
In-flight Smoke, Final Report No. 1844 by the Aircraft Accident Investigation Bureau concerning the serious incident to the aircraft Embraer EMB-145LU, HB-JAH operating under flight number CRX 3439 on 28 November 2001 during approach to Zurich Airport

Micro-summary: A smoke emergency on this EMB-145 triggers a diversion.

Event Date: 2001-11-28 at 1511 UTC

Investigative Body: Aircraft Accident Investigation Bureau (AAIB), Switzerland

Investigative Body's Web Site: <http://www.bfu.admin.ch>

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Aircraft accident investigation bureau

Final Report No. 1844 by the Aircraft Accident Investigation Bureau

concerning the serious incident
to the aircraft Embraer EMB-145LU, HB-JAH
operating under flight number CRX 3439
on 28 November 2001
during approach to Zurich Airport

Ursachen

Der schwere Vorfall ist darauf zurückzuführen, dass die Triebwerkzapflucht (*bleed air*) für den Betrieb der *airconditioning packs* mit grosser Wahrscheinlichkeit aufgrund der Verkohlung von drei Einspritzdüsen des rechten Triebwerkes kontaminiert wurde und deshalb im Flugzeug ein Brandgeruch und Rauch auftrat.

Im darauf folgenden Anflug brach die *crew coordination* im Zweimanncockpit weitgehend zusammen. Dazu haben folgende Faktoren beigetragen:

- Unzweckmässige Installation der Sauerstoffmasken im Cockpit
- Verunreinigte Sichtscheibe der Maske des Copiloten
- Zeitweise nicht funktionierende Mikrofone der Sauerstoffmasken

General remarks to this report

In accordance with Annex 13 of the International Civil Aviation Organisation agreement (ICAO Annex 13) this report has been prepared solely for the purpose of accident/incident prevention. The legal assessment of accident/incident causes and circumstances is no concern of the investigation (art. 24 of the Air Navigation Law).

The masculine form is used exclusively in this report regardless of gender for reasons of data protection.

If not otherwise stated, all times in this report are indicated in universal time coordinated (UTC). At the time of the accident, the Central European Time (CET) was valid for the area of Switzerland. This CET was equal to the local time (LT). The relation between LT, CET and UTC is: $LT = CET = UTC + 1 \text{ h}$.

The german-language version of this report is authoritative.

Persons with a well-founded interest in the results of the investigation can, within 30 days after delivery of this investigation report, request the report to be reviewed by the Review Board (Eidgenössische Flugunfallkommission – EFUK) for completeness and conclusiveness (Air Navigation Law, LFG; SR 748.0, of December 21, 1948, Art. 26b, Par. 2, revised version of 1994).

The Aircraft Accident Investigation Bureau (AAIB) of Switzerland would like to thank the authorities and other organizations for the given support throughout the investigation.

Final Report

Owner	State Street Bank and Trust Company of Connecticut, c/o Lenz & Stähelin AG, Bleicherweg 58, 8027 Zürich
Operator	Crossair AG, Postfach, 4002 Basel
Aircraft type	Embraer EMB-145LU
Country of manufacture	Brasil
Aircraft registration	HB-JAH
Place	Approach to Zurich Airport
Date and time	28 November 2001, 15:16 UTC (time at which the crew realized the smell)

General

Summary

During descend towards Zurich airport the crew realized some smell in the cabin like the one coming from overheated or singed parts. The cockpit crew decided to ask for landing priority. During the approach the crew noticed light smoke in the cockpit and donned the oxygen masks. The airplane landed safely on runway 16 at Zurich. The passengers were able to leave the airplane at the assigned stand.

Investigation

Shortly after landing the investigation at the aircraft was taken up.

The serious incident is attributable to the fact that with a high probability bleed air to supply the air conditioning packs was contaminated, caused by carbon residuals on three fuel nozzles of the right engine, leading to smell of burn and smoke in the aircraft.

During the following approach the crew coordination in the multi crew cockpit broke down almost completely. The following factors have been contributing to that:

- Unsuitable installation of the cockpit oxygen masks
- Contaminated copilot's oxygen mask screen
- Intermittent failure of the oxygen mask microphones

1 Factual Information

1.1 History of the flight

1.1.1 Preflight history

The crew, consisting of two pilots and one flight attendant, was planned on that day to operate flight CRX 3438 from Zurich to Krakau (Poland) and CRX 3439 back to Zurich, with the airplane EMB-145 HB-JAH. The flight from Zurich to Krakau was uneventful. During descend to Krakau there was light icing. According to a crew statement, on ground with an outside air temperature of +1°C, a very thin layer of ice remained at the wing leading edge. The crew decided to de-ice the aircraft before departure to Zurich.

1.1.2 History of the flight

At 14:00:37 UTC the crew received the clearance for taxi to runway 26 and took off at 14:05:04. On the leg back to Zurich the commander (CMDR) was pilot non flying (PNF), the first officer was pilot flying (PF). Take-off, climb and cruise at FL 350 went uneventful. At 15:05, Munich Radar asked CRX 3439 to commence descend to FL 270. Shortly after that the crew performed the approach briefing for RWY 14 at Zurich. Some 6 minutes later, at 15:11, the flight attendant reported "smell of burning" in the cabin. The commander rearranged the work distribution on the flight deck and handed over communications with air traffic control to the first officer in order to free capacity to assess the problem. He asked the flight attendant to proceed back to the cabin to check the situation again. Shortly after, the flight attendant reported that there was no visible smoke, but certain floor panels near the wing area being very hot and that there was a smell of burn in the whole cabin. The flight deck crew also noted a light smell. Assessing the situation the flight crew had a look at the nearest airports and decided to continue towards Zurich. At this time CRX 3439 was in the area of the Kempten (KPT) VOR, Munich airport was 77 nautical miles (NM) behind and Zurich airport was 82 NM ahead of the HB-JAH. Taking the report of the flight attendant into consideration, the commander decided to ask for landing priority. He informed his first officer and the flight attendant accordingly and took over again the duties of the PNF. At 15:16, in the mean time at FL 240, the commander informed air traffic control on the frequency of Zurich sector radar about the status of the flight, declared the "PAN PAN PAN" situation and asked for landing priority. Furthermore he asked for the fire brigade to be ready upon landing. CRX 3439 was then cleared to descend to FL120. At 15:17 the commander stated that there was neither smoke nor smell at this time and therefore there was no need to put on the oxygen masks. The first officer agreed with that.

The commander, his mother tongue being English, in addition to communication with air traffic control took over the control of the aircraft and asked the first officer to inform the passengers about the actual situation in German. After the first officer had informed the passengers, the commander asked him to have a look into the "cabin smoke and cockpit" checklist. Shortly after that CRX 3439 was handed over to Zurich arrival control. On this frequency, the crew, having the approach briefing for runway 14 already completed (based on ATIS information), was informed to expect runway 16 for landing. Due to the high workload the crew decided thereafter to stop trouble shooting using the checklist procedure and to return to the standard work distribution. At 15:21 the CMDR noticed

some light smoke on the flight deck and decided that he and his copilot had to don the oxygen masks. It turned out to be difficult to take the masks out of their compartments. After a while, the copilot estimated it to have been about 30 seconds, both pilots wore their full facemasks. From now on communication with air traffic control and intercom communications between the pilots became very difficult. Due to an intermittent failure of a switch the mask microphones worked only partly. In addition, the copilot's full face mask screen was heavily contaminated, giving him the impression that smoke development had increased.

Based on the hampered communication and the copilot's contaminated full face-mask screen, the two pilots had a different perception of the actual situation. The two statements below illustrate the difference in the perception of the pilots about the approach:

CMDR: *At this point visual contact established, final checks done and normal landing performed. As our F/A (flight attendant) did not report a worsening situation, I decided to complete the roll out and vacate the runway. After vacating, I asked the F/A to advise situation in cabin. She advised it was OK and even seemed better, so I decided to taxi to stand. Oxy masks removed and contact re-established correctly.*

Copilot: *(translation from German) The autopilot overshot the localizer as usual, but was unable to get back, probably we have been to close approximately 7-8 NM. Due to the bad visibility I asked the commander several times to take over the airplane, but he didn't understand me due to our communication problem. Finally he realized it and took over control. ATC cleared us down to 3000ft, I loudly confirmed this several times, but obviously that was not heard. The commander tried aggressively to regain the localizer using the TCS button. I checked the altitude and didn't see a problem in that, we also were established on GP. Then I realized that we still had set inbound course 137 for ILS14, but with the correct frequency of RWY16. I corrected that. ATC communications had been alternately done by both of us because Tower obviously did not hear us, or if, then only after several attempts. From my standpoint the situation was severe, because of my bad vision and having a possible go-around in mind, as we have had centered the localizer late. Finally we have been on the localizer (approx. 5-6 NM, that means before we passed the Stadlerberg) and had visual contact to the runway at approx. 3-4 NM, before that we had visual ground contact. Due to the mentioned communication problems the final check was quiet difficult again. I insisted and finally made the final check for myself. Landing and rollout were without any problems, the fire brigade was ready. Due to the smoke I expected a rapid disembarkation. A view back into the cabin after leaving the runway confirmed my impression. ATC communication was still a problem. I was surprised when I saw the commander taking off his mask. I did the same shortly after and realized there was almost no smoke at all in the cockpit*

After several interventions of Zurich arrival the commander managed to line-up the aircraft on the ILS 16 inbound course with the aid of radar vectors. After distinct corrections regarding glide path and inbound course the aircraft landed at 15:29 UTC on runway 16 and taxied to the assigned stand. The passengers left the aircraft through the normal doors.

1.2 Injuries to persons

	Crew	Passengers	Third parties
Fatally injured	---	---	---
Seriously injured	---	---	---
Slightly injured or uninjured	3	18	

1.3 Damage to aircraft

No damage to aircraft.

1.4 Other damage

No damage to third parties.

1.5 Personnel information

1.5.1 Pilot

Person	Australian citizen, born 1966		
Licence	CH ATPL/JAR, first issue 27 Juli 2001		
Ratings	Instrument Rating Cat. III, valid until 16 January 2002		
Aircraft ratings	EMB145, valid until 16 July 2002		
Medical certificate	Last periodic examination on 20 March 2001, result: fit to fly		

1.5.1.1 Flight experience

Flight hours	Total	2431	last 90 days	160
	On the type involved in the serious incident	218	last 90 days	160

1.5.2 Copilot

Person	Swiss citizen, born 1971
Licence	CH CPL/JAR, first issued 7 September 1998
Ratings	Instrument Rating Cat. II, valid until 28 June 2002
Aircraft ratings	EMB145 Copilot, valid until 28 June 2002, last Proficiency Check at 28 June 2001
Medical certificate	Last periodic examination: 23 February 2001, Result: fit to fly

1.5.2.1 Flight experience

Flight hours	Total	2062	Last 90 days	153
	On the type involved in the serious incident	469	Last 90 days	153

1.5.3 Flight attendant

French citizen, born 1977

Trained as flight attendant on EMB145 during November 2000

S/C (Senior Cabin Crew) since 1 August 2001

1.6 Aircraft information

Aircraft Type	Embraer EMB-145LU
General Information	Two engined low wing jet, engines tailmounted
Year of manufacturing / Serial number	2000 / 145341
Engines	Allison Engine Company, Inc. AE3007A1 Left engine: CAE311590, TSN 2573 Right engine: CAE311595, TSN 2573
Permission	commercial VFR by day/night, IFR Cat. I/II, B-RNAV (RNP 5)
Operating Hours	2573 h

1.7 Meteorological information

1.7.1 Summary

A high pressure area extended from the Azores to the Alps. With north-westerly high altitude winds a weakened occlusion passed Switzerland.

1.7.2 Meteorological situation at Zurich airport at the time of the incident

Weather/Clouds 1-2/8 base 900 ft AGL, 3-4/8 base 1300 ft AGL,
5-7/8 base 2000 ft AGL

Visibility 8 km

Wind 240 degrees, 4 Knots

Temperature/Dewpoint +04 °C / +03 °C
Freezing level: around 4500ft AMSL

Atmospheric pressure QNH 1020 hPa

Dangers No visible dangers

Sun position Azimut: 248° Altitude: -9°

1.7.3 Wind and Temperature in the free atmosphere

	Wind	Temperature	Dewpoint
850 hPa (FL 050)	260 degrees 25 kts	- 01 °C	- 02 °C
700 hPa (FL 100)	280 degrees 25 kts	- 08 °C	- 10 °C
500 hPa (FL 180)	290 degrees 35 kts	- 24 °C	- 26 °C
300 hPa (FL 300)	300 degrees 40 kts	- 51 °C	- 59 °C

1.8 Aids to navigation

All relevant ground navigation equipment has been reported to be working normal.

1.9 Communications

Communication from ground stations to the aircraft was normal. Communication between the aircraft and the ground stations was disturbed due to an intermittent failure of mask microphone switches.

1.10 Aerodrome information

Zurich Airport is located in north-east Switzerland. The airport reference point (ARP) has coordinates N 47 27.5 / E 008 32.9. The reference elevation of the airport is 1416 ft AMSL and the reference temperature is specified as 24 °C.

The Zurich airport runways have the following parameters:

Runway	Dimensions	Elevation of ends of runways
16/34	3700 x 60 m	1390/1386 ft AMSL
14/32	3300 x 60 m	1402/1402 ft AMSL
10/28	2500 x 60 m	1391/1416 ft AMSL

1.11 Flight Recorders

The digital flight data recorder (DFDR) as well as the cockpit voice recorder (CVR) was removed from the aircraft after the incident and the data were downloaded. All recordings were of good to very good quality.

1.12 Wreckage and impact information

Not affected.

1.13 Medical and pathological information

Neither the crew nor the passengers suffered any health problems. None of the concerned individuals requested a doctor's visit after the incident.

1.14 Fire

No burned or scorched parts have been found on the aircraft. It can be assumed that there was no fire at any time.

1.15 Survival aspects

Not affected.

1.16 Test and research

1.16.1 The following points required special investigations:

1.16.1.1 Determine the point of origin of the smell (*smell of smoke*)

After the incident the operator's maintenance provider started detailed troubleshooting to figure out the origin of the smell. The following possibilities were taken into account:

- Overheat of a bleed air duct to/from the airconditioning packs or overheat of the panels which are installed close to those ducts or close to the air-conditioning packs, installed in the wing root
- Contaminated bleed air entering the airconditioning packs

All panels covering the bleed air ducts carrying air to/from the two airconditioning packs were removed, as well as the cabin floor panels in the area of the air-conditioning packs. Nothing remarkable was found. During a ground run the problem could not be reproduced, there was no smoke or smell of smoke, neither with the packs supplied from the APU nor with the packs supplied from the engines.

- 1.16.1.2 Leaking front fan seal: At the begin of the commercial operation the Allison AE3007A1 engines installed on the Embraer 145 were the cause of some cases of contaminated bleed air. That problem happened also to other aircraft types equipped with the same engines. In those cases oil passed to the compressor due to a not properly fitting front fan seal, causing burned oil to get into the air-conditioning packs via bleed air. The consequences were about the same as the one experienced on flight CRX3439. The engines installed on HB-JAH have been inspected after the incident, no defects were found on the front fan seals.
- 1.16.1.3 Residual carbon around the fuel nozzles. The troubleshooting experience sheet for the EMB145 describes the following case:

'FAULT/PROBLEM: Oil or Fuel Smell/Haze in the Cabin (like burnt oil, or burnt fuel). Engine related fuel smell is caused by fuel nozzles contaminated with hard carbon deposits on the primary and secondary fuel discharge ports and air paths. Carbon built up on the fuel nozzle tip inner air passage disrupts the air flow and results in back flow and fuel smell due to fuel deflected back upstream of the nozzle into the diffuser forward and outside of the combustion liner still the diffuser case.'

In the troubleshooting process there where three fuel nozzles found on the right engine of HB-JAH, which were contaminated with carbon built up.

1.16.2 Donning of the oxygen masks

The aircraft HB-JAH was equipped with quick donning full face masks (picture 1), manufactured by B/E Aerospace. A push-button activated inflatable harness system allows a quick donning of those masks. They were stored in separate stowage compartments called "stowage box" located left of the pilot seat and right of the copilot seat (picture 2). Those stowage boxes have been layed out for oxygen masks without a full face part while in this aircraft full face masks were installed. The space in the stowage box to stow the full face mask, was very tight. To allow an easy pull out of the masks out of the stowage boxes and to avoid scratches on the full face mask screen the manufacturer installed a cloth bag, called "liner", in the stowage boxes.

The copilot reported problems pulling his oxygen mask out of the stowage box. During the investigation it was found that there was no liner installed because there have been some cases in which the mask and the liner got caught up.

For flights above FL250 quick donning masks are required. According to certification requirements they have to be donned within 5 seconds. Practical tests with other crews and other aircraft out of the operators EMB 145 fleet showed that as a rule the masks were not donned within the required 5 seconds due to problems to get the masks out of the stowage box.

Ten (10) months before this serious incident the manufacturer of the masks informed the operators in a "service information letter" about the mentioned problems and proposed a modification. This modification included a new liner, which is attached to the bottom of the stowage box and which is supposed to remain in the stowage box when the mask is pulled out. This modification has not been performed on Crossair's airplanes. Later on, partly as a consequence of this serious incident, the modification has been performed on all of Crossair's Embraer 145.

1.16.3 Transparency of the mask screen

Wearing the oxygen mask with its restricted transparency, the copilot assumed that the development of smoke had increased. The screen of his mask was on the inside and the outside covered with a layer. During a spot check on some aircraft of the EMB-145 fleet the investigators found four (4) other masks with considerable soiled screens.

About three months after this serious incident, the manufacturer of the masks informed all operators having installed this type of mask about the origin and the process to remove this layer. This layer developed some time after the production of the masks due to a material like wax, used in the production process and not properly removed afterwards.

1.16.4 Function of the mask microphones

After having put on the masks, the pilots have been confronted with communication problems which hampered the communication and teamwork in the cockpit considerably. The communication problems were caused by an intermittent failure of the mask microphones mute switch.

The microphones built into the masks were from the manufacturer "Telex". About the function principle of those masks: during inhaling oxygen flows into the mask, in which the microphone is installed (picture 4). In order not to send the loud noise of the expanding oxygen into the intercom system, those microphones have an electromechanical function (called reed-switch), which should switch the microphone off during the breath in. Due to a malfunction this reed-switch function was unreliable, from time to time the microphone remained off despite the pilot was not inhaling. As a result the intermitting function of the microphones hampered the communication between the pilots considerably.

According to a service letter of the microphone manufacturer, the so called reed-switch, which interrupts the microphone circuit during inhaling, can be overridden. In the mean time this measure has been completed on the whole EMB-145 fleet.

1.16.5 Inspection interval

Before this serious incident the interval between required inspections of the oxygen masks has been at every C-check. Such C-checks are performed every 4000 flight hours. After this incident the inspection interval for this oxygen masks has been lowered to every 400 flight hour

1.17 Organizational and management information

Not affected.

1.18 Additional information

Not affected.

2 Analysis

2.1 Technical aspects

During trouble shooting, carbon residuals were found on three fuel nozzles of the right engine. This trouble shooting was performed in accordance with the manufacturer's trouble shooting experience sheet. Since this is a known problem a similar incident should be prevented by inspections with a defined interval.

The difficulty of taking out the oxygen masks from their stowage boxes as well as the contamination of the full face mask screens is not acceptable. The inspection of the mask functionality at an interval of only 4000 hours on the occasion of the C-Check is by far insufficient. The oxygen masks are an emergency equipment that must be functional any time.

2.2 Human and operational aspects

The experience shows that in case of smoke development respectively fire on board there is only a very limited time available to either solve the problem or have the aircraft on the ground. In addition, in such cases the flight crew only has limited information about the real hazard potential of the situation. For this reason the assessment of the situation by the crew as well as the decisions taken was adequate.

The heavily contaminated screen of the copilot's full face mask gave him the impression of an increased smoke development. Therefore the assessment of the situation made by the two pilots was quite different. The additional communication problems inside the cockpit as well as with air traffic control hampered the crew coordination in a way that it practically broke down, at least during certain phases of the approach.

The recordings of the approach show that it was only partially stabilized. Under the described circumstances it was however appropriate to land the aircraft anyway.

3 Conclusions

3.1 Findings

- The crew were in possession of the necessary licences.
- The aircraft was certified for commercial operation under IFR, day and night.
- The smell of scorched or overheated parts was realized in the cabin and in the cockpit.
- There was light smoke observed in the cockpit.
- The crew asked for landing priority at Zurich airport.
- Wisps of cloud were in the approach sector of runway 16.
- It proved to be difficult to pull the oxygen masks out of their stowing boxes.
- The copilot's full face mask screen was heavily contaminated which falsified his assessment of the situation regarding smoke development.
- Due to the intermittent functioning of the mask microphones, communication between crew members as well as with air traffic control was strongly hampered. Crew coordination during approach was thereby heavily spoiled.

3.2 Causes

The serious incident is attributable to the fact that with a high probability bleed air to supply the air conditioning packs was contaminated, caused by carbon residuals on three fuel nozzles of the right engine, leading to smell of burn and smoke in the aircraft.

During the following approach the crew coordination in the multi crew cockpit broke down almost completely. The following factors have been contributing to that:

- Unsuitable installation of the cockpit oxygen masks
- Contaminated copilot's oxygen mask screen
- Intermittent failure of the oxygen mask microphones

4 Safety recommendation

4.1 Safety deficiency

During an approach into Zurich airport with light smoke development in the cockpit the following deficiencies have been observed:

- Difficulties to pull the oxygen masks out of their stowage boxes.
- The copilot's full face mask screen was heavily contaminated which falsified his assessment of the situation regarding smoke development.
- Due to the intermittent functioning of the mask microphones, communication between crew members as well as with air traffic control was strongly hampered. Crew coordination during approach was thereby heavily spoiled.

The oxygen masks are part of the emergency equipment of an airplane. The functioning of the masks must be assured at any time.

4.2 Safety recommendation No. 355

The Federal Office for Civil Aviation shall ensure that on all correspondingly equipped airplanes, the installation, function as well as the maintenance of the used oxygen masks be checked in an interval adapted to the installation.

4.3 Measures taken after the serious incident

4.3.1 Swiss International Airlines

As a consequence of this serious incident as well as some other incidents in connection with these oxygen masks and partly on request of the FOCA, Swiss International Air Lines, according to their own statement, performed the following steps:

- *Modification of the mask liner*
Installation of a modified mask liner to provide a rapid and unhindered unstowage and application of the oxygen mask. (Quick-Donning). (B/E Aerospace 118816-SIL-1)
- *Contamination of the full face mask screen*
Replacement of the faulty masks with new masks, produced under new quality guidelines. Additionally, check of the masks within the maintenance program every 400 hours.
- *Mask microphones*
Removal of the reed-switch causing communication problems. (B/E Aerospace 145250-SIL-2)
- *Quick Donning Training*
Introduction of a fleet wide temporary Last Flight of the Day Check of the oxygen masks done by the pilots. During this check the masks have to be pulled out of the stowage box and then tested for their functionality.

Berne, 6 April 2006

Aircraft Accident Investigation Bureau

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Picture 1



Full face mask

Picture 2



Oxygen mask, halfway pulled out of the "stowage box"

Picture 3



Copilot's heavily contaminated full face mask screen

Picture 4



Built in mask microphone