U.S. Department
of Transportation

Federal Aviation Administration

Memorandum

Subject: **INFORMATION:** Equivalent Level of Safety Finding For Cabin Altitude Warning System – High Altitude Takeoff and Landing Operations

Date: March 17, 2004

FAA Project Number: **AT0134IB-T**
Embraer DCA: **145-00-5396, 145-00-1459**

Reg. Ref: § **25.841(b)(6)**

From: Manager, Propulsion/Mechanical Systems Branch, Transport Standards Staff, ANM-112

Reply to Attn. of: Todd Thompson
Extension: 1175

To: Manager, International Branch, Transport Standards Staff, ANM-116

ELOS Memo # AT0134IB-T-S-1

The purpose of this memorandum is to inform the certificate/validation management certification office of an evaluation made by the Transport Airplane Directorate on the establishment of an equivalent level of safety finding for the Embraer models, EMB-145XR and EMB-145LR.

Background

Embraer intends to certify the EMB-145XR and EMB-145LR for takeoff and landing at airports with elevations up to 10,000 feet. The existing cabin altitude warning activates at 9,900 +/- 100 feet and could cause nuisance warnings during operations into high altitude airports. Transferring the cabin altitude warning from 9,900 +/- 100 feet to 14,500 +/- 500 feet would eliminate these nuisance warnings .

Special design feature are needed to reset the cabin pressure altitude warning system for this type of operation. Hence, Embraer has designed a cabin environmental and pressurization control system (CPCS) that inhibits the usual cabin pressure altitude warnings and resets the warning threshold for high altitude operations. The proposed system has been designed to function for takeoffs and landings up to 13,500 feet. The Brazilian issue paper, Ficha De controle De Assuntos Relevantes (FCAR) HIS-02, dated May 26, 2003, addresses the approval of the proposed system for takeoff and landings up to 13,500 feet, although the initial altitude request for certification and an equivalent level of safety will be limited to only 10,000 feet.
[Reference: Embraer's Major Modification Application 145-00-1459 and Design Change Approval 145-00-5396.]

Applicable Regulation

Section 25.841(b)(6) requires, "Warning indication at the pilot or flight engineer station to indicate when the safe or preset pressure differential and cabin pressure altitude limits are exceeded. Appropriate warning markings on the cabin pressure differential indicator meet the warning requirement for pressure differential limits and an aural or visual signal (in addition to cabin altitude indicating means) meets the warning requirement for cabin pressure altitude limits if it warns the flight crew when the cabin pressure altitude exceeds 10,000 feet."

Regulations(s) Requiring an ELOS

§ 25.841(b)(6).

Description of compensating design features or alternative standards which allow the granting of the ELOS (including design changes, limitations or equipment need for equivalency)

Embraer has designed and incorporated a cabin pressure control system with a manually selectable (by the pilot) mode which will allow safe takeoffs and landings at airports with elevations above 8,000 feet, and up to 13,500 feet for the EMB-145XR and EMB-145LR. The cabin altitude warning system of annunciator indications and master warning alerts shifts from 9,900 $\pm$ 100 feet to 14,500 $\pm$ 500 feet. If the high altitude mode is selected and the aircraft holds between 10,000 and 14,500 feet, the occupants and crew may be exposed to cabin altitudes of 10,000 feet or greater for duration in excess of that allowed by the operating rules and without cabin altitude warning. [See the attached Brazilian issue paper FCAR HIS-02 for further details]

Embraer proposes to shift the cabin altitude warning to 14,500 feet when operating at airports between 8,000 and 10,000 feet. With the existing cabin altitude warning tolerances the airplane can operate at airports elevations less than or equal to 9,500 feet without nuisance warnings. Therefore, the FAA finds that the cabin altitude warning should only be shifted when operating at airports between 9,500 and 10,000 feet.

Explanation of how design features or alternative standards provide an equivalent level of safety to the level of safety intended by the regulation

The FAA has previously granted an equivalent level of safety to other airplanes with similar operating characteristics and features. The system as described by the applicant is similar to other previous designs. However, like other previous designs, the pressure control design itself cannot compensate for the flight crew's ability to react and perform critical functions at 14,500 feet the same as would be expected at 10,000 feet and below. As part of the compensating factors to provide an equivalent level of safety there should be,

i. An indicator to alert the flight crew that the cabin high altitude warning has shifted,

ii. Airplane Flight Manual procedures for operations in the high altitude landing or takeoff mode, and

iii. One pilot should wear and use an oxygen mask when the cabin altitude warning has been shifted from 9,900 feet to 14,500 feet.

[See the attached Brazilian issue paper FCAR HIS-02 for further details]

FAA approval and documentation of ELOS

The FAA approves the Equivalent Level of Safety (ELOS) addressed herein contingent on the following validations by the CTA:

i. An indicator to alert the flight crew that the cabin high altitude warning has shifted,

ii. Airplane Flight Manual procedures for operations in the high altitude landing or takeoff mode, and

iii. One pilot should wear and use an oxygen mask when the cabin altitude warning has been shifted from 9,900 feet to 14,500 feet.

This memorandum provides standardized documentation of the ELOS that is non-proprietary and can be made available to the public. The Transport Directorate has assigned a unique ELOS memorandum number to facilitate archiving and retrieval of this ELOS. This number should be listed in the Type Certificate Data Sheet in the Certification Basis Section. The following is an example of how it should be listed.

Equivalent Level Of Safety Finding has been made for the following regulation:
§ 25.841(b)(6) Warning indication at the pilot or flight engineer station to indicate when the safe or present pressure differential and cabin pressure altitude limits are exceeded. (documented in TAD ELOS Memo AT0134IB-T-S-1)

Neil O Scholkamp 3/17/04

Manager, Propulsion & Mechanical Systems, Branch, ANM-112 — Date

ELOS Originated by CTA [Based on FAA Generic IP]

CTA: Helio Tarquinio
FAA: Todd Thompson, ANM-116

FICHA DE CONTROLE DE ASSUNTOS RELEVANTES (FCAR)
(Issue Paper)

Project:	H.01-061E-0 EMB-145XR	Nº:	HSI-02
Reg. Ref.:	RBHA/FAR 25.841(b)(6)	Stage:	4
Pol. Ref.:	FAA Generic Issue Paper	Date:	26 May 2003
Subject:	Cabin Altitude Warning System - High Altitude Takeoff and Landing Operations	Issue Status:	Closed
Enclosure:		Compliance Target:	Pre-TC

EQUIVALENT LEVEL OF SAFETY

STATEMENT OF ISSUE:

Embraer intends to certify the EMB-145XR for takeoff and landing at airports with elevations up to 10 000 feet. In accordance with RBHA/FAR 25.841(a), the cabin pressure altitude cannot exceed 8 000 feet under normal operating conditions. For this situation, RBHA/FAR 25.841(b)(6) requires crew warning indication when the cabin pressure altitude exceeds 10 000 feet.

Takeoffs and landings at airports above 8 000 feet obviously circumvent these normal regulatory provisions. Special design features are needed to reset the cabin pressure altitude warning system for this type of aircraft operation. Hence, Embraer has designed a cabin environmental and pressurization control system (CPCS) that inhibits the usual cabin pressure altitude warnings and resets the warning threshold for the specific conditions at these high altitude operations. The proposed system has been designed to function for takeoffs and landings up to 13 500 feet. Therefore, this FCAR addresses the approval of the proposed system for takeoff and landings up to 13 500 feet, although the initial altitude requested for certification will be limited to only 10 000 feet (in accordance with major modification application n° 145-00-1459/2003 rev. A, dated 12 May 2003).

DISCUSSION:

In accordance with the provisions of RBHA 21.21(b)(1), Embraer submitted a request to deviate from the RBHA/FAR 25.841(b)(6) when applied to the EMB-145XR take-off and landing operations at airports with field elevations between 8 000 feet and 10 000 feet. Embraer wishes to obtain approval for takeoff and landing operations at high altitude airports with elevations up to 10 000 feet, without activation of the 10 000 feet cabin altitude warning. Embraer designed a cabin pressure control system that they believe will provide an equivalent safety level to the requirements of RBHA/FAR 25.841(b)(6) for takeoffs and landings up to 13 500 feet.

The cabin altitude should equal the aircraft altitude when departing or landing. Embraer has designed and incorporated a cabin pressure control system with a manually selectable (by the pilot) mode which will allow safe takeoffs and landings at airports with elevations above 8 000 feet, and up to 13 500 feet

for the EMB-145XR. The cabin altitude warning system of annunciator indications and master warning alerts shift from 9 900 ± 100 feet to 14 500 ± 500 feet. If the high altitude mode is selected and the aircraft holds between 10 000 feet and 14 500 feet, the occupants and crew may be exposed to cabin altitudes of 10 000 feet or greater for duration in excess of that allowed by the operating rules and without cabin altitude warning. The operating rules RBHA 91.211, 121.329(b) and 135.89(a) address the use of oxygen to prevent hypoxia and related degraded pilot performance.

CTA POSITION:

Current RBHA/FAR 25.841(b)(6) regulatory language states:

"(6) Warning indication at the pilot or flight engineer station to indicate when the safe or preset pressure differential and cabin pressure altitude limits are exceeded. Appropriate warning markings on the cabin pressure differential indicator meet the warning requirement for pressure differential limits and an aural or visual signal (in addition to cabin altitude indicating means) meets the warning requirement for cabin pressure altitude limits if it warns the flight crew when the cabin pressure altitude exceeds 10 000 feet."

The intent of RBHA/FAR 25.841(b)(6) is to warn the crew when the safe or preset pressure differential and cabin pressure altitude limits are exceeded. For the EMB-145XR, Embraer claims that its pressurization system, along with appropriate limitations and operating procedures, meets this intent. Notwithstanding, during high altitude takeoff and landing operations the rule cannot be strictly complied with for obvious reasons, as explained under the "Statement of Issue" section; therefore, the present FCAR is released as an equivalent level of safety to document the proposed alternate means of compliance with the above requirement.

The significance of the cabin pressure limit cannot be overstressed, since 10 000 feet pressure altitude represents the lowest limit for the compensatory stage of hypoxia during daylight flight. Also, per Amendment 25-87, published in the U. S. Federal Register (61 FR 28684, 5 June 1996), and effective 5 July 1996:

"Without supplementary oxygen most people will begin to experience a reduction in night vision or general visual acuity at approximately 5 000 feet altitude. At an altitude of approximately 10 000 feet, a person will begin to display measurable deterioration in mental abilities and physical dexterity after a period of several hours."

Furthermore, the proposed system and operating procedures must reestablish quickly enough the RBHA/FAR 25.841(a) requirements governing maximum cabin pressure altitude during normal operations to avoid a noncompliance issue after takeoff from high altitude airports with elevations up to 13 500 feet.

The CTA approved Airplane Flight Manual (AFM) must include limitations and procedures that are found to be acceptable for all operating modes. When operating with the cabin altitude warning shifted to an altitude above 10 000 feet, at least one pilot is required to use oxygen continuously, until the cabin pressure has reached 8 000 feet. At last, it is imperative that the AFM contain information regarding the operation of the cabin altitude warning system when operating in the high altitude landing or takeoff mode.

EMBRAER POSITION: (Ref. Embraer letter GEC-2715/2003, dated 04 July 2003)

"Embraer has added a HALTO operation mode to the current normal operation mode of the EMB-145LR CPCS to enable the EMB-145XR to take-off and land at airports with elevations from 8 000 ft up to 13 500 ft.

When operating under the CPCS normal mode - airports with elevation below 8 000 ft - the EMB-145XR CPCS retains the same characteristics of the EMB-145LR, including the indication and alarms.

The EMB-145XR CPCS HALTO mode incorporates the following special design features, which reset the system indication for the specific conditions at the high altitude operations:

- A "HI ALT LDG-T/O" advisory message on EICAS version 10.5 and on ("HI ALT LDG-T/O" caution message on previous EICAS version);
- The cabin altitude indication color range on EICAS is modified to meet the new HALTO mode (see table 1);
- The cabin altitude aural warning is shifted from the current 9 900 ft ± 100 ft to 14 500 ft ± 500 ft;
- The passenger oxygen mask automatic deployment is shifted from 14 000 ft ± 500 ft to 14 500 ft ± 500 ft; manual deployment continues available; and
- The pre-pressurization and abort mode functions on the digital controller during takeoff are inhibited.

As described above, the changes affect only the indication and alarm features of the CPCS, with no effect on the system logic or programmed laws even in the CPCS HALTO mode.

The HALTO mode of the EMB-145XR CPCS is selected by pressing the bezel button on the VSpeed menu, located on the MFD panel. The HIGH ALT icon becomes boxed when selected, and unboxed if not selected.

In order to comply with the RBHA/FAR 25.841 the system has safety devices to assure that differential pressure and cabin altitude will be kept at safe levels, exactly as in the EMB-145LR.

According to RBHA/FAR 25.841(b)(6) warning indication must be provided at the pilot or flight engineer station to indicate when the safe or preset pressure differential and cabin pressure altitude limits are exceeded. The EMB-145XR CPCS indicates on the EICAS the cabin altitude, cabin altitude rate of change and cabin differential pressure to the crew. In case of one or more parameters become outside nominal limits, the color changes in order to alert crew, according to the following table:

Table I - CPCS Indication Parameters

Parameter	Range	Color	
		Normal mode	HALTO mode
Cabin altitude	-1 500 to 37 000 ft	Green: -1 500 to 8 300 ft Amber: 8 400 to 9 900 ft Red: 10 000 to 37 000 ft	Green: -1 500 to 8 300 ft Amber: 8 400 to 14 400 ft Red: 14 500 to 37 000 ft
Cabin altitude rate of change	-2 000 to 2 000 ft/min	Green	
Cabin differential pressure	-0.5 to 10.0 psi	Green: 0.0 to 7.9 psi Amber: -0.1 to –0.3 psi 8.0 to 8.3 psi Red: -0.4 to -0.5 psi 8.4 to 10.0 psi	

In case of failure of CPCS, the digital controller sends a caution message to the EICAS, "PRESN AUTO FAIL", to indicate to the crew that system has failed. In case of CPCS failure or ECS failure causing the cabin to depressurize, the cabin pressure acquisition module (CPAM) sends a discrete signal to the aural warning system, in order to alert crew of high cabin altitude. The following table shows the CPCS indication in case of failure, as well as signals characteristics.

Table II - CPCS Alerting Signals

Designation	Source	Indication local
10 000 ft warning (normal mode) 14 500 ft warning (HALTO mode)	CPAM	Aural warning system
CPCS failure caution message	Digital controller	EICAS

As the intent of the RBHA/FAR 25.841(b)(6) is to warn the crew when the safe or preset pressure differential and cabin altitude limits are exceeded, the system features implemented on the EMB-145XR guarantee that the CPCS HALTO mode meets this intent for the specific condition of such operation.

The EMB-145XR CPCS is designed to reestablish the RBHA/FAR 25.841(a) quickly after takeoff from high altitude airports by deselecting the HALTO mode. The AFM procedure will require the pilot to deselect HALTO mode when the cabin pressure altitude is below 9 700 ft.

In the EMB-145LR CPCS, as well as the EMB-145XR CPCS normal mode, during takeoff sequence the cabin altitude remains constant as long as the scheduled cabin altitude (ZCOT) is greater than theoretical cabin altitude (ZCTH) or 15 minutes occurs, whichever happens first. The purpose of this sequence is to avoid the re-selection of landing altitude in case of aborted flight and emergency return to the take-off field.

In the CPCS HALTO mode this logic is inhibited and the cabin pressure starts to descend to levels below 10 000ft after takeoff, allowing the crew to unselect HALTO mode reestablishing the 8 000 ft cabin pressure limit.

During the high altitude landing and takeoff operation the passenger oxygen mask auto deployment occurs at 14 500 ft ± 500 ft to avoid the drop of the masks while the EMB-145XR is on takeoff, approach or landing into a high elevation airport, due to tolerance of the altimetric switch.

In order to assure pilots will not forget to return to CPCS normal mode, amber cabin altitude indication is kept for cabin altitudes above 8 300 ft, as well as to keep monitoring while system achieves 8 000 ft normal cabin control altitude.

The boxed HIGH ALT icon on the MFD VSpeed Screen, the HIGH ALT LDG-T/O advisory message on the EICAS as well as the amber cabin altitude color range on the EICAS constitute visual means to alert/advise flight deck crewmembers when the HALTO mode is selected and that an action is required to reestablish the CPCS normal mode.

The AFM supplement for operation in high altitude airports will require at least one pilot using the oxygen mask for cabin altitudes above 8 000ft.

In summary, it is Embraer understanding that the EMB-145XR pressurization system, along with its appropriate limitations and operating procedures, fully meets the intent of RBHA/FAR 25.841(b)(6)."

CONCLUSION:

Embraer position addresses CTA concerns and is considered acceptable. Therefore, the requirements as stated in CTA position above are being adopted as an equivalent level of safety with the current RBHA/FAR 25.841(b)(6).

This FCAR is considered closed.

TECHNICAL COORDINATION:

HT	Originator	EES	EEV	EPR	ESE	ESM
Hélio	José Luiz	Abreu	Tanaka	César	Rui	Alvarenga

MANAGEMENT COORDINATION:

HGP	HGE	HGI	HGR	DAC
Pablo	José Luiz	Bassi	Cavali	N/A

FDH APPROVAL:

CLÁUDIO PASSOS SIMÃO – Ten.-Cel.-Eng. **Date: 04 September 2003**
Aeronautical Certification Division, Chief