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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C.

Excerpts from Empire Airlines ATR 42 Pilot Handbook (Adverse Weather)

(15 Pages)

ATTACHMENT
28

This chapter is divided in three parts:

– Icing
– Cold weather operations
– Operations in wind conditions.

ICING

I - GENERAL

Icing conditions are defined as follows;

- Atmospheric icing conditions

  Atmospheric icing conditions exist when OAT on ground and for takeoff is at or below 5°C or when TAT in flight is at or below 7°C and visible moisture in the air in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow sleet and ice crystals).

- Ground icing conditions

  Ground icing conditions exist when the OAT is at or below 5°C when operating on ramps, taxiways, and runways where surface snow, standing water or slush is present.

- Regulatory requirements

  Certification requirements defined in JAR/FAR 25 Appendix C consider droplet sizes up to 50 microns in diameter. No aircraft is certified for flight in condition with droplets larger than this diameter.

  However, dedicated flight tests have linked unique ice accretion patterns to conditions of droplet sizes up to 400 microns. Procedures have been defined in case of inadvertent encounter of severe icing.

- Organization of this sub-chapter

  It will address the following areas:

  • Operations within the certified envelope.

  • Information about severe icing beyond the certified envelope

  • Good operating practices

II – OPERATIONS WITHIN THE CERTIFIED ICING ENVELOPE

PREAMBLE

Icing conditions should never be assessed with complacency. Although the aircraft is adequately protected for most of the encountered cases, any severe icing exposure should be minimized by a correct evaluation and proper avoidance actions.

A) GENERAL

Operations in atmospheric icing conditions require SPECIAL ATTENTION since ice accretion on airframe and propellers SIGNIFICANTLY modifies the aerodynamic characteristics.

The primary considerations are as follows:

a – Even small quantities of ice accretions, which may be difficult to detect visually, may be sufficient to affect the aerodynamic efficiency of an airfoil. For this reason, ALL Anti-icing PROCEDURES and SPEED LIMITATIONS MUST BE COMPLIED WITH as soon as and as long as ICING CONDITIONS are met and even before ice accretion actually takes place.

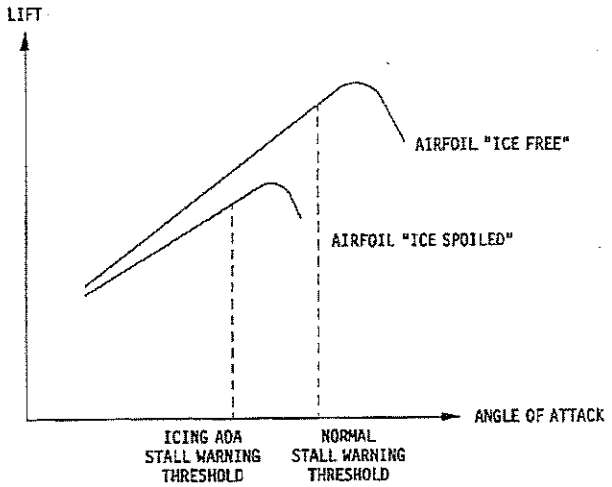
b – Main effects of ice accretion on airfoils are:

- Maximum achievable LIFT is reduced
- For a given angle of attack, LESS LIFT and MORE DRAG are generated . IN order to maintain a SAFE MARGIN AGAINST STALL, which will occur at a higher speed when ice accretion spoils the air foil:
  – The stall warning threshold must be reset to a lower value angle of attack.

This lowered threshold is effective when switching horns anti-icing ON and illuminating the ICING AOA green caption.

THE LOWER AOA OF STALL WARNING THRESHOLD DEFINED FOR ICING REMAIN ACTIVE AS LONG AS THE ICING AOA CAPTION IS ILLUMINATED.

– Accordingly, the minimum maneuver / operating speeds defined for normal (no icing) conditions (see PH 2.02.01) MUST BE INCREASED. These new minimum speeds are called MINIMUM ICING SPEEDS. They are defined further in paragraph B.



c – Anti-ice and deice systems are provided. The AIRFRAME deicing will LIMIT the amount of ice adhering to the airfoil but CANNOT eliminate ALL ICE ACCRETION because of the unprotected elements on the leading edges and the continuous accretion between two consecutive boot cycles. RESIDUAL ICE must be considered, not only during periods when accretion develops, but ALSO AFTER ICING CONDITIONS HAVE BEEN LEFT (continued climb above icing clouds as an example).

d – Ice accretion may also affect forces required to maneuver the flight controls. On ATR 42:

- Rudder forces are not affected.
- Aileron forces are some what INCREASED when ice accretion develops, but remain otherwise in the conventional sense.
- Pitch forces are not affected in flaps 0°, 15° and 30°. Flight with ice accretion (even small) and flaps 45° shows a tendency for pitch forces to reduce (and eventually reverse) in case of significant push overs. This tendency is made worse by increasing IAS towards V_{FE}. It is the reason why use of flaps 45° is prohibited in normal operation and must be considered only as an emergency position (ditching/forced landing).

B) MINIMUM ICING SPEEDS

– The minimum maneuver / operating speeds defined for normal conditions (2.02.01) MUST BE INCREASED and the new value enforced whenever:

ICE ACCRETION { <u>is possible</u> (flight in atmospheric icing conditions) / <u>or exist</u> (ice accretion developing or residual ice)

They are defined by the following table where V_S is the non-affected stall speed as given in 2.01.03.

FLAPS	V_{mHB}	V_{mLB}
0°	1.5 V_S	1.45 V_S
15°		1.32 V_S Takeoff - 2nd segment
		1.45 V_S Final / TO / En route
		1.39 V_S Go-around
30°		—
45°	PROHIBITED	

Relevant MINIMUM ICING SPEEDS are also provided in the operating data booklet for all weights.

C) PERFORMANCE IMPLICATIONS

The drag increase associated with ice accretion will induce a decrease in performance which may be taken into consideration. The dominant effects are:

▷Twin ENGINE ceiling is reduced

▷Single ENGINE ceiling is reduced

However, on the ATR 42, the performance loss may be minimized by using FLAPS 15°.

This is the reason why, IF OBSTACLE LIMITATIONS EXISTS whenever MINIMUM ICING SPEEDS ARE IMPOSED (ICING AOA light illuminated) SINGLE ENGINE CRITICAL PHASES (FINAL Takeoff CLIMB, EN ROUTE, DRIFT DOWN PROCEDURES) MUST BE PERFORMED WITH FLAPS 15° CONFIGURATION.

✍**Note**:If no obstacle limitation exist, FLAPS 0° may be used for single engine cruise in order to benefit from a higher cruise speed but at a lower cruising altitude.

▷BEST CLIMB GRADIENT SPEED

It is essential to understand that the MINIMUM ICING SPEEDS must be observed to maintain a minimum safe margin against stall BUT ALSO TO MINIMIZE PERFORMANCE LOSSES: the MINIMUM ICING SPEED is always close to BEST CLIMB GRADIENT SPEED with ice accretion. ANY ATTEMPT TO REDUCE BELOW MINIMUM ICING SPEED can only give a LOSS of steady climbing performance.

✍**Note**: All performance data given for ICING CONDITIONS were derived from flight test measurements performed with ICE SHAPES representative of the worst icing cases considered by certification and applicable losses of propeller efficiency.

Because of variability of REAL ICING, climb and cruise performances published for icing conditions MUST BE regarded as operational information only.

D) DETECTION

– Ice accretion may be primarily detected by observing the

Icing Evidence Probe (IEP). At night, this IEP is automatically illuminated when NAV lights are selected ON. Ice accretion may also be detected on windshield, airframe (leading edges), wipers and side windows.

– The ice detector may help the crew to recognize the beginning of ice accretion (ICING light steady + MC + sc).

– Clear ice accretion may be difficult to detect. If clear ice is suspected, temporary selection of airframe boots is recommended as the action of boots will shatter the ice and make its observation much more obvious.

E) PROCEDURES IN ATMOSPHERIC ICING CONDITIONS

During operations with AP ON during climb and descent, vertical speed mode should not be used unless the airspeed is carefully monitored. The suggested procedure is to use IAS mode with a speed selected which is equal to or greater than the appropriate minimum speed (V_{mLB} or V_{mHB} in accordance with the BANK selection on the autopilot).

☝**CAUTION**: Close attention should be paid to the appearance of an AILERON MISTRIM message flashing on the ADU: if the message appears, apply the AILERON MISTRIM procedure.

✍**Note**: Permanent heating (Probes/windshield) is **always** selected ON.

▷ENTERING ICING CONDITIONS

- **ANTI-ICING (PROP-HORNS-SIDE WINDOWS-ENGINES) ..... ON**

  ✍**Note**: Horns anti-icing selection triggers the illumination of the "ICING AOA" green light, and lowers the AOA stall warning threshold.

- **PROP MODE SEL ..... ACCORDING TO SAT**

- **NP ..... SET ≥ 86%**

- **MIN. MANEUVER/OPERATING ICING SPEED .....BUGGED AND OBSERVED**

- **ICE ACCRETION .....MONITOR**

Note 1: These procedures are applicable TO ALL FLIGHT PHASES including takeoff.

Note 2: After takeoff, Np MUST NOT be deliberately set below Np = 86%. This is to ensure there is sufficient centrifugal effect to avoid ice accretion on the propeller blades.

In addition, low propeller RPM, and consequently high blade angle of attack can, in certain cases, considerably increase airfoil icing.

The association of contaminated propeller leading edge and low propeller RPM generates a turbulent airflow, which, in certain conditions, may lead to uneven ice accretion involving 100% of the aerodynamic chord of the wings. Stall induced by this accretion occurs earlier than anticipated and is asymmetric.

▷**AT FIRST VISUAL INDICATION OF ICE ACCRETION, AND AS LONG AS ATMOSPHERIC ICING CONDITIONS EXIST**

- **ENG START ROTARY SELECTOR.....CONT RELIGHT**
- **ANTI-ICING (PROP–HORNS–SIDE WINDOWS–ENGINES)..... ..... CONFIRM ON**
- **DEICING (AIRFRAME)..... ON**
- **ENG AND AIRFRAME MODE SEL..... ACCORDING TO SAT**
- **MIN. MANEUVER/OPERATING ICING SPEED.... BUGGED AND ..... OBSERVED**

- BE ALERT TO SEVERE ICING DETECTION.

  In case of severe icing, refer to 2.04.05.

  Notes: 1. When ice accretion is visually observed, DEICERS MUST BE selected and maintained ON as long as icing conditions exist.

  2. Ice detector may also help the crew to determine continuous periods of ice accretion as the ICING light remains illuminated as long as the ice detector senses ICE ACCUMULATING.

The ice detector may not detect certain ice accretion form (see PH 1.13.15).

3. If a noticeable performance decrease and (or) significant vibrations occur due to propeller residual icing then, in order to improve the deicing of the blades, it is recommended:
   - To check the PROP MODE SEL is set according to SAT.
   - TO INCREASE propeller RPM to 92% (and MAX RPM if need be) for continuous periods of not less than 5 minutes in order to benefit from increased centrifugal effect.
4. If ice accretion is seen by the detector with Level 2s or Level 3s still OFF, the ICING light will flash until Level 2s and Level 3s are switched ON.

▷WHEN LEAVING ICING CONDITIONS

DEICING, CONT RELIGHT and ANTI-ICING may be switched OFF.

Note: Leaving DEICING in operation UNNECESSARILY is detrimental to boot life.

The DE ICING blue light on memo panel will blink if deicers are still ON more than 5 minutes after ice detector has stopped signalling ice accretion (ICING amber light OFF).

The DEICING (flashing) blue light on memo panel may be observed even when the aircraft is still in atmospheric icing conditions.

▷WHEN THE AIRCRAFT IS VISUALLY VERIFIED CLEAR OF ICE

ICING AOA caption may be cancelled and normal speeds may be used.

Note: Experience has shown that the last part to clear is the ice evidence probe. As long as this condition is not reached, the icing speeds must be observed and the ICING AOA caption must not be canceled.

F) Takeoff in Ground Icing Conditions but Without Atmospheric Icing Conditions

A. GENERAL

1. Contaminant may adhere to wheels brakes when taxiing on contaminated ramps, taxiways and runways.
2. During takeoff, there is no projection on wings or engines' nacelles but contaminant might affect the propellers:

B. PROCEDURE

For takeoff in ground icing conditions but without atmospheric icing conditions, the following procedure must be applied:

BEFORE TAKEOFF

ENG START rotary selector..... CONT RELIGHT
PROPELLERS Anti-icing ONLY..... ON

AFTER Takeoff

LANDING GEAR (if possible)..... CYCLE
PROP ANTI-ICING..... AS RQD
ENG START rotary selector..... AS RQD

Notes:

1. Takeoff may be scheduled using normal minimum $V_2 = 1.2\ V_S$.
2. Horns anti-icing must not be selected ON to avoid lowering the AOA of stall warning threshold.
3. When anti-icing procedure using type 2/4 fluids is performed, see 2.02.08 pages 17,19 and 20.

G) SUMMARY

DEFINITIONS:

ICING CONDITIONS: See Definition page 1. There is a risk of ice accretion.

ICE ACCRETION: Ice is building up on the air frame. ICING amber light illuminates.

RESIDUAL ICE: Some ice is remaining on the airframe. **May be in or out of icing conditions.**

CONDITIONS	SYSTEMS			SPEEDS	
		1 - PERMANENT 2 - ANTI-ICING 3 - DEICING		A. NORMAL B. ICING	
	ICING LIGHT		NP (%)	ICING AOA LIGHT	
IN FLIGHT					
– NON ICING CONDITIONS	OFF	1	ANY	OFF	A
– ICING CONDITIONS	OFF	1 + 2	≥ 86	ON	B
– ICE ACCRETION	ON	1 + 2 + 3	≥ 86	ON	B
– END OF ICE ACCRETION	OFF	1 + 2	≥ 86	ON	B
– END OF ICING CONDITIONS	OFF	1	ANY	ON	B
– NO MORE RESIDUAL ICE	OFF	1	ANY	OFF	A
ON GROUND					
– NON ICING CONDITIONS	OFF	1	–	OFF	A
– ICING CONDITIONS	–	1 + 2	–	ON	B

H) LIMITATION

– TAKEOFF FLAPS 0

Takeoff flaps 0° in icing conditions is prohibited.

III - SEVERE ICING

A) GENERAL

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 (supercooled 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. All the ice not shed by using the ice protection systems may seriously degrade the performance and controllability of the airplane.

B) CONDITIONS OF FORMATION

The airplane is certificated for a range of droplet diameter, a range of icing temperature and a range of water content in the icing cloud. If one or more of these main parameter is exceeded, the flight is performed outside the certification frame. Three phenomena may lead to surpass the ice protection capabilities:

1) **Mechanical phenomenon: Droplet Diameter:**

The droplet diameter may be up to 3 to 30 times greater than the upper limit of the certification envelope in freezing drizzle/freezing rain conditions. The inertia of droplets is such that the ice may cover all the frontal surface of airfoil exposed to the cloud, outside of the protected areas.

Depending on the angle of attack of the airfoil, a ridge may form mainly on the upper side of the airfoil (e.g. flaps 15°) or a granular pattern may accrete on the lower surface of the airfoil up to 50% of the chord (e.g. flaps 0°). Freezing rain and freezing drizzle conditions are found typically at low altitudes with a static air temperature around -4°C/25°F (3000 ft) and associated with temperature inversion.

However, freezing drizzle condition may be found at higher altitudes (up to 15000 ft) with a static air temperature down to -18°C/0°F. They may be the consequence of the turbulence effect which leads to a coalescence process of small droplets into large droplets. It may be encountered on top of stratiform clouds.

2) Thermal phenomenon

Skin temperature and/or liquid water content. When the flight in icing conditions is such that the total air temperature is above 0°C with a static air temperature close to 0°C, droplets cannot freeze on the leading edge because the skin temperature is positive, they roll along the chord until they encounter a surface at a negative temperature. The leading edge is free of ice but a ridge or rivulets may be formed aft of the protected areas. The rivulets are oriented n the airstream direction. They accumulate on the lower and upper surfaces. This phenomenon may occur also with colder temperatures but when a large amount of water is present in the cloud. The structure of the leading edge is not cold enough to freeze the whole water amount and the remaining droplets freeze with delay behind protected parts.

3) Mixed Icing Condition

Mixed icing condition may be encountered in the range of temperatures -10°C–0°C. It is basically an unstable condition, it is extremely temperature dependent and it may change quite rapidly. This condition may surpass the ice protection capabilities because the aggregate of impinging ice crystal/snow and water droplet can adhere rapidly to the airplane surpassing the system capabilities to shed ice, causing significant reduction in airplane performance as in case of system failure.

C) CONSEQUENCES OF SEVERE ICE ACCRETION

The consequences of severe ice accretions are ice location dependent. If the pollution extension occurs on the lower surface of the wing, it increases the drag and the airplane speed decreases. It may lead to stall if no action is taken to recover correct speed.

If the pollution occurs first on the upper part of the wing, the drag is not affected noticeably but controllability anomalies may be encountered. Severe roll anomalies may be encountered with "flaps 15" accretions flown with flaps 0 setting. It should be emphasized that it is not the flaps 15 configuration itself that is detrimental, but the low angle of attack that may result from such a setting, especially close to V_{FE}. This low or negative AOA increases the wing upper side exposure to large droplet impingement. This is why holding with any flaps extended is prohibited in icing condition (except for single engine operations).

D) DETECTION

– During flight, severe icing conditions that exceed those for which the airplane is certificated shall be determined by the following. Severe icing is characterized by ice covering all or a substantial part of the unheated portion of either forward side window.

Note: This cue is visible after a very short exposure (about 30 seconds).

and/or

Unexpected decrease in speed or rate of climb

and/or

The following secondary indications:

- Water splashing and streaming on the windshield.
- Unusually extensive ice accretion on the airframe in areas not normally observed to collect ice.
- Accumulation of ice on the lower surface of the wing aft of the protected areas.
- Accumulation of ice on the propeller spinner farther aft than normally observed.

The following weather conditions may be conducive to severe in-flight icing:

- Visible rain at temperatures close to 0°C ambient air temperature (SAT).
- The occurrence of rain when SAT is below freezing temperature should always trigger the alertness of the crew.

EXIT THE SEVERE ICING ENVIRONMENT

There are no regulatory requirements to certify an aircraft beyond JAR/FAR 25 Appendix C. However, in case of inadvertent encounter with such conditions, the "severe icing" procedure must be applied (refer to 2.04.05).

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