Boletim Especial de Aeronavegabilidade
(*Special Airworthiness Bulletin*)

ATA: 30 – Ice and rain protection

BEA Nº 2023-03

Subject: Operation in icing conditions – adherence to standard operating procedures

Date: May 12th, 2023

1. INTRODUCTION

This Special Airworthiness Bulletin (BEA) is intended to provide information regarding the Embraer EMB-500 ice protection system and to alert owners and operators about the importance of proper adherence to the standard operating procedures established by the airplane manufacturer.

This bulletin is informative, and the recommendations herein are not mandatory. Up to this time, there is no airworthiness concern that would warrant an Airworthiness Directive (AD) according to Regulamento Brasileiro de Aviação Civil (RBAC) nº 39.

Manufacturer: Embraer

Affected Aeronautical Product: Airplane model EMB-500

2. BACKGROUND

2.1 Le Bourget, France accident

An accident with an Embraer airplane model EMB-500 (commercial designation Phenom 100) occurred on February 08th, 2021. The airplane took off from Venice (Italy) with Le Bourget (France) as the destination. The investigation was performed by BEA (*Bureau d´Enquêtes et d´Analyses pour la sécurité de l´aviation civile*), which issued the final report associated with the accident.

Data from the investigation indicated that the flight crew selected the landing speeds for non-icing conditions, in accordance with the manufacturer´s normal procedures addressed in the Quick Reference Handbook (QRH).

Before starting the descent to the destination, the crew was informed about the presence of severe icing between 3,000 and 5,000 ft.

They carried out the approach by applying the manufacturer´s normal procedure for an approach in non-icing conditions. The approach speed selected by the crew was 22 kt below the approach speed in icing conditions and was, according to the manufacturer, close to the stall speed in the event of ice contamination.

During the final approach, the airplane´s speed decreased, the angle of attack increased from 10º to 28º and the stall warning was activated. For the aircraft configuration on this accident with the WINGSTAB de-ice system activated the stall warning would be activated with 9.5º. The airplane stalled with a right bank angle of around 10º and touched down hard on the runway, which resulted in right and nose landing gear failure.

The investigation observed the presence of ice on the wing and stabilizer leading edges after the accident, which indicates that the deactivation of the de-ice system may have resulted in new ice formation on the aircraft at the end of the approach or that the ice that had built up may not have been completely broken up.

At 3,000 ft, the crew activated the wing and stabilizer de-ice system (WINGSTAB de-ice) for a period of 21 seconds, which corresponds to a complete de-ice cycle. The crew indicated that they observed through the cockpit window that the ice which had built up on the wing leading edges had broken up. They then deactivated the de-ice system and did not activate it again. The following hypothesis was made by BEA: light and clouds did not allow the crew to determine the actual degree of contamination of the wing; after deactivating the de-ice system, the crew no longer actively monitored the leading edges to ensure that there was no formation of ice; or the crew observed this build-up of ice but underestimated its consequences.

2.2 Gaithersburg, Maryland, EUA accident

On December 08th, 2014, an Embraer EMB-500 airplane, operated by Sage Aviation LLC, crashed while on approach to Gaithersburg, Maryland airport. The investigation was conducted by the National Transportation Safety Board (NTSB)

Data from the investigation indicated that the crew selected the landing speed in accordance with the QRH for non-icing conditions (operation with the WINGSTAB de-ice system turned off).

The CVDR recorded a TAT below 10º C when the airplane was at an altitude of about 6,000 ft and a TAT below 5º C at an altitude of about 5,000 ft. Pilot reports indicated icing conditions in the clouds, with cloud tops from 4,300 to 5,500 ft; and the right-seat passenger observed the presence of snow. The investigation indicated that the airplane flew in conditions favorable for structural icing for several minutes without either airplane ice protection system activated.

During the final approach, the airplane began to roll to the right, reaching a bank angle of about 21º before starting to roll to the left. The airplane speed decreased, the angle of attack increased to 21º, and the stall warning annunciation sounded. For the aircraft configuration on this accident with the WINGSTAB de-ice system activated the stall warning would be activated with 9.5º. The airplane rolled about 59º to the left and then went through several roll oscillations before returning to wing level and then starting another roll to the right. The airplane rolled to 100º right and continued to roll to the right to about 154.5º. The airplane impacted three houses and the ground about 3/4 mile from the approach end of the runway. A post-crash fire involving the airplane and one of the three houses, which contained three occupants, ensued.

2.3 Berlin, Germany accident

On February 15th, 2013, an air accident involving an Embraer EMB-500 airplane occurred on a flight from Kortrijk-Welvelgem Airport, Belgium to Berlin-Schönefeld Airport, Germany. The accident investigation was conducted by the BFU (*Bundesstelle* *für Flugunfalluntersuchung - German Federal Bureau of Aircraft Accident Investigation*).

Data from the investigation indicated that the crew selected the landing speed in accordance with the QRH for non-icing conditions (operation with the WINGSTAB de-ice turned off).

While the airplane was passing FL97 during the descent the pilot completed the checklist and selected the landing speeds for non-icing conditions as no visible moisture was identified.

Regarding the weather, the following information was given to the pilots, among others: "moderate icing reported below 3,000 ft and cloud base 1,400 ft", but the pilots only activated the windshield anti-ice and the engine anti-ice system of both engines. According to the CVDR, OAT was about -1,5º C at the time the aircraft was flying at 3,000 ft (upper limit of the clouds). The airplane began to descend and entered the clouds with only the windshield anti-ice and the engine anti-ice system of both engines activated. The pilot had not activated the WINGSTAB de-ice system even with low temperatures and visible moisture because the pilot had not seen any ice accretion.

During the final approach, the speed decreased and the angle of attack on the left sensor increased to 17.2º. The airplane began to roll left and reached a bank angle of 30º. The left-wing had suddenly dropped and touched the runway. Subsequently, the airplane rolled right, and the right main landing gear had come down hard. The landing gear fractured, and the airplane slid along the runway.

The investigation indicated ice accretion at the nose, the entire length of both wing leading edges, the leading edges of the horizontal stabilizer, and the front end of the landing gear components after the accident.

3. EFFECTS OF ICE FORMATION ON THE AIRPLANES

The aim of this BEA is not to revise all effects of ice formation the airplanes. ANAC recommends the *National Aeronautics and Space Administration* (NASA) course available at https://aircrafticing.grc.nasa.gov/index.html for an overall view regarding this topic. On this BEA the most relevant concepts will be reviewed using figures from this reference.

The ice formation decreases both the angle of attack in which stall occurs and the maximum lift that the airfoil is capable to provide, as shown in Figure 1. Consequently, the stall speed increases.

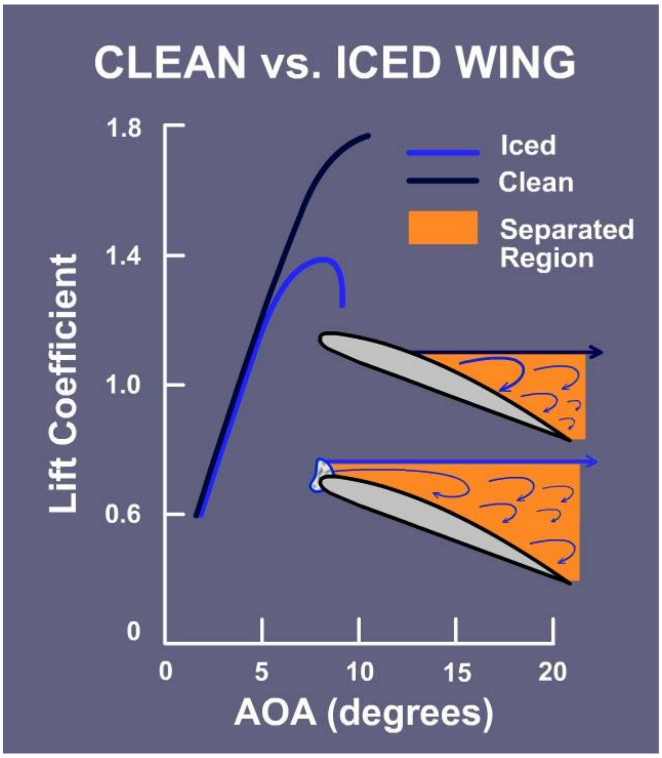


Figure 1: Ice formation on the airfoil. Source: https://aircrafticing.grc.nasa.gov/

4. ICE PROTECTION SYSTEM

The EMB-500 ice protection system consists of the following:

- Thermal anti-ice system for engine air intakes.
- Electrical heating system for windshield and probe.
- Pneumatic de-ice system for wing and stabilizer leading edge. This pneumatic system consists of inflatable boots. When the system is activated, the boots are inflated for 5 seconds each minute using engine air bleed and subsequently deflated, which produces cracking and shearing stresses in the ice causing it to be broken into pieces and breaking the ice interface with the de-ice surface.

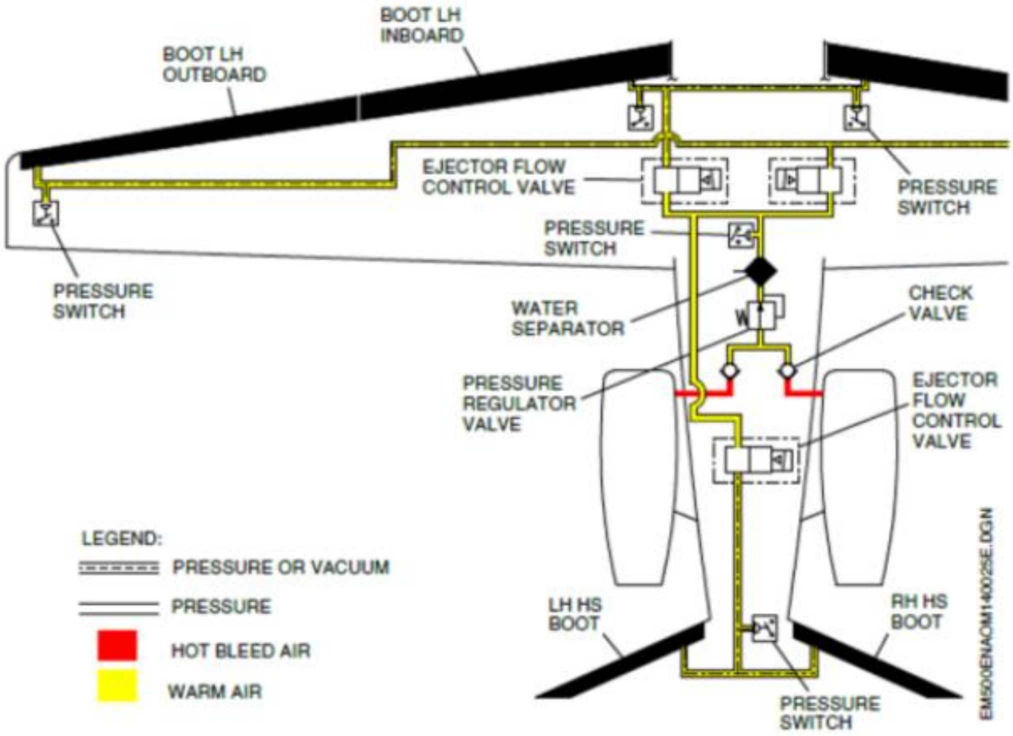


Figure 2 – Diagram of wing and horizontal stabilizer de-ice system.

5. STALL WARNING AND PROTECTION SYSTEM

The EMB-500 stall warning and protection system consists of the following:

- Aural warning “STALL, STALL”, which provides pilots situation awareness if the airplane is approaching a stall condition, as well as a visual indication of low speed on the airspeed tape on both PFD *(Primary Flight Display*) with red and amber indications.

- Stick pusher that activates to prevent the airplane from entering a potentially hazardous stall condition.

The stall warning and protection system is based on the angle of attack. The stick pusher activation, red and amber indication in the airspeed tape, and the aural warning “STALL, STALL” are based on AOA limits considering the specific airplane condition.

With the same airplane configuration but with the de-ice system activated, the stall warning and the stick pusher activate at lower AOA, consequently, at higher speeds corresponding to these AOA. This design characteristic protects the airplane against the effects of ice formation on the airplane. The higher speeds corresponding to AOA limits related to the stall warning and stick pusher activation with the de-ice system activated are annunciated to the flight crew through an advisory CAS message SWPS ICE SPEED.

6. AIRPLANE FLIGHT MANUAL PROCEDURES AND AIPLANE CERTIFICATION

6.1 System Activation

The Limitations and the Normal Procedures Sections of the EMB-500 AFM indicate that during the descent or approach the crew must check if icing conditions exist or if are forecasted. If TAT is between 5º C and 10º C with visible moisture, the engine anti-ice system must be activated. If TAT is below 5º C with visible moisture or at the first sign of ice accretion, the windshield, and WINGSTAB protection systems must be activated.

The Limitations Section indicates that icing conditions may exist whenever the Static Air Temperature (SAT) on the ground or for takeoff, or Total Air Temperature (TAT) in flight, is 10°C or below and visible moisture in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow, sleet, and ice crystals). The AFM establishes that ice protection systems must be activated when icing conditions are forecasted.

AFTER TAKEOFF/CLIMB, CRUISE, DESCENT OR APPROACH

The crew must activate the ice protection system when flying in icing conditions or if icing conditions are forecasted as follows:

If TAT is between 5°C and 10°C with visible moisture:

ENG 1 & 2 Switches .... ON

WINGSTAB Switch .... OFF

WSHLD 1 & 2 Switches .... OFF

The CAS messages A-I E1 (2) ON must be displayed after a delay of approximately 10 seconds.

If TAT is below 5°C with visible moisture, or at the first sign of ice accretion anywhere on the airplane, or ICE CONDITION message (if applicable) is displayed, whichever occurs first:

ENG 1 & 2 Switches .... ON

WINGSTAB Switch .... ON

WSHLD 1 & 2 Switches .... ON

The CAS messages A-I E1 (2) ON, D-I WINGSTB ON and SWPS ICE SPEED must be displayed after few seconds.

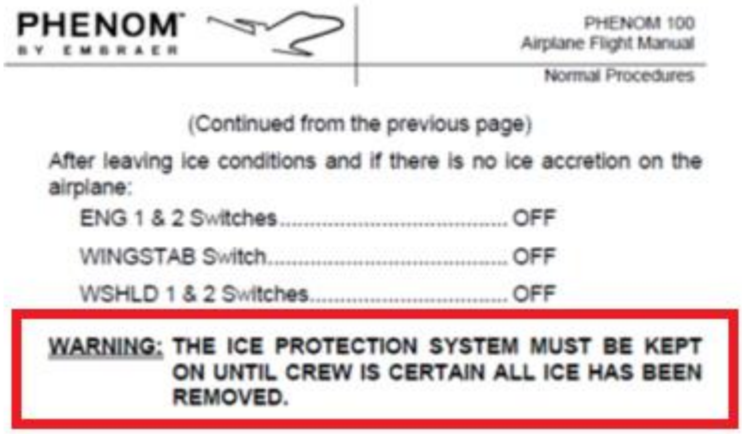
Figure 3 – Extract of the AFM Normal Procedures Section

It is important to highlight that, according to previous understanding, it was required to consider that a minimum ice formation should be present before boots systems activation. Recent studies confirm that this problem does not exist in modern boots systems, as it is indicated in the NASA course. (https://aircrafticing.grc.nasa.gov/1_1_3_7.html).

Therefore, it is important to ensure no delay in the ice protection systems activation. The WINGSTAB protection system activation, in accordance with the AFM procedures established by the airplane manufacturer, is essential to ensure the proper stall and protection system function to prevent a hazardous stall condition.

6.2 System deactivation

According to the AFM, after leaving ice conditions and if there is no ice accretion on the airplane, the systems may be turned off. However, the WINGSTAB switch must remain at the ON position until the flight crew can be sure that the entire wing, including unprotected areas and areas behind the wing deicing boot, are free of ice accretion.


PHENOM BY EMBRAER

PHENOM 100
Airplane Flight Manual
Normal Procedures

(Continued from the previous page)

After leaving ice conditions and if there is no ice accretion on the airplane:

ENG 1 & 2 Switches .... OFF
WINGSTAB Switch .... OFF
WSHLD 1 & 2 Switches .... OFF

WARNING: THE ICE PROTECTION SYSTEM MUST BE KEPT ON UNTIL CREW IS CERTAIN ALL ICE HAS BEEN REMOVED.

Figure 4 – Extract of the AFM Normal Procedures Section

The highlighted warning note is essential. The ice protection system minimizes ice accretion in protected areas when the airplane is flying in ice conditions, but it does not eliminate completely the ice accretion. In addition, there are unprotected areas such as wing roots and wing tips. When the airplane exits the ice condition it is possible that ice formation still exists in the airplane. The stall warning and protection system must be maintained in the ice conditions configuration (SWPS ICE SPEED) and in the EMB-500 design it results in the WINGSTAB protection system maintained activated (WINGSTAB switch must remain at the ON position).

There are some conditions that provide high confidence that the airplane is clear of ice. An airplane that take-off from an airport with cold weather but the destination is an airport with temperatures above 0^{o} C in high altitudes, for instance. A typical example is a flight from New York to Miami during certain periods of the year. A performance penalty associated with the stall warning and protection system for ice conditions is not applicable in these cases. This is the reason that the AFM allows the ice protection system to be turned off and the stall warning and protection system to be set to a non-ice conditions configuration.

The ice protection system MUST NOT be turned off in approach and landings if it is not possible to be sure that all ice accretion in the airplane is removed, as in the accidents described in this BEA.

There are other airplane designs that allow the ice protection system to be turned off without the reset of the stall warning and protection system to non-ice conditions configuration. This is not possible in the EMB-500 design and this is the reason to highlight that the ice protection system must be kept on, with the message SWPS ICE SPEED annunciated, until it is possible to be highly confident that there is no ice formation in any part of the airplane.

7. AIRPLANE PERFORMANCE

The WINGSTAB de-ice system activation results in lower limits of the angle of attack to activate the stall warning and protection system and higher correspondent speeds. Consequently, approach and landing speeds are higher, which affects the required landing distance.

The impact on airplane performance is usually higher in airplanes equipped with boots systems because a higher residual ice formation is natural even with the system functioning properly. In thermal ice protection systems, the leading edge is kept clean of ice although an ice accretion after the protected area is possible (runback ice).

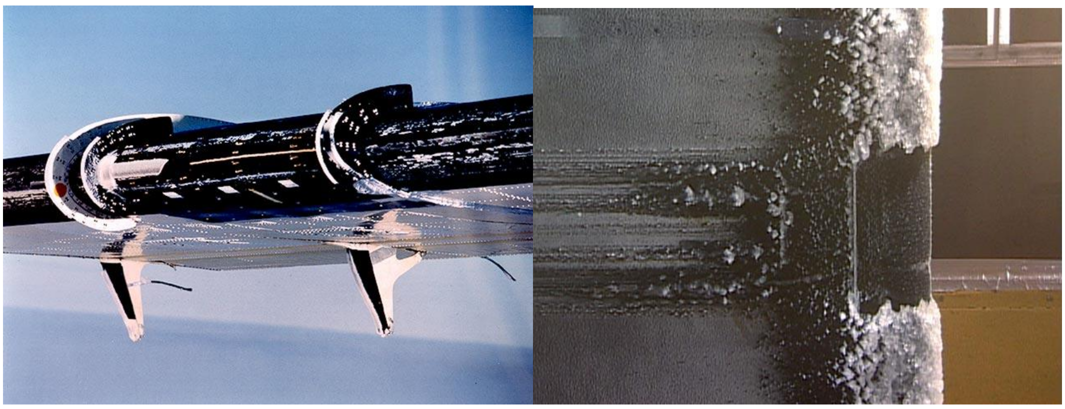


Figure 5: Residual ice formation in the boots system (left) and runback ice in thermal systems (right). source: https://aircrafticing.grc.nasa.gov/

The airworthiness requirements for airplanes equipped with boots systems require an evaluation of the airplane control with ice contamination more severe than for airplanes equipped with thermal systems, which results in low limits of the angle of attack to activate the stall warning and protection system and high approach and landing speeds.

In addition, the required engine air bleed for the WINGSTAB de-ice system results in loss of performance for an OEI (one engine inoperative) go-around, which may preclude the landing at the initial destination airport.

ANAC alerts owners and operators about the risk associated with pilots that deactivate the ice protection system, not in accordance with the procedures established by the airplane manufacturer. The non-adherence to the procedures with the intent to avoid the need for deviations to alternative airports jeopardizes airplane operation safety as may result in a stall without alert. ANAC highlights that accidents had occurred due to a lack of adherence to the procedures established by the manufacturer as described in section 2 of this BEA.

8. RECOMMENDATION:

ANAC alerts owners and operators about the importance to adopt the procedures established by the airplane manufacturer, to avoid undetected ice formation that may result in a stall condition without alarm in the EMB-500:

8.1 Ice protection systems must always be activated in low temperatures and visible moisture, according to the airplane flight manual.

8.2 Ice protection systems may be deactivated only after leaving ice conditions and if the pilot is certain that there is no ice formation in any part of the airplane.

8.3 If icing conditions exist or if are forecasted, landing and approach speeds must be consistent with the configuration with ice protection systems activated. After leaving the icing condition and if the pilot is certain that there is no ice formation in any part of the airplane, the speeds may be reset to the non-icing condition configuration.

8.4 Ice protection systems must not be turned off to avoid a performance penalty.

8.5 ANAC recommends owners and operators be aware of the Embraer informative video.

ANAC highlights that EMB-500 airplanes equipped with Garmin 3000 have installed an ice detector as standard equipment. The ice detector is an optional equipment for EMB-500 airplanes equipped with Garmin 1000. The ice detection system facilitates ice condition identification, but it is the primary responsibility of the pilot to determine the ice protection system activation and deactivation.

9. ADDITIONAL INFORMATION

9.1 Embraer video with orientation to pilots regarding flight in icing conditions. https://www.youtube.com/watch?v=1EftwCgj3VM

9.2 NASA online courses. https://aircrafticing.grc.nasa.gov/index.html

Reference:

1. BEA Report "Stall on short final in icing conditions, hard landing, rupture of main landing gear and nose gear, fire, runway veer-off", available in https://bea.aero/fileadmin/user_upload/9H-FAM_EN.pdf

2. NTSB Report "Aerodynamic stall and loss of control during approach – Embraer EMB-500, N100EQ - Gaithersburg, Maryland – December 8, 2014", available in https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR1601.pdf

3. BFU Report CX001-13, available in https://www.bfu-web.de/EN/Publications/FinalReports/2013/Report_13_CX001_EMB500_Berlin-SchF.pdf?__blob=publicationFile&v=1

4. EMB-500 AFM

For further information contact

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