every other aspect of airline operations, there is not only a significant body of knowledge, but also very advanced, redundant technologies which have eliminated “guess work,” but that guess work is still inherent in flying safely in icing conditions or avoiding them altogether. We know the effects of flying too fast or too slowly and have safeguards, including specific speed limits, throughout the system to avoid those regimes. We know the impact of improper loading on performance, and have established firm loading limits to ensure our aircraft remain controllable. Limitations for in-flight icing, however, remain a difficult problem to solve for a number of reasons. First, despite the fact that much research has been done on in-flight icing and our knowledge today is far superior to that of even a few years ago, we still have much more to learn. We still do not fully understand the nature of icing in the atmosphere, how to assess the risk of a specific icing encounter from the flight deck, and most importantly, we do not yet have the means necessary to avoid operating in conditions which exceed the capabilities of the aircraft’s ice protection system.

Secondly, the nature of the actual atmospheric phenomena that we refer to generally as “icing” vary widely and their effect on airplanes can be equally variable, making it extremely difficult to establish norms and limits for operations. Conditions acceptable for one airplane may very well prove hazardous for another airplane or even to the same airplane at a later time, but with only slightly different operating and atmospheric conditions. So we are faced with a dilemma. Just as inadequate training or limited experience may leave a pilot unaware of an icing hazard, considerable experience, but without hard data to know exactly what the experience was, can leave a pilot erroneously believing he or she is operating in conditions which appear to match conditions that have been previously safely negotiated.

Part of the difficulty in establishing standard operating procedures and limitations that apply to all fleets and all operations is the difficulty of testing, during the certification process, how the aircraft will react across the spectrum of conditions that may be encountered in daily operations. We are making great strides in fully defining the icing environment in terms that can be used to establish limits and procedures, but there is more to be done. Airplanes are tested in a limited set of icing conditions during certification, but ultimately are approved for flight in icing conditions without quantifiable limits set to alert pilots that they are encountering icing conditions beyond what the airplane was tested for during the certification process. The expectation is that operating rules and pilot judgment will ensure that this broad condition known simply as “icing” will be safely negotiated at every encounter and this is simply not a reasonable assumption. Regardless of their level of experience or training, pilots need to know whether existing conditions are within the capability of the aircraft they are flying. They need to know what type of icing conditions they are entering, and what effects the icing is having on the controllability of the specific airplane they are flying at the specific time of the encounter. The pilot community has inconsistent information and guidance when having to decide how they should react after encountering in-flight icing conditions or whether they should takeoff or proceed into reported freezing rain or drizzle.

In 1995, following an outcry in the aftermath of an aircraft icing related accident near Roselawn, Indiana, the FAA began taking incremental steps to address icing issues and improve the safety standards for flight in icing conditions for all aircraft categories. A good first step was the creation of the Ice Protection Harmonization Working Group (IPHWG) organized under the

Aviation Rulemaking Advisory Committee (ARAC). The IPHWG included representatives from ALPA and other international and industry organizations that had a direct interest and expertise in aviation icing concerns. While much research in icing has been done since 1995 that has resulted in some new federal rules stemming from the IPHWG recommendations, the focus of these rules has been on new airplane type designs and smaller, so-called “regional” airplanes. These are the airplanes with the greatest history of accident/incident events involving icing. However, ALPA is concerned, and disappointed, that in the 15 years since that tragic icing accident near Roselawn; new rules have not expanded to include all aircraft categories that are certified for flight in icing conditions. Despite available information from research and studies, pilots are still facing the same dilemma of having to make subjective assessments about flying into an icing environment. The pilot must decide if it is safe to proceed into icing conditions without quantifiably knowing beforehand what the effects will be on the aircraft. And while pilots always have the final decision whether or not it is safe to fly in any situation, since neither pilots nor airlines have quantifiable data on which to base these critical safety decisions, pilots come under tremendous pressure from airlines to continue into conditions that they may feel are marginal for the sake of supporting the business aspects of the airline. Captain’s authority is supported fully by some airlines, and less so by others. In any case, that authority must be based on and supported by clear and consistent rules that are backed by factual data. Consequently there is still more work needed by the FAA to establish rules that address all aircraft categories and to provide pilots with decision tools to ensure consistent standards of safety for flight into icing conditions.

CONSISTENT GUIDANCE NEEDED

Any amount of icing accumulation on an aircraft will begin to deteriorate its performance and controllability, and once airborne it is up to the pilot using whatever means available to first recognize and then respond accordingly when in-flight icing conditions are encountered. Current icing certification processes allow aircraft to legally operate, with limited exceptions, in icing conditions provided they are designed and properly equipped with working de-icing/anti-icing systems[1]. A known icing condition is generally defined as an atmospheric condition in which the formation of ice has been observed or detected in-flight. As long as the conditions do not deteriorate beyond the capabilities of the aircraft's ice protection systems, flight in icing is manageable. However, allowable flight into icing conditions does not include any quantifiable limits on the accumulation rate or type of icing the aircraft will encounter. This essentially results in subjective analyses by each pilot on each flight. This subjectivity means pilots never truly know if they are operating their aircraft in a manner consistent with its capabilities. The solution must ultimately be to provide pilots with defined parameters for operations, such as we have for nearly every other aspect of operating an airliner today.

An icing environment of particular concern is supercooled large droplets, or SLD icing which is defined as liquid droplets with diameters greater than 0.05 mm at temperatures less than 0^{o} C. Research and testing have revealed that operations in an SLD environment can quickly deteriorate into a severe icing situation with ice forming in locations not normally prone to icing and perhaps overwhelming the ability of the airplane ice protection system to remove the ice from where it normally forms. Aircraft with inflatable deicing boots, typically used in small regional turboprop operations appear to be the most vulnerable to this phenomenon. Turbojets

[1] Flight in "Severe Icing" should be avoided and is defined as when the rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary.

are also affected by SLD but their time of exposure to these conditions is typically less than turboprops flying at the lower altitudes where SLD normally occurs. These SLD encounters are usually associated with conditions of freezing rain or freezing drizzle. Although flight in severe icing is universally prohibited once encountered, to date there has been no clear and concise position from regulators, with respect to operations in reported freezing rain and freezing drizzle in order to preclude a severe icing encounter involving SLD. Consequently, we see operators routinely flying a wide variety of aircraft in conditions of reported freezing rain or drizzle without measures to prevent flight into SLD conditions that may lead up to a severe icing encounter. For example, some carriers have a policy that takeoffs are prohibited in moderate or heavy freezing rain, and heavy freezing drizzle, while other carriers have no specific guidance or policy other than flight in severe icing is prohibited and a caution that flight in light freezing rain or freezing drizzle may exceed the capabilities of the aircraft's ice protection system. In either case there is no quantified or standard guidance provided by the FAA on operations in such conditions, and without consistent company policy and procedures to follow, it is up to the discretion of the pilot to determine whether to proceed or divert the flight. A policy to include quantifiable guidance is needed from the FAA to enable a more standardized level of safety regarding go/no-go decisions into known icing conditions that could quickly deteriorate into a severe icing encounter.

DESIGN & CERTIFICATION

Aircraft flight characteristics are unique to each aircraft type and vary depending upon the icing conditions encountered; consequently information about how a specific aircraft's flight handling characteristics will deteriorate in icing is often general in nature and inconsistent from airline to airline. Currently a pilot's own flight experience in icing and/or training is the most reliable source for fulfilling that information gap. Unfortunately, there is a disparity between how aircraft are certified for flight in icing conditions and how information from the certification process is made available as operational guidance to pilots. Guidance and regulatory criteria provided to manufacturers for icing certification is highly quantifiable in terms of specific droplet sizes, liquid water content, and durations of icing encounters. These criteria establish a standard, repeatable flight test environment in which the aircraft icing protection systems and flight characteristics are evaluated by a test pilot during the certification process. After certification, the only certification information that may be available to a line pilot is a single sentence in the aircraft operations manual stating “certified for flight in icing.” There are usually no specific or quantifiable limits provided to the line pilots to enable a determination when icing conditions have exceeded those evaluated during the certification process. This disparity creates a gap in information between icing flight conditions tested during the development and certification process versus in-flight icing conditions encountered during revenue operations. The line pilot is the one who must bridge this gap when he or she encounters environmental icing conditions that have not been evaluated in the design and certification process. ALPA firmly believes, and has repeatedly commented, that evaluation of these conditions should occur in the design and certification process not on a revenue flight. New certification methods using either more flight testing or better simulations of icing conditions are needed to ensure that airplane performance is fully evaluated in all types of icing environments that will be encountered in revenue flight operations. Limitations must then be clearly established for operations in icing conditions, and these limits should be readily discernable to the line pilot through the onboard detection and alerting systems.

Once an aircraft has entered into an icing condition, the pilot must rely on experience and training, however limited it may be, to continuously monitor the ice accumulation rate and to know when the build-up appears to have the potential to exceed the capabilities of the aircraft. However, no amount of training or experience can substitute for an accurate, reliable means of determining whether icing conditions are within or outside the designed and certified capability of the specific airplane. Current methods to help the pilot monitor ice accumulation include ice detector systems that can be either manual or automated. Manual systems can be as simple as a probe or "post" mounted outside the cockpit in a position that collects ice and is visible to the pilot. Unfortunately in low visibility situations, as is typical of flights in icing conditions, flight crews can have difficulty seeing such devices outside the aircraft, particularly during night operations. Also due to workload and human factors issues associated with long periods of operation in what may be considered acceptable icing conditions, a manual ice detector that must be constantly checked but rarely changes is a poor means of alerting pilots to severe icing. An example of an automated detection system currently in use is an electronic probe that detects the presence of ice and then provides a signal to the flight deck that alerts the crew via a visible display and/or aural warning. Currently installed detectors merely alert the crew to the presence of ice accretion on the aircraft. After an alert has activated the crew must then monitor and assess the accumulation rate and icing type before deciding the next steps to ensure safety. ALPA contends that aircraft should be equipped with automated detector systems to provide the crew with information on the type of icing that their aircraft is experiencing and when it is exceeding conditions beyond certification criteria. It would automatically alert the crew to the fact that they are approaching conditions which may exceed the capabilities of their aircraft's ice protection system. With that information the flight crew can then take the necessary steps, which needs to be clearly defined to the crew, to escape those conditions (i.e., change altitude or route).

TRAINING

Although training alone is not the solution, to enhance safety in icing conditions, high quality training specific to the airplane being flown is needed to help the pilot not only recognize the presence of icing but to also assess the level of severity and to respond accordingly. This is not a trivial task that can be accomplished with a general statement such as "do not fly into severe icing." It is important that training tools include example ice accretions that pilots might see on their airplane. NASA Glenn Research Center has done significant work in this area, so some information is already available. Also, because the loss of control due to severe icing can be much different than other loss of control events for which pilots train, flight simulator programming of such events and pilot training on recovery techniques must be developed. This is particularly important for airplanes that have a known susceptibility or accident history in severe icing.

ADVISORY MATERIALS & COMPANY MANUALS

FAA regulations, advisory materials, and company manuals can be vague and allow for conflicting interpretations. Specific prohibitions against flight into conditions not considered in certification are usually absent. Some manuals actually contain tacit approval for flight in these conditions for some types of aircraft. There is often not a consistent operational message presented to the pilots. For example, manuals from different airlines can vary significantly. Oversight by Certificate Management Units (CMUs) or Principal Operations Inspectors (POIs) of the individual airline's guidance contained in manuals can vary considerably due to the differences in their knowledge and experience in aircraft icing. ALPA recommends that the

FAA develop and establish clear criteria for pilots and operators to use for go/no-go decisions for flight into known freezing rain and drizzle conditions. I have attached to my testimony extracts from several flight manuals to help illustrate the wide variation in information available to pilots, all of whom might be operating in the same environment.

GROUND DE-ICING

Significant progress has been made on the effectiveness of ground de-icing fluids. However methods to ensure that the de-icing fluids are providing the expected protection are often complicated and do not always account for the actual conditions encountered. Current procedures used by pilots to determine how long they can wait on the ground after being de-iced include tables that provide what is called "holdover time". This is the time during which the anti-icing fluid remains effective and within which the aircraft should takeoff. This holdover time is a function of the anti-icing fluid type, outside air temperature, and the type of precipitation. Industry research determines the length of the holdover times for a variety of precipitation types to include freezing rain and light freezing drizzle. However, these precipitation types involve droplet sizes greater than that used during aircraft icing certification tests. But line pilots see that the holdover tables do include these precipitation types and infer that the aircraft was tested in these conditions. It is important to understand that anti-icing fluids applied to the aircraft prior to departure protect the aircraft while on the ground only. They are designed to flow off the aircraft upon takeoff, leaving only the certified aircraft ice protection system as protection. It is important that the FAA develop guides and processes for determining de-icing fluid holdover times that are representative of the actual conditions the aircraft will be exposed to prior to and during take-off.

IN-FLIGHT ICING FORECASTING

Finally, it must be emphasized that while I have discussed the need for training to understand how severe icing affects an airplane when it is encountered, the goal must still be to avoid any encounter that carries the potential for a hazardous situation to develop. This is a well-established strategy for coping with other kinds of severe weather in aviation. For example, I may have procedures I can employ in the event of an inadvertent entry into a thunderstorm, but I still attempt to avoid them in the first place using a combination of onboard equipment, training, judgment, and weather forecasting tools. Avoiding a hazardous icing encounter is no different. Under the leadership of the National Center for Atmospheric Research and other weather research organizations, forecasting of in-flight icing has improved and experimental products are available for operational use on the Internet. Use of them, especially by regional air carriers is increasing, and methods of delivering updated products to the cockpit for real-time decision making are being developed. At this point, the operational benefit of improving technology is not widespread, but is increasing. ALPA strongly supports continued adoption of tools to avoid areas of severe icing and urges the FAA to develop a process to educate and encourage companies to improve the safety of their operations through use of new weather forecasting technologies as they continue to develop and their benefits are proven.

Thank you again, for the opportunity to testify on this important subject.

Attachments

Example Information in Operator Flight Manuals Regarding Icing Operations
Example 1; Legacy Carrier Flight Manual: (prohibition on flight in Freezing Rain (FZRA) or Freezing Drizzle (FZDZ))

Cold weather operations:
PROHIBITED OPERATIONS
CAUTION: Prior to taxiing in conditions where takeoff, approach, or landing is prohibited, verify that the taxiway conditions are suitable for operations (e.g., ATIS, braking action reports, friction Mu reports, etc.).

Flights may not operate when, in the opinion of the Captain or dispatcher, icing conditions are expected that might adversely affect the safety of the flight.

• ***Takeoff***, ***approach***, and ***landing*** are ***prohibited*** under the following conditions:
- Moderate Freezing Rain (FZRA)
- Heavy Freezing Rain (+FZRA)
- Heavy Freezing Drizzle (+FZDZ)

• ***Takeoff*** is ***prohibited*** under the following conditions:
- Snow pellets/small hail (GS) of any intensity
- Heavy ice pellets (+PL)
- Moderate ice pellets (PL) mixed with any other form of precipitation

Example 2; Regional Carrier Flight Manual: (prohibition on flight in Freezing Rain (FZRA) or Freezing Drizzle (FZDZ))

Takeoff in Freezing Precipitation Conditions.

— Takeoffs are permitted under the following conditions:
• Frost;
• Freezing fog;
• Light or moderate snow/snow grains;
• Light freezing rain[1];
• Light or moderate freezing drizzle[1];
• Rain on a cold soaked wing

— Takeoffs are prohibited under the following conditions:
• Heavy snow;
• Snow pellets;
• Ice pellets[2];
• Moderate or heavy freezing rain;
• Heavy freezing drizzle;
• Hail.

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1. When operating during light freezing rain/freezing drizzle using Type I fluid, the flight crew must have the aircraft anti-iced with Type IV fluid.
2. Flight crews operating in conditions of light and moderate ice pellets and light ice pellets mixed with other forms of precipitation may commence the takeoff up to the specific allowance time listed in Table x.x, "Ice Pellet Allowance Times, Winter 2008-2009" using the corresponding outside air temperature (OAT) subject to the provisions of Paragraph x.x, "Restrictions".

Example 3; Regional Carrier Flight Manual: (no prohibition on flight in FZRA or FZDZ)

Severe Weather Restrictions
(FAR 121.601)
The Pilot in Command and Flight Dispatch personnel shall make every effort to be watchful for and continuously monitor the development and progress of severe weather which might adversely affect company flying operations and communicate the existence of such weather for dissemination to other flights as appropriate. Such weather phenomena as moderate or greater icing, severe turbulence or wind shear, severe thunderstorm activity, hail, tornados, water spouts and winds in excess of 50 knots shall be reported.

To avoid the most critical icing maintain an altitude below the freezing level or above the level of minus 15° Celsius.

In-flight Icing

1. Severe icing conditions are defined as airframe icing accumulation such that deicing/anti-icing equipment fails to reduce or control the hazard, requiring immediate flight diversion.

2. Icing may be regarded as severe either because of the rate of accumulation or the location of the accumulation. If the ice accretion is on an unprotected part of the wing the icing is not controllable by ice protection equipment. A common cause of ice accumulation on unprotected portions of the wing is flight in super-cooled large droplets (SLD). These large droplets are found in freezing drizzle and freezing rain. Droplets of this size are able to penetrate the boundary layer, accumulating on areas of the wing aft of the protected surfaces (boots or heated wing).

3. If a flight crew finds itself in an SLD environment, they are encouraged to remain aware of freezing levels and anticipated time of exposure to potentially severe icing. Any prolonged exposure, especially in holding or on extended vectors, necessitates a request for an immediate altitude change to exit the conditions. Areas of freezing rain and freezing drizzle may be encountered on arrival as well as on departure.

Note: When operating in icing conditions, do not accept an ATC assigned airspeed that is at or below the minimum recommended for the conditions.

<u>For Turboprop Airplane</u>

Airframe Ice Protection

For operation of wing and stabilizer de-icing boots and for adherence to minimum airspeed and autopilot/flight director limitations for icing conditions, icing conditions exist when:

The OAT or SAT is +5 degrees C (plus 5°C) or colder and there is any type of visible moisture present (such as clouds, fog with visibility of one mile or less, rain, snow, sleet, or ice crystals), or Any amount of ice is observed on any part of the aircraft, or If it is not certain that there is no ice accumulation on the aircraft.

The de-icing boots can be turned off when:
- The OAT or SAT is warmer than +5°C and there is no ice on the windshield wiper or
- No visible moisture (such as clouds, fog with visibility of one mile or less, rain, snow, sleet, ice crystals) is present and 5 de-icing boot cycles (15 minutes in continuous mode) have been completed after exiting visible moisture (shorter time may apply to meet the requirement to have completed boot inflation before landing flare). Both the Airfoil Boot De-icing Timer Control (Auto Cycling - ONE CYCLE and CONT modes) and the Airfoil De-icing Boot Manual Control System must operate normally prior to dispatch when icing conditions exist enroute or are forecast.

Note: If unacceptable propeller vibration occurs in the temperature range of -10° C to - 12° C SAT due to prop ice, use MAX as required until vibrations cease. Use caution in MAX mode as runback ice may occur.

Wing and stabilizer de-icing boots must be operated in icing conditions as defined for operations of wing and stabilizer deicing boots.

Note: Minimum airspeed and autopilot/flight director limitations for icing conditions must be maintained as long as operating in icing conditions as defined by "Airframe Ice Protection" on page xxx

Note: This supersedes any relief by the Master Minimum Equipment List (MMEL) or Minimum Equipment List (MEL), which may be contrary to this requirement.

Severe icing may result from environmental conditions outside of those for which the airplane is certificated. Flight in freezing rain, freezing drizzle, or mixed icing conditions (super cooled liquid water and ice crystals) may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or may result in ice forming aft of the protected surfaces. This ice may not be shed using the ice protection systems, and may seriously degrade the performance and controllability of the airplane.

During flight, severe icing conditions that exceed those for which the airplane is certificated shall be determined by the following visual cues. If one or more of these visual cues exists, immediately request priority handling from Air Traffic Control to facilitate a route or an altitude change to exit the icing conditions.

The use of maximum continuous power is allowed to exit severe icing conditions regardless of number of engines operating.
1. Unusually extensive ice collected on the airframe in areas not normally observed to collect ice.
2. Accumulation of ice on the surface of the wing aft of the protected area (deice boot).

3. Accumulation of ice on the propeller spinner farther aft than normally observed. If ice accumulated aft of the ring painted on the spinner this is an indication of accumulations farther aft than normally observed as stated above.

Since the autopilot may mask tactile cues that indicate adverse changes in handling characteristics, use of the autopilot is prohibited when any of the visual cues specified above exist, or when unusual lateral trim requirements or autopilot trim warnings are encountered while the airplane is in icing conditions.
All wing ice detection lights must be operative prior to flight into icing conditions at night.

1. Visible rain at temperatures below 0°C ambient air temperature.
2. Droplets that splash or splatter on impact at temperatures below 0°C ambient air temperature.
During flight, severe icing conditions that exceed those for which the airplane is certificated shall be determined by the following visual cues. If one or more of the following visual cues exists while in-flight, immediately request priority handling from Air Traffic Control to facilitate a route or an altitude change to exit the icing conditions.

a. Unusually extensive ice collected on the airframe in areas not normally observed to collect ice.
b. Accumulation of ice on the wing aft of the protected area.
c. Accumulation of ice on the propeller spinner farther aft than normally observed.
Since the autopilot may mask tactile cues that indicate adverse changes in handling characteristics, use of the autopilot is prohibited when any of the visual cues specified above exist, or when unusual lateral trim requirements or autopilot trim warnings are encountered while the airplane is in icing conditions.

3. Procedures for Exiting Severe Icing
The following procedures are applicable to all flight phases from takeoff to landing. While severe icing may form at temperatures as cold as -18°C, increased vigilance is warranted at temperatures around freezing with visible moisture present (see previous section). If the visual cues are present that indicate the possible presence of severe icing, accomplish the following:

a. Immediately request priority handling from ATC to facilitate a route or an altitude change to exit the severe icing conditions in order to avoid extended exposure to flight conditions more severe that those for which the airplane has been certificated.
b. Max Continuous Power with both engines operating may / should be used.
c. Avoid abrupt and excessive maneuvering that may exacerbate control difficulties.
d. Do not engage the autopilot.
e. If the autopilot is engaged, hold the control wheel firmly and disengage the autopilot.
f. If an unusual roll response or uncommanded roll control movement is observed, reduce the angle-of-attack.
g. Do not extend flaps during extended operations in icing conditions. Operation with flaps extended can result in a reduced wing angle of attack, with the possibility of ice forming on the upper surface further aft on the wing than normal, possibly aft of the protected area.
h. If the flaps are extended, do not retract them until the airframe is clear of ice.
i. Report these weather conditions to ATC.

For Turbojet Airplane

F. Takeoff

1. Normal takeoff techniques should be used, as applicable.
2. If wing leading edge roughness is observed or suspected in any way, DO NOT attempts a takeoff.
3. The use of reduced takeoff thrust settings is prohibited if the runway is contaminated or if wing and/or cowl anti-icing is being used.
4. Takeoffs in icing conditions require extra diligence in the monitoring and cross-checking of the engine instruments, particularly N1, to ensure that there is sufficient thrust available. 5. Power application should be done as symmetrically as possible to avoid yawing moments during the first portion of the takeoff roll.
6. Always be aware of the penalties to airplane performance (i.e. takeoff and landing distance, takeoff speed adjustments) incurred when taking off on contaminated runways, more so with the anti-ice in use.
7. Ensure that there is sufficient cleared runway width available for takeoffs on contaminated surfaces.
8. Takeoffs on contaminated runways are prohibited when:

a. Crosswind component exceeds 25 knots.
b. Standing water or slush is more than 0.50 inch (12.7 millimeters) in depth.
c. Wet snow is more than 1.00 inch (25.4 millimeters) in depth.
d. Dry snow is more than 3.00 inches (76.2 millimeters) in depth.

9. Apply brakes and advance engine thrust levers. If the airplane starts to creep or slide on the ice or snow during engine power check, release the brakes and begin the takeoff roll. Anticipate lags in nosewheel steering response and nosewheel skidding and apply corrections as necessary.

G. After Takeoff & Enroute

Before entering icing conditions, select ENG COWL ANTI-ICE on. Do not delay use of Anti-Ice protection or rely only on visual icing cues to determine if anti-ice protection is required. Even small amounts of ice accumulations can dramatically affect the flight characteristics of the [aircraft type].
With Wing Anti-ice on, operations below 78% N2 are allowed unless:

- Flying through moderate or heavier icing
- Ice accretion is visible on the wings
- N1 vibration increases
- Wing or Cowl A/I caution message illuminates.

Enroute use of flaps is prohibited. Prolonged use of flaps in icing conditions should be avoided. The flaps should not be extended in icing conditions except when required for takeoff, approach, or landing. If the flaps are deployed in icing conditions for extended periods, or in severe icing, light to moderate buffet may be encountered. No handling difficulties result.

Example 4; Regional Carrier Flight Manual: (no prohibition on flight in FZRA or FZDZ)

Severe Icing

• Operation in areas of Severe Icing conditions is **Prohibited**
• Severe Icing conditions are indicated by ice accretion on the cockpit side windows
• If Severe Icing is encountered:
— WING and Cowl Anti-icing Systems must be ON
— Leave icing conditions

Example 5; A Regional Carrier Flight Manual: (no prohibition on flight in FZRA or FZDZ)

ADVERSE WEATHER

COLD WEATHER OPERATIONS
A. The winter season presents additional problems to airplane operation resulting from low temperatures, the potentially hazardous effects of precipitation contaminating the airplane and the aircraft movement area, and extreme turbulence. Removal of these contaminants on runway surfaces, taxiways, aprons, holding bays and other areas, rests on the administration of the airports concerned, based on flight safety and schedule considerations. However, it is the ultimate responsibility of the pilot-in-command to see to it that the airplane is in a condition for safe flight prior to takeoff. Use of the ATIS or other means to acquire accurate ambient temperature and other pertinent meteorological conditions cannot be overemphasized.

B. Cold weather operations refer to ground handling, takeoffs and landings conducted on surface conditions where frozen moisture is present.

ICING CONDITIONS (AC 91-74A)
A. [Ground operations]

B. At warm temperatures, the amount of moisture the air can hold is greater than at cold temperatures. However, there have been instances in which supercooled water has been found in cumulus clouds at temperatures as cold as -40°C. Although there is very little chance of encountering this condition, it is normal to encounter moisture at outside air temperatures colder than 0°C. Significant accumulations of ice are possible in freezing rain and in clouds with considerable vertical activity.

C. Some turbine engine designs have shown a susceptibility to ice crystals that form in the atmosphere because of convective weather activity. Turbine engine upsets have occurred from ice accreting within the engine at altitudes up to 42,000 feet and temperatures colder than -45°C (-50°F). These high altitude ice crystals in large concentrations, typically found near convective weather systems, do not accrete on external airframe surfaces, or trigger ice detectors, and may not be visible on current technology airborne radar systems.
NOTE Flight in areas of moderate or greater turbulence, icing and heavy precipitation require use of continuous ignition until clear of such areas.

ANTI-ICE SYSTEMS USAGE
Activate anti-ice (engine cowling and wing systems) prior to entering icing conditions (see Limitations section of this manual) or when ice is detected by the ice detection system. When in-flight, if ice detector is not working, turn anti-icing systems ON prior to entering icing conditions.

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SUPER - COOLED LARGE DROPLET ICING

A. Icing Conditions

Icing conditions exist when the total air temperature is 10°C (50°F) or less and visible moisture is present in any form. This includes cloud, fog, mist, rain, snow, sleet and ice crystals. Regardless of visible ambient moisture and temperature clues, icing conditions also exist when there are visible signs of ice accumulation on the airplane or when the ICE cautionary message is displayed.

B. Cloud Forms

In discussion of icing, cloud types can be categorized into two general classifications; stratiform (layer type clouds) or cumuliform (rising, thunderstorm) clouds. The certification requirements define icing envelopes conforming to these cloud types corresponding to continuous (stratiform) icing and intermittent (cumulous) icing types.

C. Icing Process

Icing results from super-cooled water droplets that remain in a liquid state at temperatures below freezing. In general, leading edge structures passing through such conditions will cause a certain number of these droplets to impact the leading edge surface and freeze. A relatively large or bluff body will generate a large pressure wave ahead of the leading edge which forces the air and many of the smaller droplets around it. Only droplets with sufficient mass and inertia will impact the surface and freeze. Conversely, a narrow leading edge radius generates a smaller pressure wave and so collects more of the lower mass inertia droplets.

Ice will also tend to accumulate in greater quantities and cover a larger part of the leading edge if the ambient liquid water droplets are relatively large.

D. Ice Form

Three recognizable ice forms exist; rime ice (opaque), glaze ice (clear) and frost. It is also common to observe mixed form icing comprising of mixed glaze and rime ice forms.

(1) Rime ice is rough and opaque in appearance and generally forms a pointed or streamlined shape on the leading edge.

(2) Glaze ice is transparent and often produces a wedge shape or concave ice shape with double horns. This is caused by partial run back of the impinging water droplets to positions aft of the stagnation point. Ice initially forms here as a thin layer of sandpaper ice which then grows to form the glaze horns.

(3) Frost may form as a thin layer of crystalline ice on all exposed airplane surfaces. Frost is generally associated with ground operations.

E. Super-Cooled Large Droplet Icing Conditions Super-cooled large droplet conditions are distinct from the icing described above because of the propensity for the ambient liquid water to be contained in droplets of relatively large mass and inertia. This causes a larger proportion of the water to impact the leading edge surfaces.

In addition, the droplets impacting the surface will do so further aft than smaller droplets. On the protected wing surfaces this may result in formation of ice ridges on the trailing edges of the slats.

F. Recognition of Super-Cooled Large Droplet Icing Conditions

(1) It is known that super-cooled large droplet (SLD) may be prevalent in pristine atmospheres typical of coastal maritime environments; however, there are no defined means for prior indication of SLD icing conditions or for differentiating SLD from other icing conditions.
(2) The presence of SLD can only be determined by observation of the resulting ice accumulation on unprotected surfaces.
(3) The indicator for differentiating SLD icing is observation of ice accumulation on the flight compartment (cockpit) side windows. Any ice accumulation on the side windows should be taken as the indication that SLD icing conditions are present.
G. Procedures
(1) Operation in SLD icing conditions is prohibited. Following recognition of SLD icing conditions by observation of side window icing, the engine cowl and wing anti-icing systems must be activated. Even with anti-icing systems being active, it is necessary to leave SLD icing conditions immediately.
(2) After leaving SLD icing conditions, the wing leading edges should be observed for signs of ice formation on the slat trailing edges or aft of the slat on the unheated wing upper surface. If ice is observed on or aft of the slats, then the Ice Dispersal Procedure should be accomplished.