



# *Certification, Operational and Safety Issues Associated with Takeoff in Freezing Drizzle and Freezing Rain*

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## *Contents of Presentation*

- ◆ Certification of flight in icing
- ◆ Operational regulations and guidance
- ◆ Types of aircraft icing accidents – takeoff and in-flight
- ◆ Hazards of SLD icing
- ◆ Aeroplane design features contributing to risk
- ◆ Accident record in SLD conditions
- ◆ Safety board recommendations
- ◆ Current Canadian operations
- ◆ Fundamental questions
- ◆ Transport Canada Civil Aviation (TCCA) initiative
- ◆ Summary

# *Certification of Flight in Icing – FAR 25 Appendix C*

- ◆ Aeroplanes are currently certified to operate in in-flight icing conditions using an icing atmosphere defined in FAR 25 Appendix C
- ◆ Flight characteristics are determined to be satisfactory with ice accretion on the unprotected surfaces and ice accretion on the protected surfaces appropriate to the ice protection system operation
- ◆ In general, the majority of flight tests for flight characteristics are done with artificial ice shapes established using numerical icing codes and icing wind tunnel results, with limited confirmation in natural icing



## *Icing Certification – Conditions Exceeding FAR 25 Appendix C*

- ◆ Appendix C does not include Supercooled Large Droplet (SLD) icing conditions
- ◆ SLD icing conditions include freezing drizzle and freezing rain
- ◆ Ice protection systems designed to be effective in Appendix C will provide some protection in SLD icing conditions, but the extent of protection is unknown

# Certification Approval – Aircraft Flight Manual (AFM) Information

- ◆ Typically the Aircraft Flight Manual (AFM) contains a statement similar to:
  - “The aircraft is approved for operation in atmospheric icing conditions”
- ◆ In general, no information is provided qualifying this statement for SLD icing conditions
- ◆ However following an accident in 1984, the FAA issued a number of Airworthiness Directives for specific aeroplane types adding information to the AFM with respect to severe icing conditions (including SLD)

# FAA Airworthiness Directives Qualifying AFM Information

- ◆ Applicable to turbopropeller powered Transport and Commuter category aeroplanes with wing pneumatic deicer boots
- ◆ Required an additional Warning in AFM limitations:
  - Severe icing may result from icing conditions outside those of certification
  - Flight in freezing drizzle and freezing rain may result in ice build-up on protected surfaces or aft of protected surfaces
  - Severe icing can be identified by visual cues
  - If encountered, must immediately exit severe icing conditions and must not use autopilot
- ◆ This Warning could be *interpreted* that takeoff in freezing drizzle and freezing rain is not permitted

## *Operational Regulations and Guidance*

- ◆ FAA, EASA/JAA, TCCA have regulations pertaining to ground and in-flight icing conditions
- ◆ All authorities have requirements for “clean aircraft” for takeoff
- ◆ There do not appear to be any explicit regulations relating to takeoff in freezing drizzle and freezing rain

# *Operational Regulations and Guidance – FAA*

- ◆ FAR 121.629 Operation in icing conditions:
  - (a) No person may dispatch or release an aircraft, continue to operate an aircraft en route, or land an aircraft when in the opinion of the pilot in command or aircraft dispatcher (domestic and flag operations only), icing conditions are expected or met that might adversely affect the safety of the flight

## *Operational Regulations and Guidance – FAA (continued)*

- ◆ FAA Notice N8000.329 FAA-Approved Deicing Program Updates, Winter 2006-2007
- ◆ Takeoff in moderate or heavy freezing rain is not approved
- ◆ If requested by the operator, takeoff in freezing drizzle and light freezing rain is permitted in accordance with an approved program, subject to a number of conditions including use of Holdover Time (HOT) data or special procedures, and increased surveillance

# Operational Regulations and Guidance – EASA/JAA

- ◆ JAA OPS 1.346 (b) Ice and other contaminants, flight procedures:
  - A commander shall not commence a flight nor intentionally fly into expected or actual icing conditions unless the aeroplane is certificated and equipped to cope with such conditions
- ◆ EU OPS (effective 2008) incorporates the wording of JAR OPS 1.346(b)
- ◆ Would appear to prohibit takeoff in freezing drizzle or freezing rain due to lack of certification for these conditions (assuming that the commander is aware of the limitations in certification procedures)

## Operational Regulations and Guidance – EASA/JAA (continued)

- ◆ EASA Safety Information Notice No. 3006-09 Ground De-/Anti-icing of Aeroplanes, notes that:
  - “Holdover times are not meant to imply that flight is safe in the prevailing conditions if the specified holdover time has not been exceeded. Certain meteorological conditions, such as freezing drizzle or freezing rain, may be beyond the certification envelope of the aeroplane”
- ◆ JAA ACJ OPS 1.345 (not currently part of EU OPS):
  - It is possible to interpret this guidance that takeoff is permitted in conditions of freezing drizzle or freezing rain provided a pre takeoff contamination check is performed
- ◆ It is understood that the AEA provides Holdover Time (HOT) data for freezing drizzle and light freezing rain
- ◆ Operational practices are unknown, but believed to include takeoff in freezing drizzle and light freezing rain

# Operational Regulations and Guidance – TCCA

- ◆ Current TCCA operational regulations:
  - **605.30** No person shall conduct a take-off or continue a flight in an aircraft where icing conditions are reported to exist or are forecast to be encountered along the route of flight unless
    - (a) the pilot-in-command determines that the aircraft is adequately equipped to operate in icing conditions in accordance with the standards of airworthiness under which the type certificate for that aircraft was issued
- ◆ However as already noted, SLD icing conditions are not currently considered in the standards of airworthiness for type certification



## *Operational Regulations and Guidance – TCCA (continued)*

- ◆ TCCA issues Holdover Time (HOT) Guidelines which include data for freezing drizzle and light freezing rain (but not for moderate or heavy freezing rain)
- ◆ By inference, it could be argued that takeoff in conditions of freezing drizzle and freezing rain is:
  - Prohibited since these conditions are not currently considered in certification
  - Permitted in accordance with the appropriate deicing/anti-icing procedures and Holdover Time (HOT) data
- ◆ However, it is not reasonable to expect operators and flight crews to be aware of, and comply with, any inferred prohibition buried in certification standards



## *Types of Icing Accidents - Takeoff*

- ◆ No or ineffective ground deicing/anti-icing
- ◆ Loss of control very close to ground:
  - Premature wing stall due to degraded aerodynamic characteristics and inability of stall protection system to protect the aeroplane
- ◆ Failure to liftoff and climb as expected, and ground impact:
  - Excessive drag
  - Reduced thrust due to engine sensor ice accretion
- ◆ Severe thrust loss or flameout:
  - Ingestion of shed ice



## *Types of Icing Accidents – In-flight*

- ◆ Ice accretion on protected and unprotected surfaces:
  - Severe icing conditions
  - Ineffective ice protection system performance
  - Delayed or inappropriate ice protection system operation
  - System failures
- ◆ Loss of control and departure from which recovery is not achieved:
  - Premature wing stall with little or no stall warning
  - Tailplane stall
  - Control overbalance
- ◆ Degradation in performance capability (airspeed and flight path):
  - Increased drag and/or decreased thrust (loss of propeller propulsive efficiency)

## *Types of Icing Accidents – In-flight (continued)*

- ◆ Combination of unrecognized performance degradation leading to premature wing stall
- ◆ Inappropriate and/or unmonitored use of autopilot vertical modes:
  - Aeroplanes without autothrust
  - Pitch mode or vertical speed mode in climb, or altitude hold mode
  - Autopilot allows speed to decay in order to maintain commanded flight path angle
  - Premature wing stall with little or no warning

## *Hazards of SLD Icing*

- ◆ Hazard associated with more extensive and/or different in-flight ice accretion in terms of size, shape, location and extent on both protected and unprotected surfaces, than that associated with FAR 25 Appendix C icing condition
- ◆ Potential hazardous effects on systems and powerplant operation
- ◆ Ground surface icing in freezing drizzle and freezing rain



## *Examples of In-Flight SLD Icing*

- ◆ Canadian operational SLD encounters illustrate some of the effects of in-flight SLD icing:
  - Pneumatic boot unable to shed ice
  - Ice aft of boot
  - Ice forming on side window
  - Ice further aft on propeller spinner
  - Ice further aft on nose
  - Heavy accretion on windshield frame
  - Potential for pitot/static system errors
  - Potential for stall warning system errors
  - Potential for powerplant operating anomalies



## *In-Flight SLD Icing – Turbojet Powered Aeroplanes with Thermal Anti-icing System*

- ◆ SLD encounters during certification testing of a turbojet powered aeroplane with a thermal anti-icing system, illustrate some of the effects of in-flight SLD icing at low temperatures:
  - Runback and refreeze ice shape on protected outer slat
  - Ice build up on spinner and fan blades
  - Ice forming on side window

## *Aeroplane Design Features Contributing to Risk*

- ◆ Smaller aeroplanes are more susceptible to the adverse effects of icing (scale effect)
- ◆ Aeroplanes with “hard” leading edges have more takeoff incidents/accidents due to ground ice contamination
- ◆ Aeroplanes with pneumatic boots may be more susceptible to adverse aerodynamic effects due to the possibility of an ice “ridge” just aft of boot
- ◆ However aeroplanes with other ice protection systems may also be adversely affected due to runback and re-freezing
- ◆ Aeroplanes with manually operated flight controls are more susceptible to hinge moment anomalies



## *Aeroplane Design Features Contributing to Risk (continued)*

- ◆ Reciprocating engine and turbopropeller powered aeroplanes will be more susceptible to the adverse effects of icing due to:
  - Typical operating environment
  - Autopilots without autothrust
  - Thrust loss due to propeller blade icing
  - Generally lower takeoff and climb speeds
    - A lower airspeed results in less temperature rise and hence a lower Total Air Temperature (TAT) for the same ambient Static Air Temperature (SAT)
  - Generally lower rate of climb
    - Greater exposure to the same vertical extent of freezing precipitation

## *Additional Risks for Smaller Aeroplanes*

- ◆ Smaller aeroplanes are more commonly used by smaller air service operators:
  - May lack the comprehensive training, control and monitoring in deicing/anti-icing procedures of larger operators
- ◆ Operate into smaller airports:
  - Less sophisticated ground deicing/anti-icing facilities
  - May lack on-site weather observation capability



## *Ground Operation and Takeoff in Freezing Drizzle and Freezing Rain*

- ◆ Ice accretion characteristics
- ◆ Ramp and taxi operation
- ◆ Takeoff

## Freezing Drizzle and Freezing Rain – Ice Accretion Characteristics

- ◆ During ground operation (ramp and taxi), ice accretion can be expected to form on all upward facing surfaces which are not protected by anti-icing fluid
- ◆ There are practical difficulties in ascertaining whether the actual conditions are freezing drizzle or light freezing rain and the applicability of HOT Guidelines
- ◆ Ice accretion on critical surfaces may be difficult to observe:
  - Ice may be a thin clear layer
  - Upper surfaces not readily visible from ground, flight deck or cabin
- ◆ Loss of anti-icing fluid effectiveness may not be obvious

## *Freezing Drizzle and Freezing Rain – Ramp and Taxi Operation*

- ◆ Ice accretion on ramps, taxiways and runways:
  - Reduced braking and ground controllability, especially in crosswind condition, on untreated surfaces
- ◆ Even on treated surfaces, there may be reduced braking performance due to the ground deicing/anti-icing chemical:
  - Recent tests have indicated that following the first application of chemical, the friction coefficient was similar to that obtained on a wet surface, but deteriorated with a second application

## *Freezing Drizzle and Freezing Rain – Takeoff*

- ◆ During and following takeoff, as anti-icing fluid flows off the leading edges, SLD ice accretion can be expected
- ◆ Takeoff with leading edge ice accretion will result in reduced lift, increased drag and reduced controllability margins during rotation and following liftoff
- ◆ Possibility of engine malfunctions (e.g. as a result of ground ice accretion and subsequent shedding)
- ◆ Possibility of other system malfunctions (e.g. airspeed error due to pitot-static system icing)
- ◆ In event of rejected takeoff, reduced directional control (especially in crosswind) and reduced braking on slippery runway

## Accident Record in SLD Icing Conditions

- ◆ In-flight accidents, due in part to SLD, have occurred to turbopropeller powered aeroplanes with pneumatic boot deicing systems and manual flight controls
- ◆ No readily identified accidents to Transport or Commuter Category aeroplanes due to takeoff in freezing drizzle or freezing rain, *when the aeroplane has been “properly” deiced and anti-iced on the ground*
- ◆ However there have been several incidents attributed to possible ice contamination in freezing drizzle/freezing rain conditions *even though deicing/anti-icing was accomplished and ice accretion was not visually observed*
- ◆ Significant number of engine related incidents associated with ground operation in SLD icing conditions

## *Safety Board Recommendations*

- ◆ The NTSB considers that the lack of design standards and the lack of certification to operate in SLD conditions to be a major safety concern
- ◆ Recommendations have been made to the FAA to revise the aeroplane certification requirements to include SLD icing conditions and to limit commercial operation of aeroplanes that do not meet these standards

# *Aviation Rulemaking Advisory Committee (ARAC)*

- ◆ Proposals have been made by the Aviation Rulemaking Advisory Committee (ARAC) to the FAA and EASA to incorporate new certification requirements to include SLD conditions
- ◆ The proposals contain specific certification requirements for takeoff in SLD conditions (if such operation is requested by the type certificate applicant)

## *Current Canadian Operations*

- ◆ Flight in icing conditions is an inescapable fact of life for Canadian operators conducting all weather operations and to all other operators who serve Canada
- ◆ Freezing drizzle and freezing rain can be expected between 1% and 5% of the time (and more in some specific locations)
- ◆ Some airports have reported up to 39 “annual freezing rain days”
- ◆ Available information indicates that takeoff in freezing drizzle and freezing rain appears to be commonplace



## *Current Canadian Operations (continued)*

- ◆ It appears that airline operators establish their own limitations, practices and guidance for flight crews and dispatchers with respect to takeoff in freezing drizzle and freezing rain
- ◆ There also appears to be inconsistency between different airline operators, even for the same type of aeroplane
- ◆ Individual pilots and operational inspectors have expressed safety concerns and have objected to takeoff in freezing drizzle/freezing rain due to the lack of certification approval of this type of operation

## *Fundamental Questions*

- ◆ Given:
  - The state of technical knowledge
  - The ambiguity in interpretation of the current operating regulations
  - The lack of certification approval
  - NTSB recommendations
  - ARAC recommendations
  - FAA policy for freezing drizzle and light freezing rain
  - The apparent safety record, to date, with current operational procedures
- ◆ Is there an accident “waiting to happen”, or a “needless concern”?
- ◆ Should the operating regulations be amended to limit this type of operation (at least for some types of aeroplanes)?
- ◆ Should the guidance to operators and flight crews be clarified?

## *Current Transport Canada Civil Aviation (TCCA) Initiative*

- ◆ TCCA has formed a multi-disciplinary team tasked with providing recommendations on the interpretation, policy and guidance concerning the application and enforcement of the regulation(s)
- ◆ As a preliminary step, it is intended to approach:
  - Aeroplane manufacturers for their recommended limitations and procedures
  - Airline operators for their individual limitations, practices and procedures
  - Airport operators to determine the criteria used to close the airport due to freezing drizzle and freezing rain
- ◆ Meteorological reporting aspects and terminology inconsistencies are to be considered

## Summary

- ◆ Currently, aeroplanes do not have certification approval to takeoff in freezing drizzle and freezing rain (neither is it prohibited)
- ◆ Certification requirements have been recommended by ARAC
- ◆ Operational regulations and policy:
  - FAA operational policy permits takeoff in freezing drizzle and light freezing rain subject to conditions
  - EASA/JAA regulations would appear to prohibit the operation, but interpretation and practice is less clear
  - TCCA regulations could be interpreted to prohibit the operation, but operation is commonplace

## *Summary (continued)*

- ◆ The NTSB has identified in-flight operation in SLD conditions as a high priority safety issue
- ◆ There are additional hazards associated with ground operation and takeoff in freezing drizzle and freezing rain
- ◆ There have been no significant accidents but there have been some serious incidents where ice accretion may not have been apparent
- ◆ Flight crews and operational inspectors have expressed safety concerns about the operation and the interpretation of the regulations
- ◆ Is there a safety issue?
- ◆ TCCA is attempting to establish operational guidance

## Questions or Comments?

- ◆ For further information or comments on the presentation, please contact:

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- ◆ For information on TCCA operational guidance initiative, please contact:

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