

Safety First

The Airbus Safety Magazine



03 | December 2006



Yannick MALINGE
Vice President
Flight Safety

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Last October we held the 13th Airbus Flight Safety Conference. This was an opportunity to share information for the 125 attendees (out of which about 30% attended for the first time) representing 80 Airbus operators.

The feedback we received was very positive, highlighting in particular the very open and fruitful exchange of information, not only between Airbus and You, our Operators, but also between Operators themselves. Notably 7 airlines shared their experiences either on crisis management or on safety related events.

We can consider this as a clear indication that the Airbus Flight Safety Conference became what we hoped for 13 years ago: "our Operators" Safety Conference.

Similarly, the Airbus Safety Magazine, the extension of our Safety Conference, has to become as well "our Operators" Safety Magazine.

Therefore we hope receiving articles from you that can be published in our next Safety First magazine to share Safety experience as we have done together during the last 13th Safety Conferences.

I hope you will enjoy reading this 3rd issue of Safety First and feel free to widely distribute it throughout your organisation.

Yours sincerely

Yannick MALINGE
Vice President Flight Safety



Safety First

The Airbus Safety Magazine
For the enhancement of safe flight through increased knowledge and communications.

Safety First is published by the Flight Safety Department of Airbus. It is a source of specialist safety information for the restricted use of flight and ground crew members who fly and maintain Airbus aircraft. It is also distributed to other selected organisations.

Material for publication is obtained from multiple sources and includes selected information from the Airbus Flight Safety Confidential Reporting System, incident and accident investigation reports, system tests and flight tests. Material is also obtained from sources within the airline industry, studies and reports from government agencies and other aviation sources.

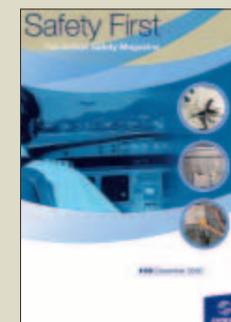
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News

13th Flight Safety Conference

Another annual Flight Safety Conference has been very successfully completed and we hope you all benefited from the information sharing between us all.

We have received some requests to use the presentations internally within some airlines, so if you want to do this or you want more information on the conference content then contact us on the e-mails below.

We are already planning next year's conference from October 15th to 18th. We will inform everyone as usual for registration.

As always we will be asking for your inputs for the conference. The more operator presentations the better so if you have ideas then let us know but also if there are specific subjects you would like to see in the conference then also get in touch with us.

As Yannick Malinge says in his editorial this is your conference.

Airbus Flight Safety Office

In the back of the magazine you will find pictures and information on the Flight Safety Team. Since the last issue of the magazine there are two new Flight Safety managers:

Frederic COMBES and Nicolas BARDOU

Both are bringing their experience from wide but different backgrounds in Airbus.

Also please note that many of our mobile phone numbers have changed

Your articles

As already said this magazine is a tool to help share information. Therefore we rely on your inputs. We are still looking for articles from operators that we can help pass to other operators through the magazine.

If you have any inputs then please contact us.

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Dual Side Stick Inputs



By: Frédéric COMBES
Flight Safety Manager

1 | Introduction

One of the basic task sharing principle for any aircraft operation is that one pilot is Pilot Flying at a time. Therefore, if the Pilot Not Flying disagrees with the Pilot Flying inputs, he/she has to verbally request corrective actions or, if deemed necessary, to take over the controls by clearly announcing "I have controls".

This will mean that he/she becomes Pilot Flying from that moment and the other Pilot Not Flying. Nevertheless, the feedback gained from line operations monitoring indicates that dual inputs still occur and are also sometimes involved in operational incidents analyzed by Airbus.

This was the case for the below described event, experienced on an A320 during turbulence

2 | Summary of the event

While climbing to FL 320 at about Mach 0.78, an A320-200 encountered significant turbulence that led roll to increase up to 40°.

The Pilots reacted to this roll departure by various dual sticks inputs in pitch and roll. The Auto Pilot disconnected consequently to stick input.

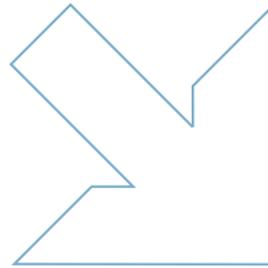
Before the event the aircraft was in climb to FL 320. The airplane had a weight of 61,2t. and was in the following configuration:

- Clean with AP 2 engaged (CLIMB / NAV) and ATHR Engaged & Active in Thrust mode.
- Managed Mach target was 0,78
- Both ND CPT & FO were selected in ARC Mode with a range of 160NM

The aircraft began an uncommanded roll to the right, which was initially counteracted by the Auto Pilot. However, at a speed above 250 kts, Auto Pilot orders on ailerons are limited at 8°. Therefore, due to the high turbulence the roll reached a value of 40° to the right.

Both pilots reacted with full LH stick orders and 10° LH rudder pedals.

This induced the disengagement of the Auto Pilot. During the next 20 seconds, the Captain and First Officer applied dual stick inputs, which lead to roll values oscillating between 33° to the left and 49° to the right, as well as to a loss of 2400 feet altitude. The Captain then re-engaged the Auto Pilot, selected Flight Level 310, and the flight resumed without noticeable event.



3 | Types of dual stick input

Analysis of reported dual side stick inputs events, reveals that there are three types of occurrences:

The “Spurious” Dual Stick inputs

Typically due to an inadvertent movement of the stick by the PNF.

For example when grabbing the FCOM or when pressing the R/T.

A spurious dual stick input only marginally affects the aircraft behavior due to only time limited & small inputs.

The “Comfort” Dual Stick inputs

Typically due to short interventions from the PNF who wants to improve the aircraft’s attitude or trajectory:

These are generally experienced in approach, during a capture (altitude localizer), or in flare, and have minor effects on the aircraft’s altitude/trajectory. However, as the PF is not aware of the PNF’s interventions, he may be disturbed and may counteract the PNF’s inputs.

The “Instinctive” Dual Stick Inputs

Typically due to a “reflex” action on the part of the PNF on the stick. This instinctive reaction may come about when an unexpected event occurs, like for example an AP disengagement, an overspeed situation or a dangerous maneuver.

Such interventions are more significant in terms of stick deflection and duration. Usually in such situations, both pilots push the stick in the same direction, which may lead to over control, a situation illustrated by the above occurrence.

4 | Operation of the sidestick

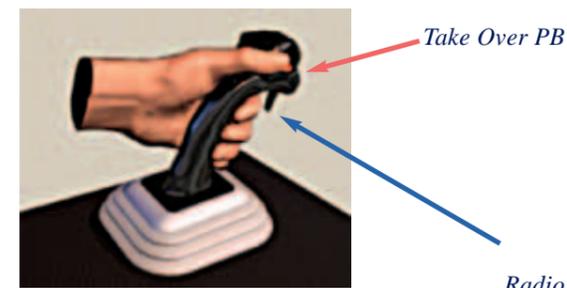
The two sidesticks are not mechanically linked as they are on older types of aircraft.

This means that both sticks may be operated independently one of the other.

When one sidestick is operated it sends an electrical signal to the Fly By Wire computers. When both sticks are moved simultaneously, the system adds the signals of both pilots algebraically.

The total is limited to the signal that would result from the maximum deflection of a single sidestick.

To avoid both signals being added by the system, a priority P/B is provided on each stick. By pressing this button, a pilot may cancel the inputs of the other pilot.



An audio signal will indicate which sidestick has priority,



and a red light comes on in front of the pilot whose stick is deactivated



With autopilot (AP) engaged, the sidesticks are kept in the neutral position, with no possibility of simultaneous inputs from either pilot.

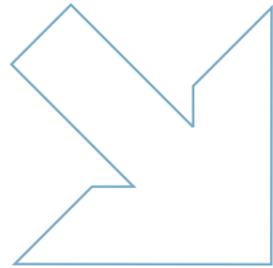
Indeed, when the A/P is engaged, it is normally disconnected by pressing the priority P/B (the pilot takes priority over the A/P) or instinctively at any time by a firm action on the stick: typically 5kg in pitch, 3.6kg in roll.

5 | Operational procedures

Simultaneous inputs by both PF and PNF on the sidesticks must be avoided. Thus, if the PNF feels he must intervene, he must do so by pressing the Priority P/B while saying “I have controls”.

These rules are reminded in the Flight Crew Training Manual 01.020 – Flight Controls and Flight Crew Operating Manual 1.27.40 – Flight Controls: Controls and Indicators”





6 | Dual Sidestick inputs warning system

In order to warn the crew in case of dual sidestick operations, Airbus has designed a package of dual input indicators and audio warning. These operate when both side sticks are deflected simultaneously by more than 2°. These visual and aural warnings have proved to be efficient means to inform the pilot of dual inputs.

Visual indication

When a dual input situation is detected, the two green priority lights located on the cockpit front panel flash simultaneously.

The visual indication is an **ADVISORY** of a dual input situation

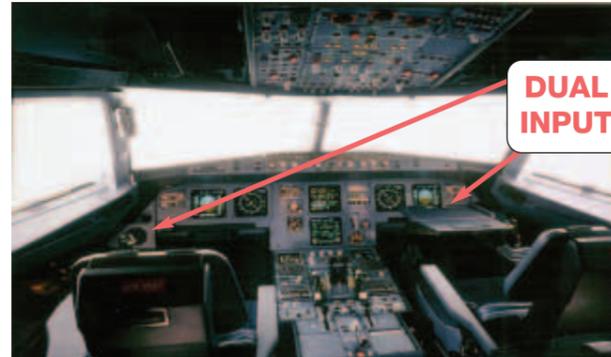


Aural Indication

After the visual indication has been triggered, a synthetic voice "DUAL INPUT" comes up every 5 sec, as long as the dual input condition persists.

The synthetic voice is a **WARNING** of a dual input situation

Note: This audio has the lowest priority among the synthetic voice audio alerts.



The visual and audio indications are designed to provide the crew with a progressive alert.

Experience has shown, that these warnings are very effective to:

- "Educate" the pilots to respect the basic task sharing principle;
- Reduce drastically the number of dual input occurrences.

The activation of these dual input warnings has no repercussion in term of :

- Crew training;
- Mixed fleet flying.

HOW TO UPGRADE YOUR SA AND LR AIRCRAFT ?

- The light and aural indicators are basic, and free of charge on retrofit, on the A320 family and A330/A340.
- It requires **FCDC** and **FWC** to be at a given standard already available on production line:
 - A320: FWC E2 Standard - FCDC 53 Standard
 - A330/A340: FWC K3/L7 Standard - FCDC M11/L14 Standard
- **Pin programs are activated on Operator request**



A330-300

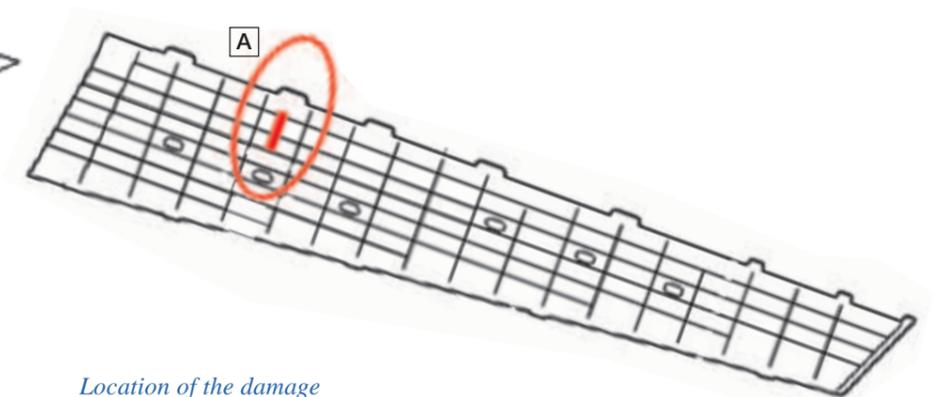
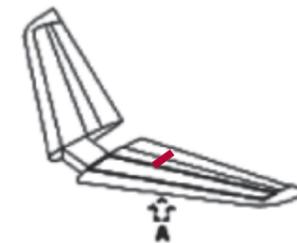
Trimmable Horizontal Stabilizer Damage



By: **Marc BAILLION**
Flight Safety Manager

1 | Introduction

This article describes an uneventful flight, during which, the aircraft was in an unsafe condition. As a result of what was erroneously considered as a minor damage, the limit loads of the THS were no more sustainable. This resulted from a wrong appreciation of composite structure damage. The objective of this article is to highlight the paramount importance of building a good knowledge of composite structure damage and repair. Composite structure training is available at Airbus training center. The Structure Repair Manual's (SRM) procedures must be respected and, if outside SRM limits, Airbus must be contacted to always ensure aircraft structural integrity.



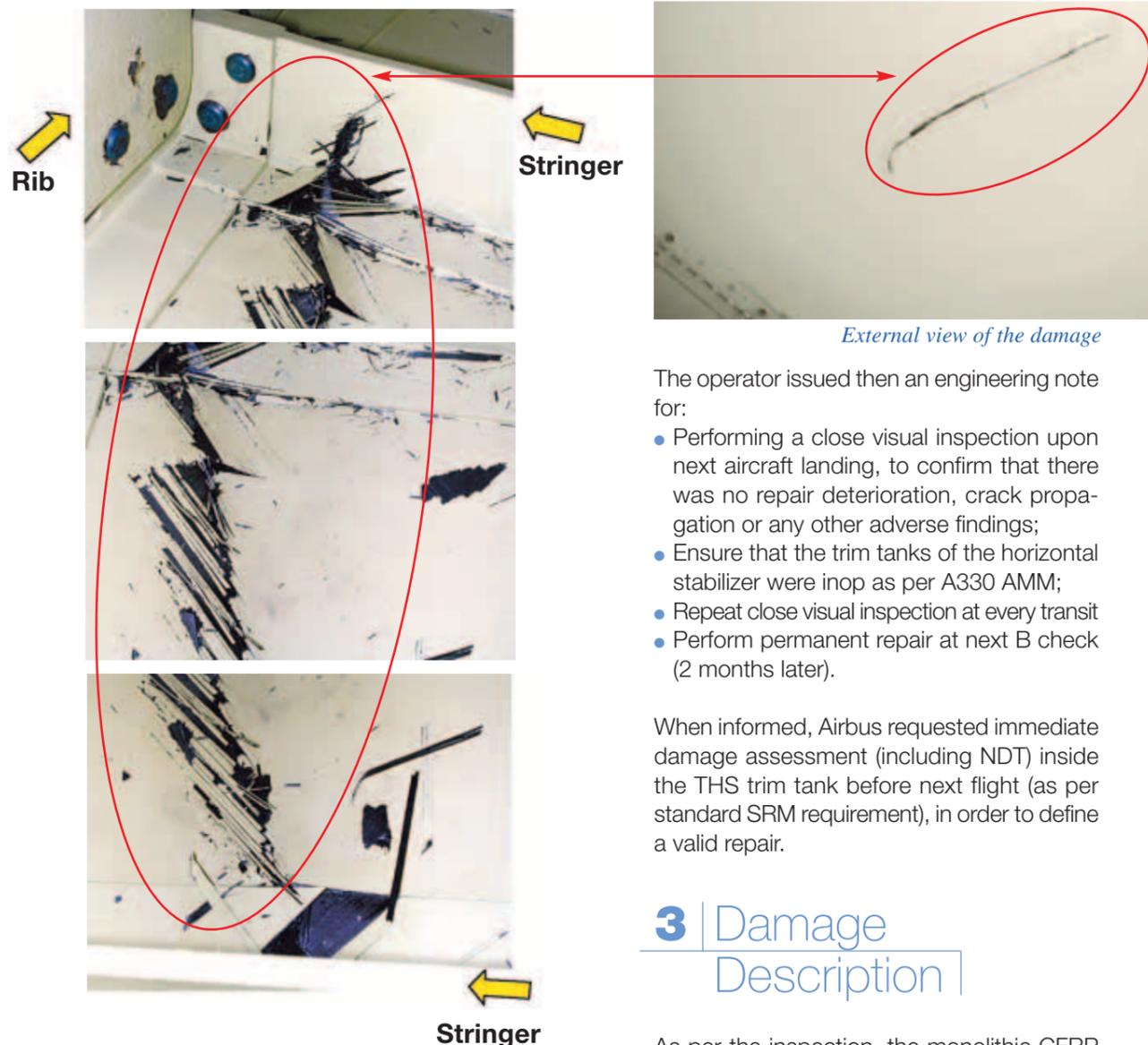
Location of the damage

2 | Description of the event

On 21st of August 2004 upon landing, the subject airplane was found with a torn lower skin of the right hand THS Lateral Box. This damage was thought to be due to a Foreign Object Damage (FOD) and resulted in a leaking Trim Tank.

A missing water servicing door (164AR) was suspected to have caused the damage. The damage was inspected externally only. The external cut was measured to be about 330mm length by 3mm width, in line of flight, located at the THS bottom skin panel, just behind second THS inboard handhole access panel.

The visible damage is shown on the picture: Based on external visual findings, the operator performed a temporary repair, by filling the damage



External view of the damage

The operator issued then an engineering note for:

- Performing a close visual inspection upon next aircraft landing, to confirm that there was no repair deterioration, crack propagation or any other adverse findings;
- Ensure that the trim tanks of the horizontal stabilizer were inop as per A330 AMM;
- Repeat close visual inspection at every transit
- Perform permanent repair at next B check (2 months later).

When informed, Airbus requested immediate damage assessment (including NDT) inside the THS trim tank before next flight (as per standard SRM requirement), in order to define a valid repair.

3 | Damage Description

As per the inspection, the monolithic CFRP panel was found cracked throughout the cut length, with large delaminations in the surrounding area.

Two stringers located on the THS bottom skin panel had been severely damaged.

Internal views of the THS are shown opposite.

with adhesive (EA934) and covered with two layers of Glass Fiber Reinforced Polymer (GFRP) plies. Trim tanks were emptied and a/c was flown back under MEL.

4 | Actions Launched

The aircraft required immediate appropriate repair, as the temporary repair did not restore the required structural integrity of the THS.

An OIT was issued (reference SE 999.0115/04 dated 15th Oct. 2004) for A310/A300-600/A300-600ST/A318/A319/A320/A321/A330/A340.

OIT recommendations are as follows:

"In case of damage, composite structure degrades in a different way compared to metallic structure. In the particular case of impact with a foreign object the internal damage might be larger than the visible external damage. On monolithic structure, impact damage will usually result in delamination around perforation and damage to structure underneath"

"...All instructions for inspection and repair of composite structure given in the SRM are to be followed, to detect damage in its full extent, and to prevent [...] inappropriate repair"

Composite structure courses are available at Airbus training department to provide specific knowledge with regard to maintenance and repair of composite structure.

See Airbus customer portal, structure training catalogue available:

- Composite structure NDT inspection (XSB2)
- Composite repair for technicians - basic (XSA2)
- Advanced composite repair for technicians (XSA3)
- And a new course:**
- Structure repair for engineers composite structures (XSC3)

For more information, please connect to: https://w3.airbus.com/crs/A233_Train/0500_catalogs/Structure_MENU.htm

5 | Conclusion

- Internal damage might be larger than the visible external damage on composite structure (monolithic, sandwich, CFRP, GFRP);
- Airbus instructions related to repair of composite structure given in the SRM are to be followed, to detect damage in its full extent, and to prevent inappropriate repair;
- SRM repair procedure to be respected or, if outside SRM limits, contact Airbus to always ensure aircraft structural integrity;
- Composite structure courses are available at Airbus training department to provide specific knowledge with regard to maintenance and repair of composite structure.



Pitot Probes Obstruction on Ground



By **Albert URDIROZ**
Flight Safety Manager

1 | Introduction

Airspeed is such a key parameter in aerodynamics, that the systems and indicators of Airbus aircraft use 3 independent airspeeds as inputs to the pilots' displays as well as to the standby indicator. Aircraft systems also use these 3 data.

At the source of the information chain are the pitot probes. Feedback from in-service experience indicates that:

- Incorrect maintenance of these probes is the most common cause for unreliable airspeed information;
- Take-offs are sometimes pursued in spite of one or two airspeed indications being unreliable.

Consequently, this article aims at reminding ground staffs of the efforts to be made in order to protect pitot probes on ground, and at recommending crews to accurately check the condition of pitot probes before flight, and to abort their take-offs when airspeed indication is detected unreliable.

2 | Investigation of an in-service occurrence

For the purpose of this review we will refer to an event that was recently experienced on an A330. However, this type of event could have happened on any other Airbus aircraft.

Prior to the flight, the aircraft spent a few hours on the stand. Storm conditions prevailed during the ground time. Pitot probes were not protected with covers and became obstructed. This was not noticed before take-off.

During the take-off run, CAS1 (Computed Air Speed) and CAS2 were indicating too low speed. However, the take-off was continued.

Later investigation of the flight data recordings and crew report resulted in the following information about the lift-off speeds:

- Ground speed was above 160kt;
- CAS1 was about 60kt;
- CAS2 was estimated to be below 80kt;
- CAS 3 was reportedly reliable.

Note: V1 and Vr of the flight are unknown to Airbus.

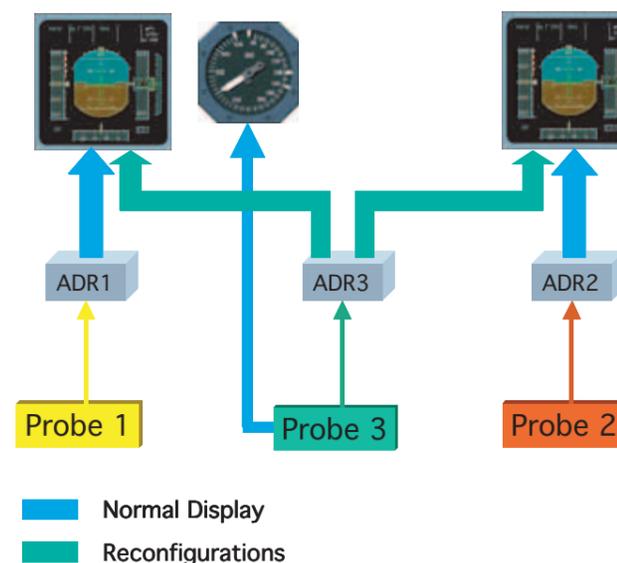
After lift-off, the following cockpit effects occurred:

- «NAV ADR DISAGREE» warning triggered;
- EFCS (Electrical Flight Control Systems) reverted to alternate law;
- Auto-thrust disengaged;
- Flight directors became unavailable;
- Later in flight, with slats and flaps still extended, VFE was exceeded, so that OVERSPEED warning triggered.

Eventually, an in-flight turn back was initiated and an uneventful landing completed.

3 | Systems architecture and response

The following sketch presents the typical architecture valid for all Airbus aircraft.

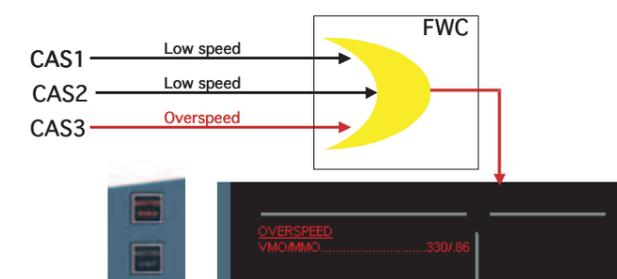


In the event referred to above, no reconfiguration to ADR3 was reported, and the information displayed on the standby indicator was the sole reliable.

3.1. Systems behavior during the event

The behavior of the systems described in paragraph 2 resulted from the AFS (Auto Flight Systems) and EFCS detecting the discrepancy between the 3 airspeeds. Since the monitoring is based on a comparison of the different speeds, and since all 3 were different, the systems could not recognize CAS3 as being the reliable speed. CAS3 being the odd among the 3 airspeeds, it was rejected at first. In this case, however, all 3 data were rapidly rejected by EFCS for computation till the end of the flight.

CAS3 being accurate during subject event, and over speed warning being computed on the basis of an «OR» condition of CAS1, 2 & 3 versus VMO/MMO, the over speed situation indicated by the Flight Warning System was actual.

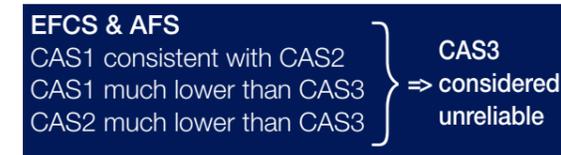


3.2. The particular case where 2 airspeeds are identically affected

A particular situation would arise if 2 pitot probes were identically affected, which would result in 2 of the 3 airspeeds being equally low to the detriment of the 3rd and sole accurate one. This hypothesis is not unrealistic, and was encountered in service when probes were clogged by dust or insects' nets. Besides, the above event was close to this situation, since CAS1 and CAS2 were "only" deviating of about 20 knots, while CAS3 was in the range of 80 knots higher.

For the sake of this demonstration, we will consider that CAS1 and CAS2 are identical and too low.

AFS and EFCS airspeed monitoring relies on a comparison of airspeeds. In our example, CAS3 would then be rejected, and computers would use the erroneous airspeeds from CAS1 & CAS2.

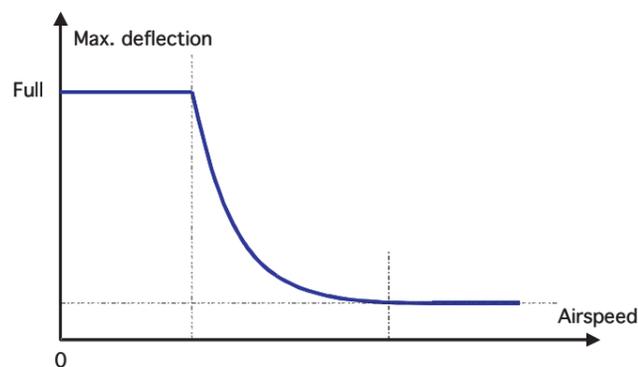




Flight controls surfaces gain efficiency with speed. For instance, the roll rate achieved with 5 degrees of aileron deflection will be much higher if aircraft flies at VMO/MMO than at low speed. This implies that, when AFS and EFCS use a too low airspeed:

- Orders to the flight controls would be too strong and may cause over-reaction, either in manual or automatic flight;
- Limitation of rudder deflection will not be adapted to airspeed (Refer to sketch).

Possible consequences in this extreme situation are loss of control or exceedance of design loads. Given these risks, all efforts should be made to maintain reliable operation of airspeed indication systems, or flight should be cancelled as soon as unreliable airspeed condition is detected.



4 Maintenance and operational recommendations

4.1. Maintenance

Protecting pitot probes with covers any time foreign objects are likely to penetrate is the main precaution to be taken. As indicated in the introduction, the most recurrent reasons for obstruction of probes is accumulation of dust, animal's remains, insects' nets etc. This recommendation should not only be adhered to in case of long time parking. In sand storm conditions, for instance, covers should be placed even when parking for a few minutes.

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SERVICE INFORMATION LETTER			
SUBJECT:	Erratic Airspeed Indication – Pitot Probes Maintenance Action		
ATA CHAPTER:	34-10		
AIRCRAFT TYPE:	A300 / A310 / A300-600 / A318 / A319 / A320 / A321 / A330 / A340 (all models)		
APPLICABILITY:	All Aircraft		
REFERENCES:	OIT SE-E/999.0009/99 TFU 34.10.00.028 for A320 family TFU 34-11-15-003 for A300/A310 family TFU 34-13-00-005 for A330/A340 family		
	SIL NUMBER:	34-084	
	PAGE:	1 of 7	
	DATE:	Nov 22/1999	
	REVISION:	2, Oct 20/2004	

In addition, Airbus has improved the maintenance program with the reduction of the interval from 2C to 1C-check for draining and flushing the pitot pressure lines.

These recommendations are highlighted in a Service Information Letter (SIL 34-084) that Airbus has issued and which is regularly updated in order to optimize the maintenance of pitot probes.

4.2. Operations

Precautions during operations start with the pre-flight exterior check, when pitot probes inspection is requested. Crews should pay particular attention to them, beware of any signs of obstructions.

Then, after take-off thrust setting, both crewmembers should scan airspeed indications. In case of detection of an unreliable condition of one of the airspeeds before V1, take-off should be aborted.

5 Conclusion

Airbus recommends that ground and flight crews be reminded of the possible consequences of flight with pitot probes obstructed:

- Loss of control;
- Exceedance of design loads.

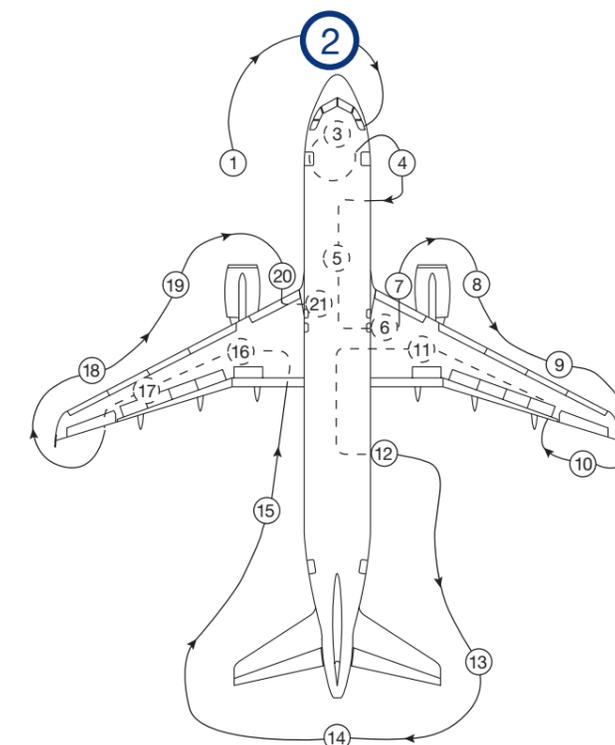
Consequently, all efforts should be made to avoid flying in such conditions by:

- Protecting pitot probes with covers as soon as necessary;

A319/A320/A321	STANDARD OPERATING PROCEDURES	3.03.05	P 2
FLIGHT CREW OPERATING MANUAL	EXTERIOR INSPECTION	SEQ 001	REV 24

② NOSE SECTION

* - Pitot probes..... CONDITION



- Adhering to improved pitot maintenance program;
- Checking pitot reliable condition during the pre-flight walk around check;
- Aborting take-off when unreliable airspeed condition is detected before V1.

To complete the subject of pitot probes obstruction, we will address the unreliable airspeed condition in flight in a future article.



A340 Thrust Reverser Unlocked



By: Vincent SWIDERSKI

A340 Propulsion System Engineer CFM56-5C

Per-Oliver GUENZEL

A330/A340 Flight Safety Coordinator

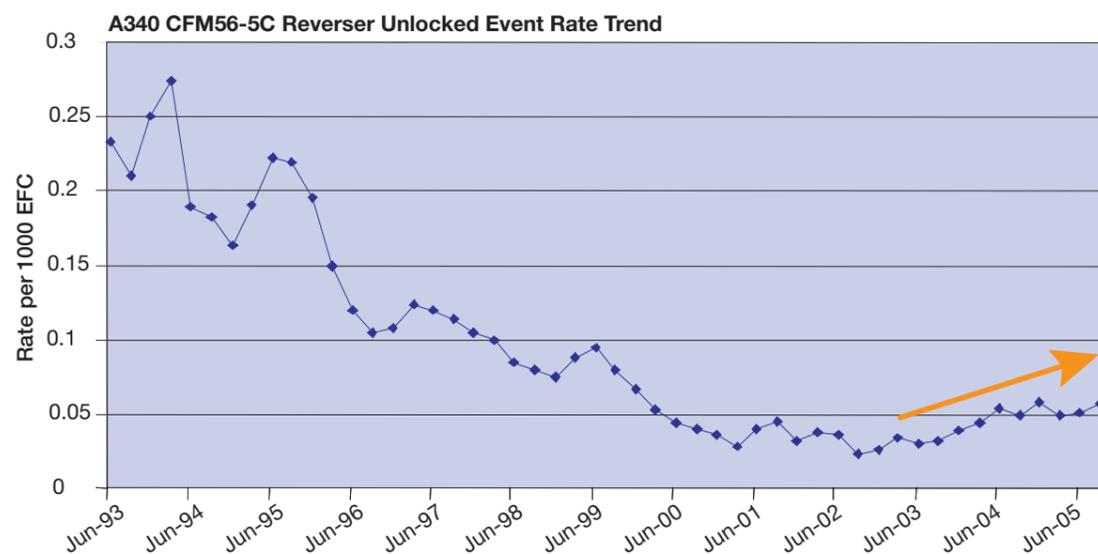


Fig 1: Trend of the "Rev Unlock" event rate since Entry Into Service

1 | Introduction

The CFM56-5C engine (fitted on A340-200 and 300) has a Thrust Reverser with 4 pivoting doors. As soon as one incorrectly locked thrust reverser door is detected, an **"ENG X REV UNLOCKED"** warning comes up on the ECAM warning display.

In the past, most **"ENG X REV UNLOCKED"** warnings were spurious. This is not the case any more, as this phenomenon has been understood and cured.

Today, most of the events are actual ones and the repetitive occurrences are due to a lack of troubleshooting as detailed hereafter.

2 | History

Since Entry Into Service, various operators are impacted by Rev Unlocked warnings. Airbus, CFM, Goodrich and Aircelle are carrying out a continuous improvement of the system. It began in August 1996 with issuance of the "ATO package" Service Bulletin (Ref A). This SB provided a first answer to the Rev Unlock phenomenon knowledge at that time. It has been followed by several other SB and led to decrease the Rev Unlock rate to under 0.05 events per 1000 Engine Flight Cycles.

However, this rate has been rising again in the last 2 years, as highlighted on Figure 1.

3 | Thrust Reverser system description

The CFM56-5C Thrust Reverser is hydraulically commanded. Each pivoting door is motioned by an actuator and secured in closed position by a locking system.

The selection of the Thrust Reverse mode sends hydraulic pressure, which opens the locking system and deploys the pivoting doors actuators.

The locking system is composed of 2 mechanical retention means (Fig 2):

The primary lock

It is the main locking element. It consists of a rotating cam located on the Thrust Reverser's forward frame, which hooks on a roller fitting fixed on the pivoting door.

The secondary lock

It ensures that the door stays closed in case the primary lock fails.

It is composed of 4 integrated "locking fingers" located in the pivoting door actuator body.

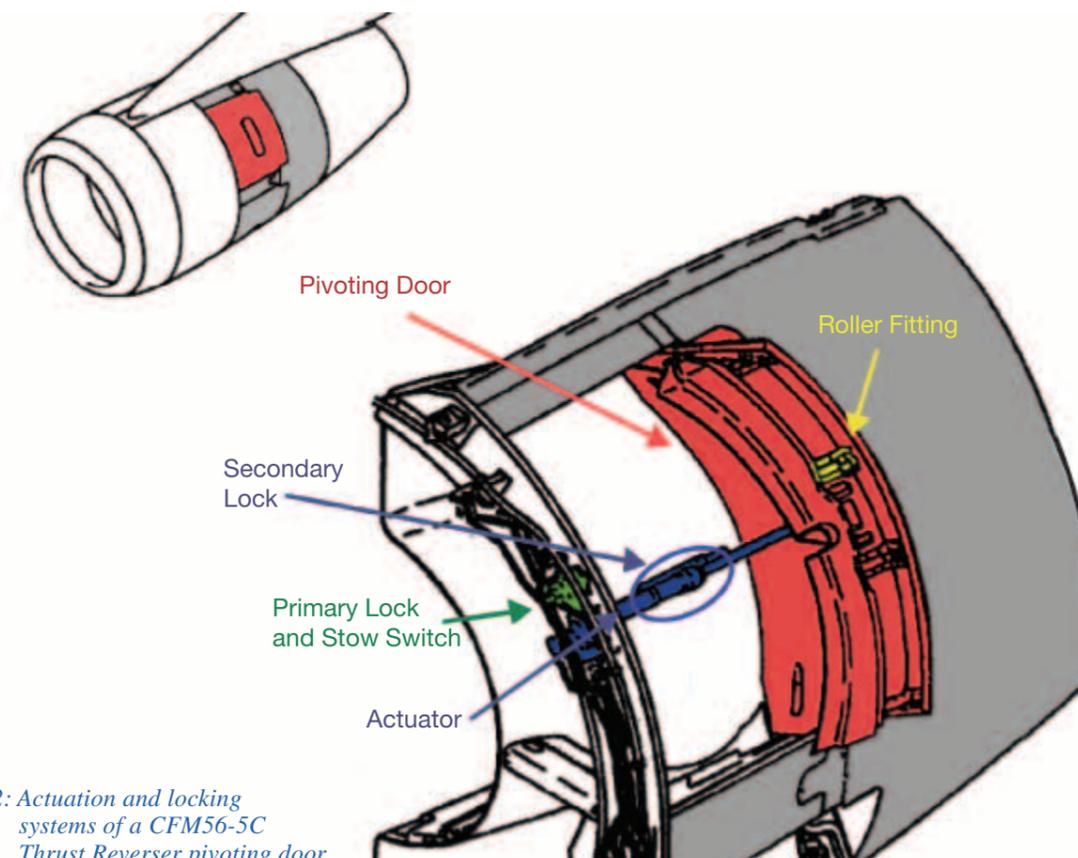


Fig 2: Actuation and locking systems of a CFM56-5C Thrust Reverser pivoting door





4 | “ENG X Rev Unlocked” root causes

When the locking system is not pressurized, the secondary lock is engaged, ready to retain the actuator in its almost full-retracted position. If the primary lock fails, the door will extend slightly above the flush position before the secondary lock engages. In that case, the stow switch sensor is released (Fig 3), which leads to the generation of an “**ENG X REV UNLOCKED**” warning on the ECAM.

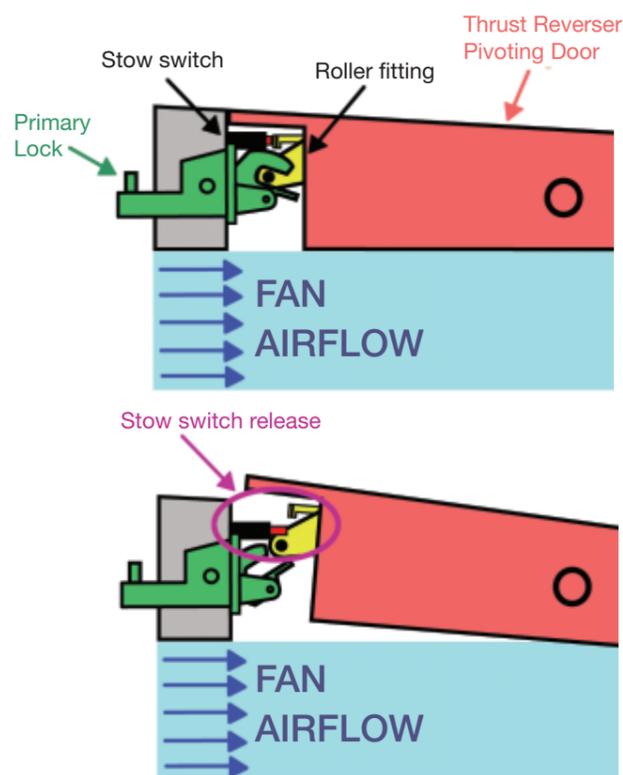


Fig 3: Release of the stow switch with Primary lock open

The continuous feedback from the operators allowed identifying that the primary lock rotating cam can fail to hook the roller-fitting due to:

- An insufficient actuator stroke;
- An incorrect rigging of the roller fitting;
- A primary lock contamination, which can prevent the rotating cam from moving freely;
- An undesirable hydraulic pressure spike in the actuation system, which can prevent the primary lock from hooking completely.

5 | Operational impact and maintenance actions

The above-described root causes usually lead to an unstable position of the primary lock between open and closed position. This unstable position switches to the open position (secondary lock activated) during the following flight due to engine acceleration/vibration. In most cases this happens during the takeoff run. An “**ENG X REV UNLOCKED**” warning is triggered and the crew performs a Rejected Take Off.

Maintenance will find a pivoting door ajar on the affected engine. Pushing the door back in its closed position will engage the primary lock and clear the issue for the next takeoff. But as the root cause has not been addressed it is likely that an “**ENG X REV UNLOCKED**” will appear after some thrust reverser actuations.

This is why troubleshooting has to be done in accordance with Ref. D or E in order to find the root cause and to apply the appropriate corrective action.

If the need to operate the aircraft does not allow any troubleshooting, the Thrust Reverser should be deactivated as per the MEL (Ref F).

6 | Preventive maintenance and permanent solution

The various investigations emphasized the importance of adhering to several maintenance practices in order to prevent the “Rev Unlocked” events.

CFM/Goodrich have released the Best Practices Manual (BPM) in January 2005.

It has proven to be very effective when applied at every C-check, but it was only applied by 25% of the operators.

To ensure a fleet-wide application, the BPM has been included in a Service Bulletin (Ref C) that is referenced as a scheduled maintenance task at each ‘C’ in the MPD (ref. H).

In addition to those practices, a final solution will introduce a set of improvements to the locking system by addressing the above root causes. See also ref. G for further information.

7 | Conclusion

Airbus permanent effort on the “Rev Unlocked” warning has eliminated the spurious triggering known from the early days of the A340-300.

Today, the majority of the events are due to actual Thrust Reverser door unlocks. Therefore:

- Adhere strictly to the ECAM procedure, which instructs to select idle on the affected engine, even if that engine has already been automatically reduced to idle by the FADEC;
- Apply proper troubleshooting before the next flight to avoid re-occurrence, or deactivate the Thrust Reverser if you can not complete the troubleshooting;
- Perform preventive maintenance, in the form of a MPD task every ‘C’ check, to minimize the operational interruptions due to “Rev Unlocked” events.

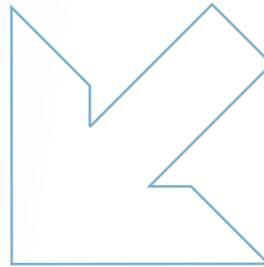
REFERENCES

- A) SB RA34078-27
- B) SB RA340A78-56
- C) SB RA34078-88
- D) TSM tasks 78-31-00-810-967/968/969/970
- E) Goodrich AOL A340/CFM56-04-047 REVISION 1
- F) MEL 78-30-01
- G) TFU 78.30.00.052
- H) MPD task 783241-C4-1





Residual Cabin Pressure



By: Michel PALOMEQUE
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A318/A319/A320/A321 program

1 | Introduction

This document intends to describe the experience regarding the in service residual cabin pressure, the consequences and the different scenarios for this residual cabin pressure.

For that purpose, a short review of the system is presented.

It will further describe the procedures and actions already in place to cover these scenarios from the operational point of view (FCOM) and training.

Then, it will introduce the new safety enhancements, which have been developed to allow the automatic release of this residual cabin pressure when in manual pressure mode by an automatic opening of the outflow valve and also the logics for a new red ECAM warning in case of residual cabin pressure.

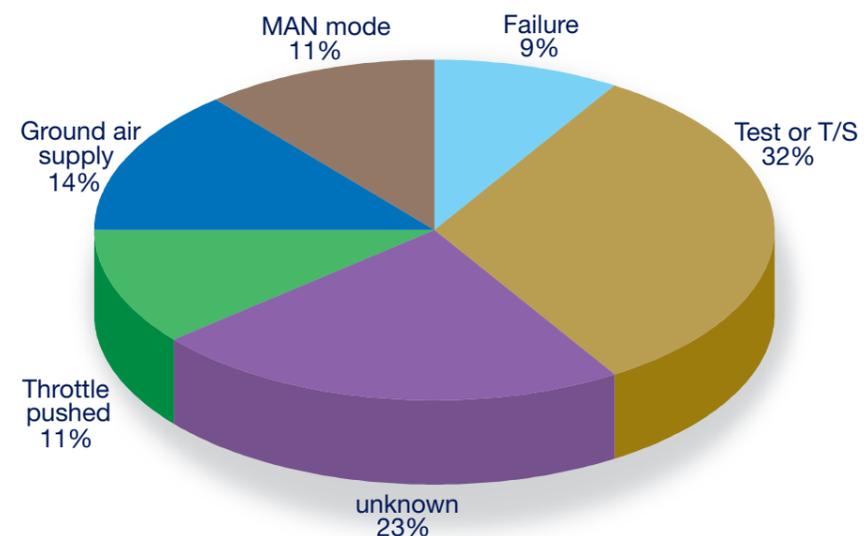
2 | In service experience

In service experience shows that several events of residual cabin pressure have been reported and led to violent door opening with potential for serious injuries.

Most of the cases have been reported on A300 and were related to ground tests or ground air cart supplying the aircraft, where ground mechanics opened a cabin door while the aircraft was still pressurized.

Nevertheless, the latest events resulted from misapplication of the Manual mode procedure after landing:

These events have driven the safety enhancements, which have been developed for the Flight By Wire (FBW) aircraft.

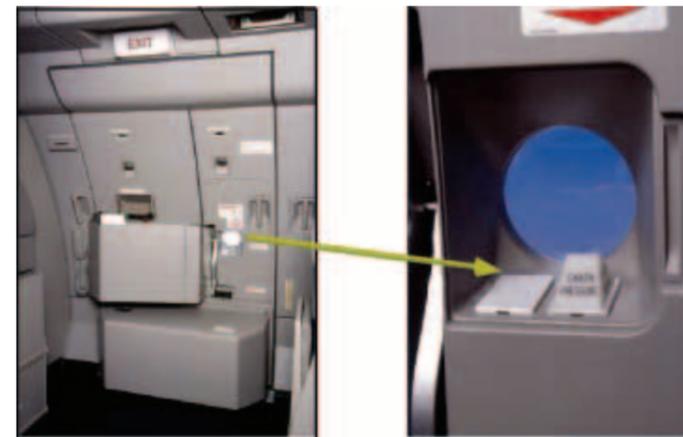


3 | Cabin pressure review

3.1. RPWS (Residual Pressure Warning System)

In case of cabin residual pressure differential, a warning light flashes red at each door, as long as $Dp > 2.5$ hPa, provided that one engine (two on A340) is stopped and the slide is not armed at this door.

This Residual Pressure Warning System (red light) is basic on A320 Family & A330/A340.



RPWS does not cover all the scenarios; it remains inhibited if:

- The slides are still armed (emergency evacuation) or
- Engines are running.

In addition, the RPWS is only a passive protection; it also relies on cabin crew compliance to procedures.

3.2. Cabin pressure system

The following generic principles apply to all AIRBUS A/C :

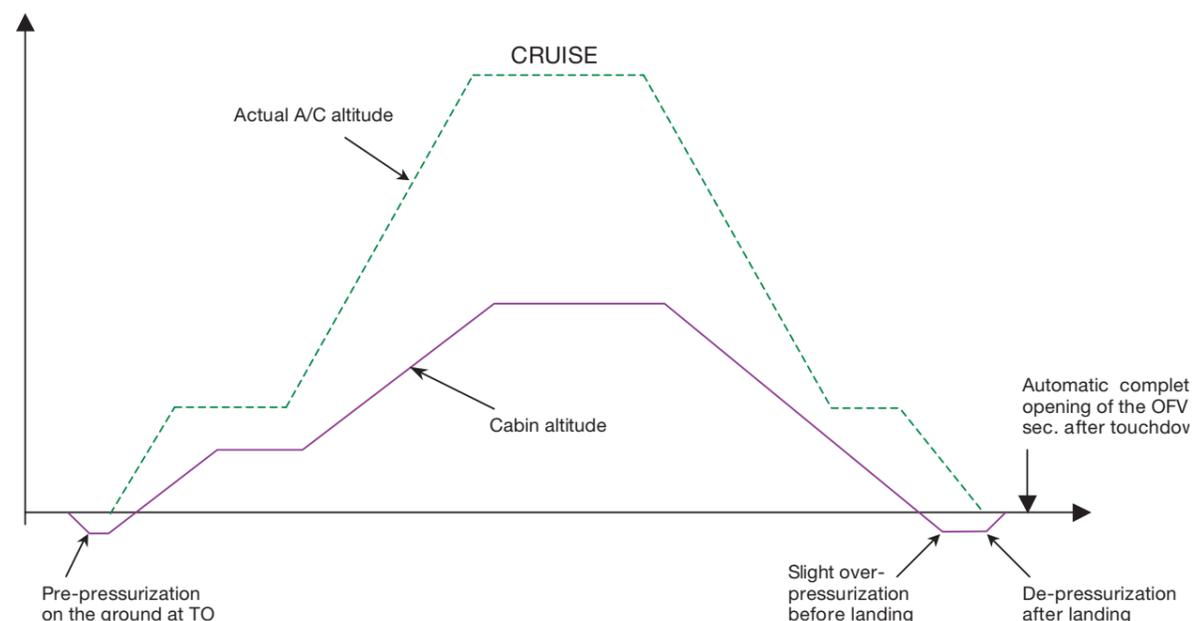
a) Control and regulation of the cabin altitude:

The cabin altitude is managed and controlled by a semi or fully automatic system, which ensures seamless and rate-limited changes of the cabin altitude as the A/C climbs or descends, with an absolute limitation at 8000 ft maximum cabin altitude. This system performs the management and control of the internal cabin (in fact, cabin, cockpit, cargo) air pressure by tuning at each moment the position of outflow valves (OFV), which let air escape from the cabin.

In case of failure of the automatic systems, the crew must ensure the cabin pressure management manually, thanks to direct control of the outflow valves at slow closing or opening speeds, by means of an UP / DN control switch: UP for cabin altitude up (open OFV), DN for cabin altitude down (close OFV).

Should the cabin altitude exceed limits: positive: about + 8.8 PSI above external ambient pressure, negative: about - 1 PSI below external ambient pressure, safety valves will open to protect A/C structure and passengers/crew.





b) Typical cabin pressurization schedule on the ground and in flight:

This chart identifies the characteristic phases of the automatic A/C cabin pressurization schedule, in particular those which may participate to a residual cabin pressure build-up on the ground:

- Pre-pressurization on the ground at TO (to avoid slight pressure bump at A/C rotation, due to the high angle of attack and air cushion effect on the aft OFV, which would cause reverse airflow entering the cabin through the OFV);
- Slight over-pressurization before landing (for the same reason as above);
- De-pressurization after A/C touchdown;
- Automatic control of the complete opening of the outflow valves x seconds after A/C touchdown.

c) Cockpit sliding windows:

Each AIRBUS A/C has cockpit-sliding windows, which may be opened to cope with some emergency situations (for instance, smoke removal). They may be used to depressurize the A/C, but their opening is possible only if Delta P is below a certain value (typically, 0.2 PSI at 180 kt), due to the force exerted on them because of the Delta P.

d) Cabin fuselage drain valves :

A number (approximately 15) of piston-type drain valves are fitted along the bottom line of the fuselage, to drain condensation water or other fluid leaks. They close when ΔP between the cabin pressure and the outside ambient air pressure exceeds a certain value (between 1 and 2 PSI, i.e. 70 to 140 hPa). But their effective section is small (about 50 mm² each).

3.3. Operational cases where a residual cabin pressure may develop

- RTO followed by an emergency evacuation:

the A/C is still pressurized (for instance, 15 hPa on WB, and 7 hPa on SA & LR). The level of residual ΔP at A/C stop will depend on several factors:

- Whether or not the CPCS is still electrically supplied and functioning with necessary inputs (like landing gear signals which may be lost) to send the OFVs opening control signals;
- Whether or not the system integrity is sufficient (possible OFV damage, loss of elec power, ...) and if yes, whether or not enough time is left for the control (x sec. after touch down) of an effective full OFV opening.

Notes:

* If the crew is not disabled, as said earlier, they can open the cockpit sliding windows for A/C depressurization, but this is possible only if ΔP is < 0.2 PSI.

* In an emergency evacuation situation, the door slides will be kept armed, so the local warnings at each door (RPWS), signalling a residual cabin pressure > 2.5 hPa, will not be given.

- At landing, in case of runway overrun or lateral excursion followed by an emergency evacuation:

the ground depressurization sequence may not be complete, (or even not performed in case of landing gear damage with flight / ground signals lost), or, if the outflow valves remain closed

because of A/C damage, a slight ΔP may be kept (if the CPCS was in auto mode, ~10 hPa or less). Obviously, if the erroneous landing field elevation selector was not in auto, and an erroneous selection was set, a larger ΔP may exist and a significant amount of time may be necessary for A/C depressurization.

Notes: same as above for RTOs.

- After use of the MAN mode:

(i.e. emergency descent or CPCS failure), bad or incomplete application of the ECAM or QRH procedure during landing / A/C return to gate on A/C not yet having the automatic outflow valve opening on the ground in MAN mode. (in the same conditions as above, on A/C equipped with automatic outflow valve opening on the ground in MAN mode, failure of this function).

- Non deliberate selection of the DITCHING function:

- Untimely DITCHING control signal;
- DITCHING mode used (e.g. for AEVC reset on the A320) then not de-selected after use. A cabin ΔP will build up if valves are fully or partially closed, doors are closed, and airflow enters the cabin.

- A/C operation under MEL condition:

the aft valve must be closed, and more time is needed for the A/C depressurization on the ground, particularly if the operational procedure is not followed (sel. one pack OFF immediately after A/C touch down).





4 | Review of the FCOM procedures in manual mode

In case of dual system failures, an ECAM warning is triggered and a procedure requests to control manually the cabin pressure.

In addition, the system page will show that the system 1 & 2 are inoperative.

This manual control is done through the MAN V/S CTL.

Depending on the failure mode, it is possible that this procedure may not allow the depressurization. In any case, it is clearly requested through a caution to check that delta P is zero before opening doors.

If for any reason, there is still significant cabin pressurization, it is possible to refer to the cabin overpressure procedure. (Only on the A320 family, due to single outflow valve configuration - paper procedure)



During flight crew training concerning an emergency evacuation, the accent is put particularly on the aborted takeoff following an engine fire or an APU fire. The check of the delta P is highlighted: The delta P should be at zero before the evacuation order is given to the cabin crew

Cabin crew training:

The training for cabin crew highlights that before opening any passenger door, the cabin crew has to check the cabin pressure indicator.

He/she must inform the cockpit crew if the red light flashes.

Before any opening of the door, he/she must hold the door assist handle.

If, on ground, in auto mode, few minutes after landing (3 minutes on A330/A340) the outflow valve is not fully open, "CAB PRESS OUTFLOW VALVE NOT OPEN" ECAM warning is displayed: It requests to open it in manual mode, or to switch off the packs if unsuccessful.

5 | Safety enhancement: modification description

2 modifications have been launched, both for A320 family and A330/A340, to cope with cases of inappropriate compliance of the procedures in manual mode after landing.

5.1. Automatic outflow valve opening in manual mode

This ground logic unit is an electronic box containing hardwired-programmed logic

It will be supplied from the DC ESS bus, and will force the automatic opening of the outflow valves on the ground in cabin pressure manual mode, or in failure cases. It drives 2 relays, one per outflow valve, to provide electrical power directly to their manual mode electrical motor, taking over their control.

So this new function will mitigate against the hazard of flight crew using the MAN pressure mode in flight and then not following the FCOM procedure after landing, i.e. fully open the OFVs. It will take over the control of the OFV automatically by means of providing electrical power directly to their manual motors using external relays.

It will also mitigate against the hazard of maintenance personnel being interrupted in the accomplishment of a pressurization test on the ground, or CPCS failure / power supply cut-off.

This new device is installed on A320 family aircraft through modification 34673 / SB 21-1154 and

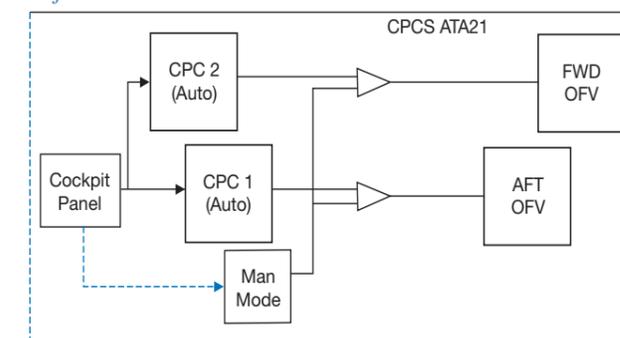
on A330/A340 through modification 53145:

SB 21-3113 for A330
SB 21-4122 for A340 basic
SB 21-5021 for A3456

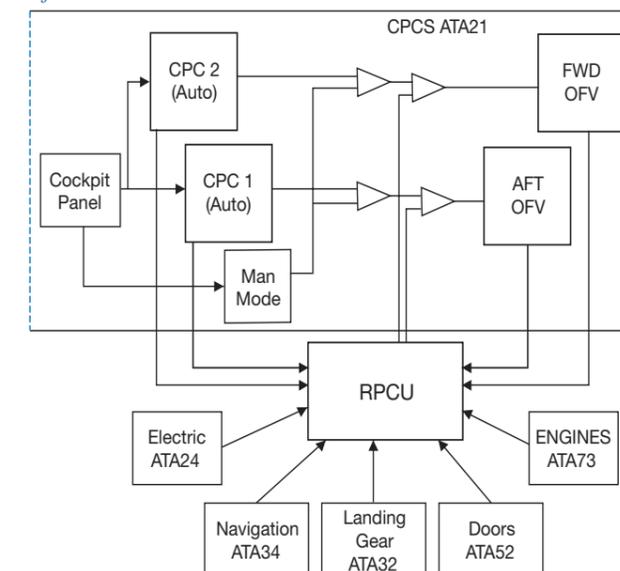
Wiring:

SB 21-3112 for A330
SB 21-4121 for A340
SB 21-5020 for A3456

Before Mod.



After Mod.



The logic for the RPCU is as follows:

Briefly, each outflow valve will fully open if:

- Landing gear shock absorbers compressed or parking brake applied;
- Thrust levers is in TO position;
- No engine is running above idle and no ADIRS delivers $V_c > 70$ kt;
- The valve is in MAN control and both CPCs are in stby;
- The valve angle is $< 100^\circ$



5.2. New red ECAM warning in case of residual cabin pressure independent of the pressurization system

In addition to this hardware device, a new red ECAM warning has been created in case of impossibility to release the cabin pressure (blanket, manual motor jam, misapplication of the manual procedure...):

CAB PR EXCES RESIDUAL PR

The first table shows the existing procedure in case of residual cabin pressure.

Flight phase 7	Flight phase 8	Flight phase 9	Flight phase 10
Status proc if Auto Sys 1+2 fault: DURING FINAL APPR: - V/S CTLFULL UP		if Auto Sys 1+2 fault: CAB PR SYS 1+2 FAULT (amber caution) - MODE SELMAN - MAN V/S CTLAS RQRD Status proc when MAN mode is selected: .1.1.1 MAN CAB PR CTL => Selection of cab alt target	
		If OFV position is between 85 % and 95 % opening: CAB PR (amber caution) OUTFLOW VALVE NOT OPEN - MODE SELMAN - MAN V/S CTL FULL UP . IF UNSUCCESSFULL: - PACK 1 OFF - PACK 2 OFF	

In case of excessive cabin residual pressure after engines OFF, on ground for more than 7 seconds, CAB PR EXCES RESIDUAL PR red warning will be activated after a time delay of 5 seconds. The ΔP sensor used for this new warning is that of the RPWS. The tables here below show the ECAM procedures without and with this new red ECAM procedure.

The second table shows the ECAM procedure with the FWC logic in case of residual cabin pressure.

		Flight phase 8 aircraft stop	
OFV open	Residual cabin pressure	RED WARNING: CAB PR EXCES RESIDUAL PR - PACK 1.....OFF - PACK 2.....OFF - CABIN CREW.....ALERT	
	No residual cabin pressure	No monitoring necessary	
OFV not open	Residual cabin pressure	CAB PR OUTFLOW VALVE NOT OPEN - MODE SELMAN - MAN V/S CTR ...FULL UP . IF UNSUCCESSFULL: - PACK 1.....OFF - PACK 2OFF	RED WARNING: CAB PR EXCES RESIDUAL PR - PACK 1.....OFF - PACK 2.....OFF - CABIN CREW.....ALERT
	No residual cabin pressure	CAB PR OUTFLOW VALVE NOT OPEN - MODE SEL.....MAN - MAN V/S CTL.....FULL UP . IF UNSUCCESSFULL: - PACK 1.....OFF - PACK 2.....OFF	

New red warning
Existing amber caution

This new red ECAM warning is available for

- A320 family with FWC H2F3 (A318 PW certification)through modification
 - Modification 35220/ SB 31-1267
- A330/A340 with FWC through modification
 - Mod 52306/ SB 31-4083 for A340/ 200-300
 - Mod 51973 / SB 31-5015 for A340/ 500-600
 - Mod 51790 / SB 31-3066 for A330





6 | Conclusion |

In service experience shows that several events of residual cabin pressure have been reported and led to violent door opening with potential for serious injuries.

Most of the cases have been reported on A300 and were related to ground tests or ground air cart supplying the aircraft, where ground mechanics opened a cabin door while the aircraft was still pressurized.

The latest events resulted from misapplication of the Manual mode procedure after landing:

In case of dual pressure system failures, an ECAM warning is triggered and a procedure requests to control manually the cabin pressure.

In addition, the system page will show that the system 1 & 2 are inoperative.

This manual control is done through the MAN V/S CTL.

In any case, several procedures are in place in order to allow the release of the residual cabin pressure, if any. In addition, it is clearly requested through a caution to check that delta P is zero before opening doors.

In case of cabin pressure double failure, the procedures must be followed up to the end (manual opening of the outflow valve and control of the cabin pressure on ground).

To cope with non compliance with the above manual procedures, 2 new modifications have been developed for FBW aircraft: the outflow valve opens automatically on ground, and an ECAM warning warns of residual cabin pressure.

Both modifications are installed and activated on production aircraft.

Even if it is always possible for a customer to ask for the non-embodiment of these safety enhancements on a brand new aircraft, in particular the installation of the RPCU, it is Airbus position that both modifications will bring an additional safety net.

Consequently, Airbus highly recommends the installation of the RPCU and of the relevant FWC, as described here below:

Automatic opening of the outflow valve even in manual mode when on ground.

It will be supplied from the DC ESS bus, and will force the automatic opening of the outflow valves on the ground in cabin pressure manual mode, or in failure cases

This new device is installed on

- A320 family aircraft through modification 34673 / SB 21-1154 and
- A330/A340 through modification 53145: SB 21-3113 for A330, SB 21-4122 for A340 basic, SB 21-5021 for A3456

New red ECAM warning in case of residual cabin pressure

In case of excessive cabin residual pressure on ground 7 seconds after engines OFF, CAB PR EXCES RESIDUAL PR red warning will be activated. The ΔP sensor used for this new warning is that of the RPWS.

This new red ECAM warning is available for

- A320 family with FWC H2F3 (A318 PW certification) through modification . Modification 35220/ SB 31-1267
- A330/A340 with FWC through modification Mod 52306/ SB 31-4083 for A340/ 200-300, Mod 51973 / SB 31-5015 for A340/ 500-600, Mod 51790 / SB 31-3066 for A330



Cabin Operations Flight Operations Briefing Notes

A Tool For Cabin Operations Safety Enhancement



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Cabin Operational Standards, Customer Services

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Manager Flight Operations Safety Enhancement, Customer Services

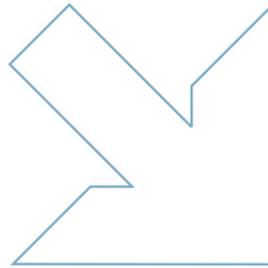
1 | Introducing the Flight Operations Briefing Notes Concept

The Flight Operations Briefing Notes (FOBN) have been designed to allow an **eye-opening** and **self-correcting** accident-prevention strategy. Since 2004, the effort has aimed at covering the entire flight profile and at addressing the main threats and hazards to flight operations safety:

- Standard operating procedures (e.g.: **Conducting effective briefings**, ...),
- Human Performance (e.g.: **Error management**, ...),
- Operating environment (e.g.: **Bird strike threat awareness**, ...),

- Adverse weather operations (e.g.: **Optimum Use of Weather Radar**, ...),
- Runway and surface operations (e.g.: **Preventing runway incursions**, ...),
- Supplementary techniques (e.g.: **Preventing altitude deviations**, ...),
- Takeoff and departure operations (e.g.: **Revisiting the stop or go decision**, ...),
- Descent management (e.g.: **Energy Management**, ...),
- Approach techniques (e.g.: **Flying stabilized approaches**, ...),
- Landing techniques (e.g.: **Crosswind landings**, ...),

In 2006, the very first Flight Operations Briefing Notes addressing threat and hazards to **cabin operations** safety have been released.



2 | Cabin Operations Domain

This new Cabin Operations domain of the Flight Operations Briefing Notes has been created to meet the respective needs of cabin crewmembers first, then of flight crewmembers and of other flight operations personnel.

The cabin operations domain provides an overview of the following aspects that need to be understood and mastered in order to enhance cabin operations safety:

- **Effective Briefings for Cabin Operations**
- **Crew Communication**
- **Dangerous Goods**
- **Ground Operations Safety**
- **Cabin Smoke Awareness**
- **Managing In-Flight Fires**
- **Ditching**
- **Decompression**
- **Turbulence**
- **Planned Ground Evacuation**
- **Unplanned Ground Evacuation**
- **Precautionary Evacuation**

Cabin crew managers and training instructors should review, customize (as required) and implement the recommendations, guidelines and awareness information, in the following domains:

- Cabin operational documentation
- Training
- Information (Cabin crew bulletins, Airline's safety magazine articles, Classroom lectures; and/or Stand-alone reading).

Line cabin crew should review and compare the recommendations, guidelines and awareness information with their current practices and enhance their techniques and awareness level, as required.

The cabin operations domain is an ideal complement of the **Getting to Grips with Cabin Safety** brochure released in 2005.

Such safety awareness references provide operators with guidance to implement their own cabin safety program.

Where to consult/download them?

The Flight Operations Briefing Notes and all other safety and operational expertise publications (e.g. Getting to Grips with ...) are regularly released on the Flight Operations Portal, which can be found in the secure area of www.airbusworld.com.



If you have access rights, go to «Secure area» (top left of home page) / «Customer login» / «Flight Operations (Home)» (on left). To obtain access rights, contact your IT administrator or refer to «Registration information» (top left).

The Flight Operations Briefing Notes are also released on the Safety Library room of the Airbus Safety First website http://www.airbus.com/en/corporate/ethics/safety_lib/

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Hypoxia an Invisible Enemy

Cabin depressurization effects on human physiology



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This article first appeared in **FAST** issue 38

When public air transportation first became commonly available, flights did not reach altitudes that represented a significant risk of reduced oxygen supply - called hypoxia - to either passengers or crew. However, in the late 1940s and 1950s aircraft were developed that allowed safe transport of the flying public at altitudes around 40,000ft, which have remained relatively constant since then.

DEFINITIONS OF HYPOXIA

Hypoxia is separated into four types:

- *Hypoxic hypoxia* is a condition caused by reduced barometric pressure, affecting the body's ability to transfer oxygen from the lungs to the bloodstream.
- *Histotoxic hypoxia* can be induced by the introduction of substances like alcohol or drugs into tissue, reducing its ability to accept oxygen from the bloodstream.
- *Hypaemic hypoxia* (or *anaemic hypoxia*) is a result of the blood being unable to carry oxygen, e.g. caused by exposure to carbon monoxide.
- *Stagnant hypoxia* results from the body's inability to carry oxygen to the brain, which can result from high gravity-forces causing blood to pool in the lower extremities of the body.

1 | Introduction

Operating at high altitude without adequate understanding, training or equipment protection can be dangerous as shown by the following extracts from two accident reports:

'One of the first encounters with the dangers of high altitude flight was reported in 1862 when a balloon flight was made to study the effects of low ambient pressure. The balloon ascended to approximately 29,000ft and during the flight a series of "strange" symptoms, notably loss of visual and hearing capability, paralysis of arms and legs, and finally, unconsciousness occurred. The team could have been lost, but was saved by one member pulling the balloon valve rope with his teeth (his arms were already paralysed), to descend the balloon. The team recovered as the balloon descended, but this marked for the first time the risk of low ambient pressure.'

'In 1998 a decompression incident occurred on an aircraft at 35,000ft. Both the captain and the first officer had received altitude-chamber training during their previous military careers and knew about the effects of low cabin pressure. The first officer attempted to control the cabin rate of climb by switching to the standby pressurization system. When use of the standby system failed to improve

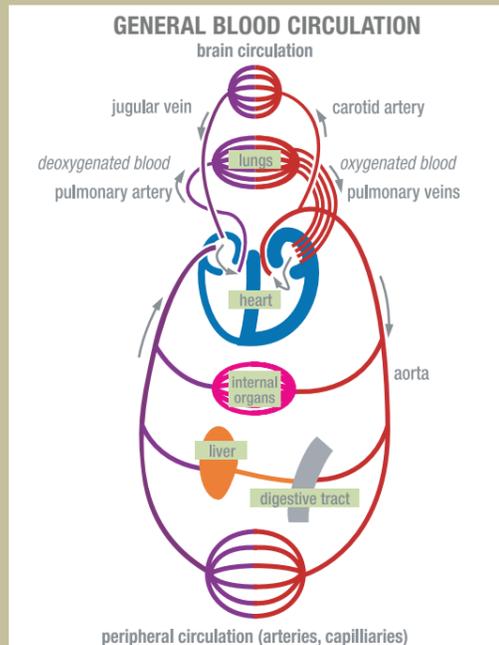
the situation, he donned his oxygen mask. The captain, who had been talking with a passenger who was visiting the flight deck, attempted to don his oxygen mask too, but in doing so he knocked his glasses to the floor. When trying to retrieve them he lost consciousness and slumped forward. The first officer attempted to help the captain but was unable to do this, so initiated a descent to 25,000ft. A short time later the first officer asked the senior flight attendant to assist the captain. To enter the flight deck the flight attendant had to remove her oxygen mask connected to the fixed cabin oxygen system. She decided not to use the portable oxygen equipment and went straight to the flight deck. Before being able to assist the captain she collapsed onto the floor. Once again, the first officer attempted to put on the oxygen mask for the captain, this time successfully. Soon afterward, the captain regained consciousness and was unaware he had been unconscious, which is a typical reaction from a victim of hypoxia.'

2 | The hypoxia effects of a quick cabin depressurization

During a quick depressurization the partial pressure of oxygen in the lungs/alveolae reduces rapidly with the effect of reverse diffusion. This means that once the oxygen partial pressure in the alveolae has reached a level that is below the level in the blood, the blood oxygen moves out of the body back into the ambient air. This effect of reverse diffusion unfortunately further reduces the already very limited oxygen storing capability of blood and supports hypoxia effects. Holding of breath cannot stop the reverse flow since the pulmonary gas expansion would lead to serious lung injury.

Human physiology

Within the lungs the alveola provide the interface between air and blood. The blood which is returned from the body tissue into the alveolae has given away most of its oxygen so that the oxygen partial pressure in the lungs is higher than in the arriving blood. A process of diffusion then drives oxygen through the thin alveolar wall into the blood.



The most important parameters for the oxygen diffusion process are the oxygen percentage and barometric ambient pressure. Changing these parameters changes immediately the oxygen saturation level in blood and with it the oxygen supply to the body tissue. Unfortunately, there is no significant storage of oxygen in the human body, unlike many other chemical substances necessary to maintain life. The blood is the only storehouse for oxygen, and its capacity is very limited. Hence, the human body lives only a hand-to-mouth existence with its oxygen supply.

As the pressure of air in the atmosphere decreases with increasing altitude, the partial pressure of oxygen in the air reduces and with it the diffusion of oxygen into the body. Reduction of oxygen availability in the body results in loss of functions ranging from slight impairment up to death. It is the nervous system, in particular in the higher centres of the brain, and the eyes which have a high metabolism with no oxygen reserve. These are most sensitive to oxygen depletion and therefore are the first to be affected by a reduced oxygen supply.

For healthy persons altitude exposure up to 15,000ft is usually not hazardous since cardiovascular and respiratory compensatory mechanisms (faster breathing and increased pulse rate/blood circulation) act to maintain adequate oxygenation at the cellular level.

The effects of reduced oxygen supply to the body (hypoxia) vary between persons, depending on health, physical fitness, age, activity level and statistical scatter with the population. Pilots and flight attendants usually require more oxygen during an emergency than healthy, seated passengers and might therefore suffer earlier from hypoxia effects.



** Dalton's Law
(1766 -1844)*

In 1801, the English astronomer and chemist, John Dalton, discovered the pressure relationship among gases in a mixture. Dalton's Law states that the pressure exerted by a mixture of gases is equal to the sum of the pressures that each would exert if it alone occupied the space filled by the mixture.

Severe hypoxia caused by a significant reduction in cabin pressure is very dangerous for flight crew because:

- The victims of hypoxia rarely notice that they are about to pass out.
- Usually there is quickly a loss of critical judgment
- Most victims often experience a mildly euphoric state
- Thinking is slowed, muscular coordination is impaired

The only effective means of protection is the quick donning of oxygen masks as the first action - before troubleshooting!



Early type of shaped oxygen mask for passengers

3 | Oxygen partial pressure

The concentration of oxygen in the atmosphere is constant at 20.95% at altitudes up to 100,000ft, which means that according to Dalton's Law* the oxygen partial pressure at sea level is 212mbar (20.95% of 1013mbar where 1013mbar is the standard atmospheric pressure at sea level).

As altitude increases above sea level the partial pressure of the component gases decreases consistent with the decrease in total atmospheric pressure. For example, the partial pressure of oxygen at 40,000ft is reduced to 39mbar only, which is far too inadequate to support human metabolism.

One means to increase oxygen partial pressure is to increase the oxygen concentration in breathing air. At 40,000ft cabin altitude an oxygen partial pressure of maximum 188mbar can be achieved by breathing pure oxygen (100% oxygen concentration without overpressure).

Another additional means for hypoxia protection is positive pressure breathing, which is usually found in modern crew oxygen masks and means the delivery of pure oxygen under pressure into the respiratory tract. For civil applications positive



Current oxygen mask for passengers

pressure breathing is able to increase additionally the oxygen partial pressure by around 20 to 30mbar provided that the overpressure condition is limited to some minutes only. This means that at 40,000ft it requires 100% oxygen concentration of the breathing gas combined with positive pressure breathing to achieve sea level equivalent conditions. Positive pressure breathing requires some training and is tiring and inconvenient, which is the rationale for having so far provided this protection feature to flight crew only (for short time use only).

4 | Time of Useful Consciousness

In the 'World of Hypoxia' the Time of Useful Consciousness (TUC) is a very important parameter. For low ambient pressure conditions it indicates the time available to perform purposeful activities, such as oxygen mask donning or aircraft control. Beyond this time frame mental and physical capabilities are dangerously impaired and finally result in unconsciousness and potentially death.

As shown in the table on the right, TUC is negatively correlated with altitude. It is important to note that even if activities are performed within the TUC time frame there is a significant deterioration of work rate and mental capability, which is correlated with the time spent at low pressure conditions (at the end of the TUC time frame, performance is much lower than at the beginning).

The TUC is the 'Window of Opportunity' for donning an oxygen mask and can be very limited so must take overriding precedence over any other activities.



Mask straps inflated

Mask in place



*Flight crew oxygen mask **

5 | Time of Safe Unconsciousness

Some experts believe that for passengers - in contradiction to the flight crew - a short period of unconsciousness during cabin depressurization can be tolerated since they are not performing an operational task. Unconsciousness is a clear sign of insufficient oxygen supply to the brain and it is obvious that this time can only be very short before permanent brain damage occurs. So far, it has not been possible to associate a specific time frame for the safe time of unconsciousness.

The uncertainties in extrapolation of animal data and the wide variability in individual tolerances have so far prevented determination of a commonly agreed value for Time of Safe Unconsciousness (TSU) among human physiology experts. It is believed that a safe time of unconsciousness is somewhere between 90 seconds and 4 minutes.

TIME OF USEFUL CONSCIOUSNESS

- 20,000ft All unacclimatized persons lose useful consciousness within 10 minutes
- 25,000ft Useful consciousness is lost after 2.5 minutes or less
- 30,000ft TUC: approx. 30 seconds
- 37,000ft TUC: approx. 18 seconds
- 45,000ft TUC: approx. 15 seconds

These data on TUC are averaged values based on tests with healthy individuals when breathing ambient air (no supplemental oxygen provided). A large individual variation in the effects of hypoxia has been found. There is evidence that TUC is shorter for people exposed to stress conditions.

* Manufacturer EROS

6 | Oxygen equipment on civil aircraft

On modern aircraft oxygen equipment is installed to provide adequate protection against the damaging effects of hypoxia in case of cabin depressurization:

For flight crew there are usually quick donning oxygen masks installed, which can be donned with one hand in less than 5 seconds. The mask straps are combined with elastic tubes that inflate and stiffen when the mask is taken from its stowage, allowing the mask to be easily put over the head with one hand. Once the grip on the mask is released, the tubes deflate and their elastic characteristics ensure a perfect fit. The required oxygen concentration of the breathing air is automatically adapted to the cabin pressure.

For the passenger oxygen supply the continuous flow concept is used on all Airbus aircraft. Oxygen is delivered continuously to an expandable oxygen bag where it is conserved during exhalation, so it is available during the next inhalation to supplement the steady oxygen flow.

It was decided at an early stage in passenger oxygen mask development that the untrained civilian population should not be expected to recognize the correct orientation for a shaped mask, and it was required that a mask should be operable in any position in which it might be donned by the user. A second basic requirement was a universal size, which finally defined the well-known cylindrical mask body.

Effect on human physiology of moderate cabin altitude

Very large numbers of aircrew and passengers have been exposed to breathing air at cabin altitudes up to 8,000ft over the last 60 years without significant deleterious effects. Although exposure to this altitude reduces the oxygen partial pressure in the pulmonary tract the tissues of the body are maintained well above the required level.

Some airlines still allow smoking in the aircraft cabin, which results in carbon monoxide inhalation with the smoke. Carbon monoxide has a 240-times greater tendency than oxygen to attach to red blood haemoglobin, thus inactivating a large amount of haemoglobin as an oxygen carrier. It has been found that the hypoxia effects from carbon monoxide and altitude are additive; hence chronic smokers are at a higher equivalent altitude than non-smokers in terms of blood oxygen supply.

Also, alcohol poisons body tissues in such a manner that they cannot use oxygen properly. Usually, it is noticed by passengers that the physiological effect of alcohol consumed during flight is more intense than at sea level, which is due to the additive hypoxia effects of alcohol and altitude.

Extract of the prime requirements

GENERAL

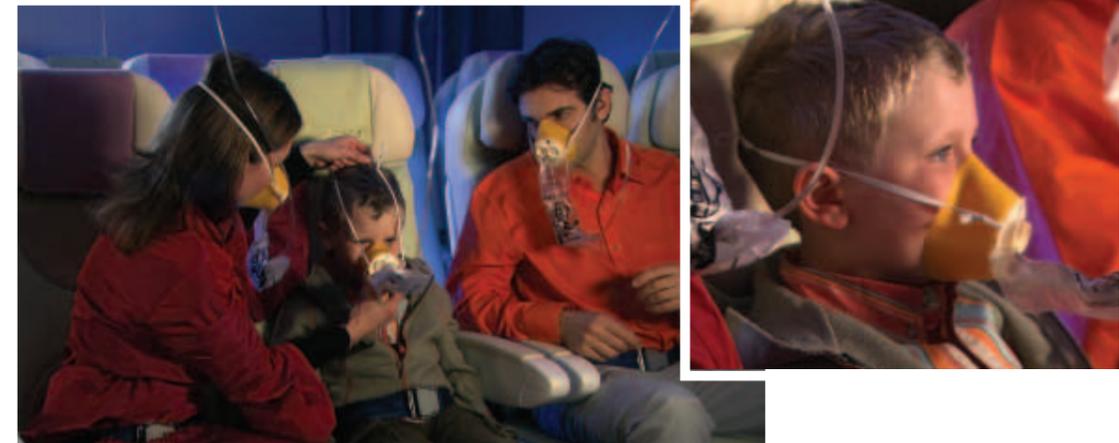
- CS/FAR 25.841 (a): Maximum cabin pressure altitude under normal operation: 8,000ft
- CS/FAR 25.841 (a): Maximum cabin pressure altitude after any probable failure condition in the pressurization system: 15,000ft
- FAR 25.841 (a) (2) (i): Maximum exposure time to cabin pressure altitude exceeding 25,000ft: 2 minutes
- FAR 25.841 (a) (2) (ii): Exposure to cabin pressure altitude that exceeds 40,000ft: Not allowed

CABIN OCCUPANTS

- CS/FAR 25.1443 (c): Provides oxygen system performance data on oxygen flow and required partial pressure of oxygen
- CS/FAR 25.1447 (c) (1): The total number of masks in the cabin must exceed the number of seats by at least 10%
- CS/FAR 25.1443 (d): Defines oxygen flow for first-aid oxygen equipment (for cabin depressurization treatment)
- JAR OPS 1.760/FAR 121.333 (e) (3): Requires first-aid oxygen for at least 2% of passengers
- JAR OPS 1.770 (b) (2) (i)/FAR 121.329 (c): Defines the percentage of passengers that need to be provided with supplemental oxygen (cabin pressure altitude dependent)

FLIGHT CREW

- CS/FAR 25.1443 (a) & (b): Provides oxygen system performance data on oxygen flow and required partial pressure of oxygen
- CS/FAR 25.1447 (c) (2) (i): For aircraft operating above 25,000ft quick donning oxygen masks are required for the flight crew which can be donned with one hand within 5 seconds
- FAR 121.333 (c) (2) (i) (A): One flight crew member needs to wear permanently his oxygen mask when the aircraft is operated above FL410
- FAR 121.333 (c) (3): In case one flight crew member leaves the controls the remaining pilot needs to use his oxygen mask when the aircraft is operated above 25,000ft



7 | Airworthiness requirements

The Airworthiness authorities have identified the risk of hypoxia and have created requirements (see table on the left).

Also, after an accident in the USA the FAA initiated a Special Certification Review (SCR) on pressurization systems. The SCR recommends that the aircraft flight manual (for aircraft certified for flights above 25,000ft) require in the emergency procedures the donning of oxygen masks as the first crew action after a cabin altitude warning.

This highlights again the importance of immediate donning of oxygen masks when cabin depressurization occurs.

8 | Conclusion

The first step for any flight crew member faced with cabin depressurization should be the immediate donning of an oxygen mask. Any delay in donning a mask will significantly increase the risk of losing consciousness before cabin pressure is regained. Severe hypoxia leads usually to the loss of critical judgement combined with a mildly euphoric state,

which makes hypoxia very dangerous for flight crew. This is highlighted also in the FAA Special Certification Review that was issued some years ago on the effects of cabin depressurization.

Moreover, in case of rapid cabin depressurization a quickly accomplished emergency descent is often the only means of fast re-oxygenation of passengers that were unable to protect themselves against hypoxia by using the passenger oxygen masks provided. Severe hypoxia is very dangerous for unprotected passengers and requires a quick return to an adequate cabin pressure or where not possible (above high terrain), it requires a check by the flight attendants that the passenger oxygen masks are correctly used.

For a long time transport aircraft have been equipped with oxygen systems for flight crew and passengers that provide an adequate protection against hypoxia. As long as these oxygen systems are used according to their simple procedures the invisible enemy hypoxia poses little danger to flight crews and passengers.

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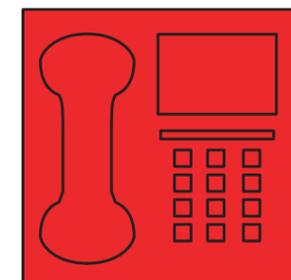
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