



# Residual Cabin Pressure



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## 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.

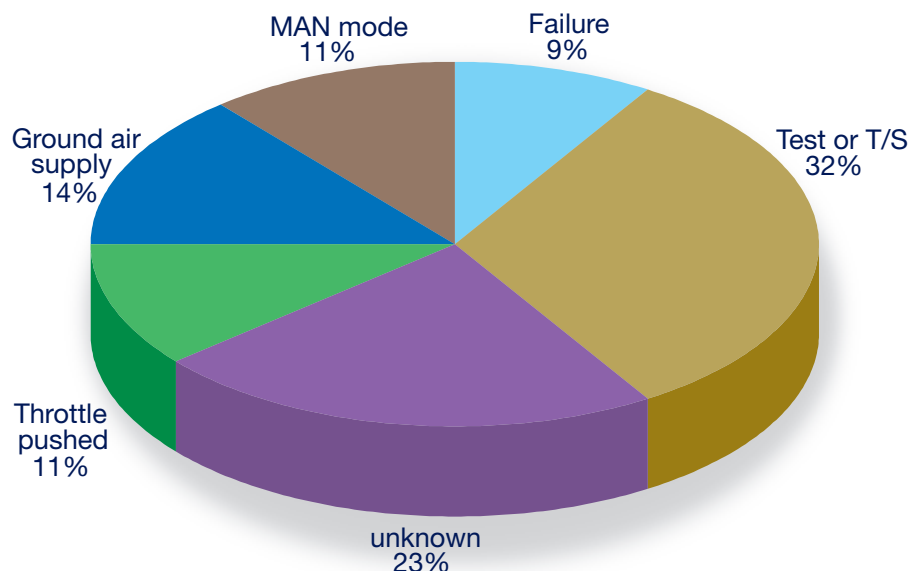
## 2 | In service experience |

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 scenarii; 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

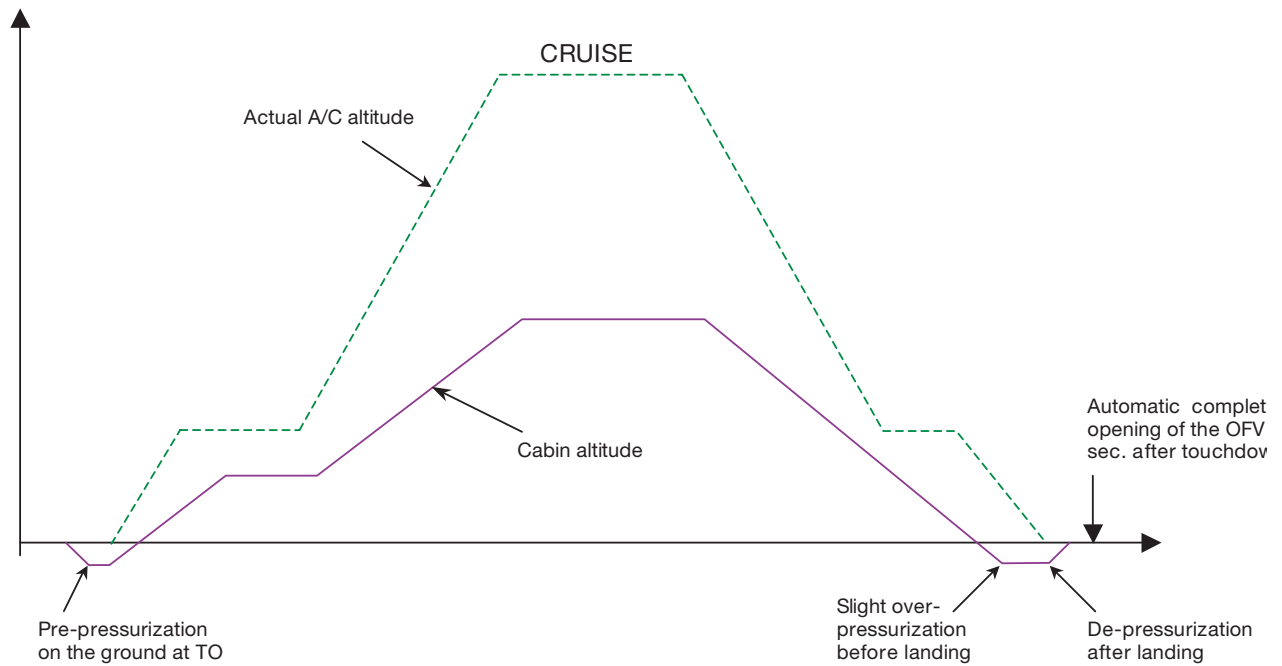
The following generic principles apply to all AIRBUS A/C :

#### 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  $\Delta P$  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 mm<sup>2</sup> 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  $\Delta P$  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  $\Delta P$  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  $\Delta P$  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  $\Delta P$  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.

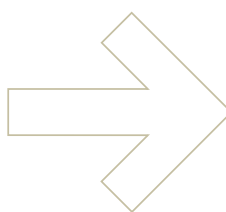
(in the same conditions as above, on A/C equipped with automatic outflow valve opening on the ground in MAN mode, failure of this function).

#### - *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  $\Delta P$  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

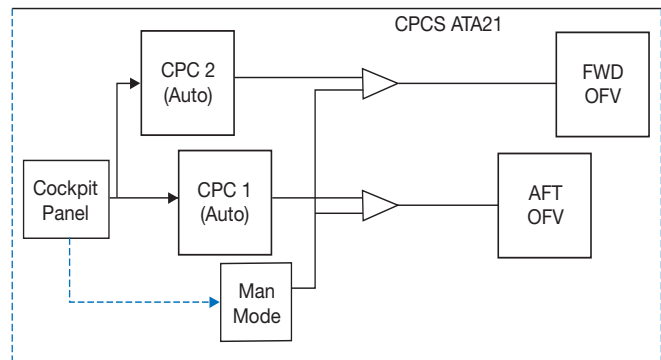
on A330/A340 through modification 53145:

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

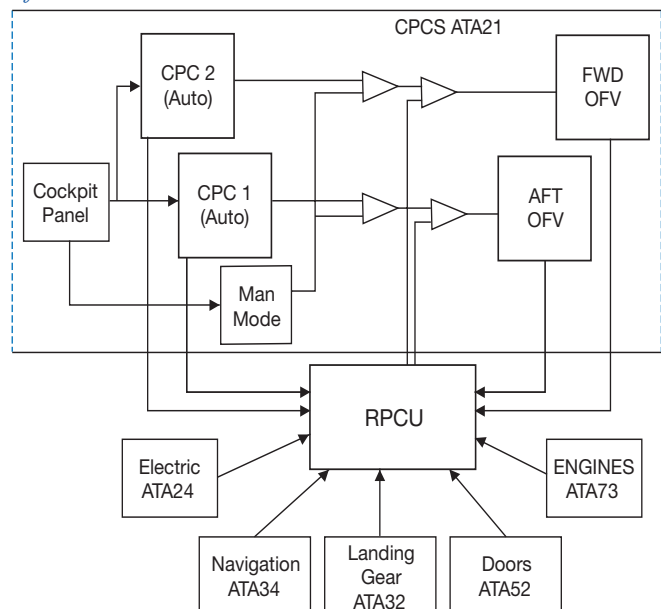
#### Wiring:

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

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  $\Delta P$  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 first table shows the existing procedure in case of residual cabin pressure.

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

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    | <b>RED WARNING:</b><br><br><b>CAB PR EXCES RESIDUAL PR</b><br><br>- PACK 1.....OFF<br>- PACK 2.....OFF<br>- CABIN CREW.....ALERT                                   |                                                                                                                                  |
|              | No residual cabin pressure | No monitoring necessary                                                                                                                                            |                                                                                                                                  |
| OFV not open | Residual cabin pressure    | <b>CAB PR OUTFLOW VALVE NOT OPEN</b><br><br>- MODE SEL .....MAN<br>- MAN V/S CTR ...FULL UP<br>. IF UNSUCCESSFULL:<br>- PACK 1.....OFF<br>- <b>PACK 2 .....OFF</b> | <b>RED WARNING:</b><br><br><b>CAB PR EXCES RESIDUAL PR</b><br><br>- PACK 1.....OFF<br>- PACK 2.....OFF<br>- CABIN CREW.....ALERT |
|              | No residual cabin pressure | <b>CAB PR OUTFLOW VALVE NOT OPEN</b><br><br>- MODE SEL.....MAN<br>- MAN V/S CTL.....FULL UP<br>. IF UNSUCCESSFULL:<br>- PACK 1.....OFF<br>- <b>PACK 2.....OFF</b>  |                                                                                                                                  |

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

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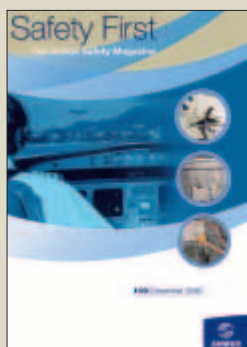
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