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Study on CS-25 Cabin Safety Requirements

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#### STUDY ON CS-25 CABIN SAFETY REQUIREMENTS

Issue 6

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5	Oct 2009	Final Report – incorporation of comments
6	Dec 2009	Final Report – minor editorial amendments

#### CONTENTS

Executive Summary4				
List of	Abbreviations5			
1	Introduction6			
2	Overview of Methodology7			
3	Literature and Data Search			
	<ul> <li>3.1 Regulatory documents</li></ul>			
4	Brainstorming Session			
5	Initial Evaluation of Threats12			
6	Detailed Evaluation of Threats and Threat Groups13			
7	Recommendations- Minor Amendments to CS-25 Cabin Safety Requirements15			
8	Recommendations- Potential Major Amendments to CS-25			
9	Recommendations- Further Research19			
10	Summary of Other Recommendations27			
11	Conclusions			
12	References			
Appendix 1 – List of CS-25 Requirements and Advisory Material Pertinent To Cabin Safety				
Appen	dix 2 – Rulemaking Documents Pertinent To Cabin Safety			
Appen	dix 3 – Summary of the Review of Certification Documents			
Appen	dix 4 – List of Relevant Accidents (1998-2007)			
Appen Annen	dix 5 – Cabin Salely Threats Not Within CS-25 Cabin Salely Remits dix 6 – Cabin Salety Threats For Mitigation by Operations Requirements			
Appendix 0 – Cabin Safety Threats For Mitigation by Operations Requirements Appendix 7 – Cabin Safety Threats Adequately Addressed by CS-25 Requirements or Having No Practical Mitigation Methods				
Appendix 8 – Cabin Safety Threats Evaluated in Detail				
Appendix 9 – Cabin Safety Threats Resulting in Recommendations for Minor Amendments to CS-25				
Attachment 1 – RIA: Power Supplies for Public Address, Interphone and Evacuation Alert Systems				
Attachment 2 – RIA: Occupant Protection from Post-Crash Fire and Smoke				
Attach	ment 3 – RIA: Requirements for Fire Protection in Remote/Isolated Compartments Not Permanently Occupied During Flight			
Attachment 4 – RIA: Reliability of the Emergency Flight Deck Access System Attachment 5 – RIA: 'Return to Seat' Sign and Intelligibility of Public Address Systems in Areas Where the Occupants are Not Normally Seated				
Attachment 6 – RIA: External Viewing Means Attachment 7 – RIA: Passenger Emergency Exit Locator Sign				

#### EXECUTIVE SUMMARY

This study has been commissioned by the European Aviation Safety Agency and is aimed at identifying both current Cabin Safety threats as experienced in aircraft accidents and future threats that may result from changes in technology. The study also reviews recent difficulties that may have been experienced in the certification of aircraft with respect to Cabin Safety issues. An assessment was made of the adequacy of the current requirements of CS-25 at Amendment 6 in addressing the identified threats and certification issues. Recommendations are then made as to any changes to the airworthiness requirements that might be required. Alternate routes for addressing the identified threats (e.g. amendments to operational rules, ETSOs, etc.) are also identified together with any future research that might be required.

The study involved a literature search of Cabin Safety research, rulemaking, and certification documentation. An analysis was carried out of 326 relevant accidents, over the period 1998-2007, selected from the Cabin Safety Research Technical Group Accident Database Issue 32, to identify Cabin Safety Threats. A brainstorming session with Cabin Safety Experts from Europe, the United States and Canada was carried out to identify potential future Cabin Safety threats.

The study identified in total 235 Cabin Safety Threats. Of these, 25 were considered to be not within the remits of CS-25 Cabin Safety requirements, 30 were considered likely to be mitigated more effectively by improvements in operational requirements (including crew training and procedures), 65 were considered to be already adequately addressed by CS-25 or having no practical mitigation methods.

The detailed evaluation of the remaining 115 Cabin Safety Threats resulted in:

- 7 recommendations for potential major amendments to CS-25 requirements
- 31 recommendations for further research on various subjects and
- 14 recommendations for other improvements to regulatory material including amendments to CS-25 guidance material, ETSOs etc.

The 7 recommendations for potential major amendments to CS-25 requirements were subjected to Regulatory Impact Assessments. These are included as attachments to this report.

A general review of the Cabin Safety requirements of CS-25 was also carried out resulting in a recommendation for 7 proposed minor amendments to CS-25.

It is concluded that improvements could be made to the Cabin Safety requirements in CS-25 (at Amendment 6) that might enhance the safety of the passengers and crew. In addition, some changes could also be made to CS-25 that might simplify the certification process without adversely affecting the level of safety. However, there are some threats that require research, prior to any amendments to CS-25, in order to ascertain the extent of the threats and to investigate potential mitigation methods.

#### LIST OF ABBREVIATIONS

AC	Advisory Circular (FAA)
AD	Airworthiness Directives
AMC	Acceptable Means of Compliance (EASA)
CAR	Canadian Aviation Regulations
CRD	Comment Response Document
CRI	Certification Review Item
CRS	Child Restraint Systems
CS	Certification Specification
EASA	European Aviation Safety Agency
ELOS	Equivalent Level of Safety (FAA)
ESF	Equivalent Safety Findings (EASA)
ETSO	European Technical Standard Order
FAA	Federal Aviation Administration (United States)
FAR	Federal Aviation Regulations (United States)
ICAO	International Civil Aviation Organization
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
JTSO	Joint Technical Standard Order (JAA)
MPS	Minimum Performance Standards
MTOW	Maximum Take-Off Weight
NPA	Notice of Proposed Amendment (EASA)
NPRM	Notice of Proposed Rulemaking (FAA)
PA	Public Address (system)
PSU	Passenger Service Unit
RIA	Regulatory Impact Assessment (EASA)
SAE	Society of Automotive Engineers
SC	Special Condition
SFAR	Special Federal Aviation Regulations (United States)
TCCA	Transport Canada Civil Aviation
TSB	Transportation Safety Board (Canada)
TSO	Technical Standard Order (FAA)
UNEP	United Nations Environment Programme

#### 1 INTRODUCTION

Cabin Safety is a field that aims to reduce fatalities and injuries resulting from an aircraft accident and provide for a safe environment for passengers and crew members throughout all phases of flight. The field addresses in-flight issues such as turbulence, decompression, and in-flight fire, as well as post-crash survivability, which includes structural crashworthiness, occupant protection from impact, emergency evacuation, post-crash fire protection, and overwater survival. Any factor that can affect the protection afforded to occupants in this respect has the potential to become a potential threat. The primary aim of this study is to identify those threats and assess whether they are adequately mitigated by the Cabin Safety requirements of CS-25.

The airworthiness requirements of CS-25, FAR 25 and CAR 525 address Cabin Safety issues in large transport aeroplanes. These requirements require continual amendment to reflect new technology developments, resolve compliance difficulties, and address safety concerns resulting from in-service incidents and accidents.

This study has been commissioned by the European Aviation Safety Agency and is aimed at identifying both current Cabin Safety threats as experienced in aircraft accidents and future threats that may result from changes in technology. The study also reviews recent difficulties that may have been experienced in the certification of aircraft with respect to Cabin Safety issues. An assessment was then made of the adequacy of the current requirements of CS-25 at Amendment 6 in addressing the identified threats and certification issues. Recommendations are then made as to any changes to the airworthiness requirements that might be required. Alternate routes for addressing the identified threats (e.g. amendments to operational rules, ETSOs, etc.) are also identified together with any future research that might be required.

#### 2 OVERVIEW OF METHODOLOGY

The methodology adopted in this study is illustrated in Figure 1. Figure 1 also references the sections of the report that provide a more detailed description of the methods adopted and the results of the evaluations carried out during the study.

The study was carried out in four phases, however references to the phase in which each part of the study was carried out is excluded from this Final Issue of the report for reasons of clarity.



Figure 1 Overview of methodology and the associated sections of the report

#### 3 LITERATURE AND DATA SEARCH

The main purpose of the literature and data search was to identify current and potential future Cabin Safety Threats by a detailed review of regulatory documents, accident data and Cabin Safety research. Documentation was also accumulated throughout the study to assist in the analysis of Cabin Safety Threats. The majority of the literature and data sources were acquired from the in-house library, accident database and internet searches. All documents referenced in this study will be made available to EASA upon request.

The Literature and Data Search included the following:

#### 3.1 REGULATORY DOCUMENTS

Cabin Safety requirements in CS-25 and associated Advisory Material.

The study was based on CS-25 Amendment 6. Appendix 1 lists the requirements pertinent to Cabin Safety as agreed with EASA, relevant Acceptable Means of Compliance (AMC) and associated FAA Advisory Circulars (AC).

Rulemaking documents including Regulatory Impact Assessments (RIA), Notice of Proposed Amendments (NPA), associated Comment Response Documents (CRD) issued by EASA, and Notices of Proposed Rulemaking (NPRM) documents issued by the FAA.

The primary sources for collecting the regulatory documents were EASA website (Reference 1) and the US FAA Regulatory and Guidance Library website (Reference 2). Appendix 2 lists the rulemaking documents pertinent to Cabin Safety.

Certification documents relevant to Cabin Safety requirements:

EASA documents- Certification Review Item (CRI) documents issued by EASA, Interpretative Material, Means of Compliance, Equivalent Safety Finding (ESF), Deviations.

FAA documents- Special Conditions- Equivalent Level of Safety Finding (ELOS), Exemptions, Special Conditions and Policy Memos.

The primary sources for acquiring the certification documents were EASA and the FAA Regulatory and Guidance Library website (References 1 and 2 respectively). A summary of the subjects addressed by these certification documents and their associated applicable requirements are contained in Appendix 3.

#### 3.2 ACCIDENT DATA

The data source used to compile the list of accidents pertinent to Cabin Safety was the Cabin Safety Research Technical Group Accident Database Issue 32 (Reference 3). Survivable or potentially survivable accidents, which occurred over the period 1998-2007, to western-built, turbine-powered large transport aeroplanes type certificated to CS/FAR/CAR 25, were selected having one or more of the following characteristics:

In-flight safety occurrence (fire/smoke, upset, turbulence, depressurisation, etc.)

Emergency landing or impact on ground or water

Evacuation

There were 326 accidents that met these criteria having sufficient textual information on the database to enable an evaluation to be made of the Cabin Safety Threats. The full list of accidents is attached as Appendix 4 to this report.

Safety recommendations issued by the investigating organisations were also recorded and were used in the evaluation of Cabin Safety Threats.

#### **3.3 CABIN SAFETY RESEARCH, SAFETY STUDIES AND BENEFIT ANALYSES.**

Cabin Safety literature was collected from reputable sources on the Internet and the inhouse library. The literature used in this study is referenced in the appropriate sections of this report and the Regulatory Impact Assessments.

#### 4 BRAINSTORMING SESSION

A brainstorming session, held at EASA offices in Cologne on the 17 February 2009, was attended by Cabin Safety specialists from European Airworthiness Authorities, a representative from Transport Canada, and a representative from the US FAA. The purpose and methodology of the study was presented to the participants and a listing provided of the Cabin Safety Threats identified from the Literature and Data search. All participants were asked to propose Cabin Safety Threats that they perceived had been omitted from the original listing generated from the Literature and Data search giving particular emphasis to those that might be more prevalent on future aircraft designs.

This session identified 30 current and future Cabin Safety Threats not identified from the literature search and data analysis.

#### 5 INITIAL EVALUATION OF THREATS

An analysis of the literature and data identified in Section 3 was carried out to identify current and future Cabin Safety Threats. The literature search identified 40 Cabin Safety Threats, the accident data analysis and brainstorming session identified a further 165 and 30 respectively. Thus in total 235 Cabin Safety Threats were identified.

Of these 25 were clearly not within the remit of CS-25 Cabin Safety requirements. The majority of these related to Rescue & Firefighting, Environmental Conditions, Fuel characteristics, etc. Although some of these threats do relate to CS-25 requirements, they are outside of those agreed with EASA as being Cabin Safety related – as contained in Appendix 1. A list of the threats considered as being outside of the CS-25 Cabin Safety requirements, and the source from which they were identified, is contained in Appendix 5.

A further 30 Cabin Safety Threats were considered to be best mitigated by operational requirements, including crew training and procedures. These Cabin Safety Threats are listed in Appendix 6.

Of the remaining Cabin Safety Threats, 65 were considered to be adequately addressed by current CS-25 Cabin Safety requirements, or considered to have no practical mitigation methods. These Cabin Safety Threats are listed in Appendix 7, which also contains a short rationale for each, that explains how they are adequately addressed by CS-25 or have no practical mitigation means.

The remaining 115 Cabin Safety Threats were evaluated to determine:

- Those that might have common mitigation methods or common applicable requirements. These Cabin Safety Threats were evaluated as a <u>Threat Group</u>.
- The remaining Cabin Safety Threats were evaluated individually as an <u>Individual</u> <u>Threat.</u>

Of the 115 Cabin Safety Threats 104 were grouped into 23 Threat Groups and the remaining 11 were evaluated individually. All were subjected to detailed evaluation as described in Section 6.

#### 6 DETAILED EVALUATION OF THREATS AND THREAT GROUPS

The 11 individual Cabin Safety Threats and 23 Threat Groups were evaluated in detail considering the following aspects:

- Current applicable CS-25 Requirements and Associated Regulatory Material (Operational Requirements, Foreign Requirements, etc).
- Accident experience and Safety Recommendations based on the accident review carried out in this study and pertinent accidents identified by the literature review.
- Research relevant to the subject.
- Rulemaking Activities by EASA and the FAA

As part of this evaluation a general review was also carried out on the Cabin Safety requirements of CS-25 at amendment 6 and the associated advisory material (see Appendix 1). From this review recommendations were made for minor amendments to the requirements.

For each of the 11 individual Cabin Safety Threats and 23 Threat Groups evaluated, conclusions and recommendations were made as to the need to amend CS-25. In some instances there may be more than one recommendation associated with each Cabin Safety Threat or Threat Group.

These recommendations fall into four categories:

- Recommendations for Minor Amendments to CS-25 see Section 7.
- Recommendations for Major Amendments to CS-25 see Section 8.
- Recommendations for Further Research see Section 9.
- Other<sup>1</sup> Recommendations see Section 10.

The evaluation sheets for the Cabin Safety Threats and Threat Groups are contained in Appendix 8 of this report and are listed below:

- 1. Unavailability of Power Supplies to Internal Communication Systems in Emergency Situations page A8-2
- 2. Issues Associated with Secured Flight Deck Doors page A8-9
- 3. Inability of Cabin Crew to Communicate with Each Other During Emergency Situations page A8-14
- 4. Inadequate Cabin Pressure Indication and Warning page A8-20
- 5. Explosive Door Openings on the Ground page A8-24
- 6. Impact Protection during Flight page A8-27
- 7. Windscreen Fragmentation due to Multiple Birdstrike page A8-33
- 8. Emergency Equipment Not Easily Retrievable or Not Conveniently Located near Cabin Crew page A8-35
- 9. Inadequate Performance or Reliability of Emergency Equipment page A8-38
- 10. General Occupant Safety page A8-40

<sup>&</sup>lt;sup>1</sup> Other Recommendations include potential amendments to guidance material and ETSOs

- 11. Issues Associated with Seat Pitch page A8-44
- 12. Cabin Air Quality and Other Health Issues page A8-48
- 13. Future Considerations for Crashworthiness Standards page A8-55
- 14. Cabin Crashworthiness page A8-58
- 15. Inadequate Seat Floor Strength and Floor Deformation page A8-65
- 16. Restraint Systems and Injury Criteria page A8-72
- 17. Optimum Ditching Parameters Cannot Be Achieved Under Certain Emergency Conditions – page A8-80
- 18. Occupant Protection from Post-crash Fire and Smoke page A8-83
- 19. Oxygen System Protection from In-Flight and Postcrash Fires page A8-90
- 20. In-flight Fires page A8-93
- 21. Fires in Class E Cargo Compartments page A8-103
- 22. In-Flight Fire in Remote or Isolated Compartments page A8-108
- 23. Assist Means Reliability and Design page A8-111
- 24. Exit Door Failures page A8-124
- 25. Evacuees Ability to Find Available Exit in a Dark/Smoke-Filled Cabin page A8-130
- 26. Cabin Crew Station Location page A8-136
- 27. Issues Related to Exits for Cargo Aeroplanes page A8-141
- 28. Evacuation Issues Related to Internal Doors page A8-144
- 29. Minimum Exit Height for Requiring Assist Means page A8-146
- 30. Emergency Exit Marking and Locator Signs page A8-151
- 31. The Use of Internal Stairways During Evacuation page A8-154
- 32. Cabin Crew Unable to Assess External Hazards Prior to Opening Exit page A8-157
- 33. Issues Related to Ditching Doors page A8-160
- 34. Emergency Exit Door Difficult to Latch Open page A8-162

#### 7 RECOMMENDATIONS- MINOR AMENDMENTS TO CS-25 CABIN SAFETY REQUIREMENTS

As part of the Initial Evaluation of Cabin Safety Threats a general review of the Cabin Safety requirements in CS-25 Amendment 6 has been carried out. The results of this evaluation, including a Rationale for the proposed amendment and a Recommendation as to the manner in which CS-25 might be amended, are contained in Appendix 9. Since these proposed amendments are of a minor nature it was not considered necessary to evaluate them by means of a Regulatory Impact Assessment.

Recommendation 1 - Minor Amendment to 25.851(a)(6)

Recommendation 2 - Minor Amendment to 25.1360(b)

Recommendation 3 - Minor Amendment to AMC 25.561(d)

Recommendation 4 - Minor Amendment to CS 25.853(f)

Recommendation 5 - Minor Amendment to CS 25.809(x)

Recommendation 6 - Minor Amendment to CS 25.807(x)

Recommendation 7 - Minor Amendment to CS 25.855

# 8 RECOMMENDATIONS- POTENTIAL MAJOR AMENDMENTS TO CS-25

As part of the Detailed Evaluation, 7 of the Cabin Safety Threats or Threat Groups were considered as potentially involving major amendments to CS-25. As such it was agreed with EASA that they should be subjected to a Regulatory Impact Assessment. The seven issues addressed by Regulatory Impact Assessments are as follows:

- 1) Power supplies for public address, interphone, and evacuation alert systems
- 2) Occupant protection from post crash fire and smoke
- 3) Requirements for fire protection in remote/isolated compartments not permanently occupied during flight
- 4) Reliability of the emergency flight deck access system
- 5) 'Return to Seat' sign and intelligibility of public address systems in areas where the occupants are not normally seated
- 6) External viewing means
- 7) Passenger emergency exit locator sign

These Regulatory Impact Assessments have been produced as stand-alone documents and are attached to this report as Attachments 1 to 7. The following is a summary of the recommendations resulting from the Regulatory Impact Assessments.

# Recommendation 8 – Amending CS-25 to address power supplies for public address, interphone and evacuation alert systems (if fitted)

Given the importance of the availability, during emergency situations, of the service interphone, PA system and evacuation alert system (if fitted), it is proposed that the integrity of the power supplies to these systems should be improved. This will require amendment of CS-25. A new rule will be required for the power supplies to the interphone system and evacuation alert system (if fitted). A revision to the existing rule CS 25.1423 for the PA system may also be required.

(See Attachment 1 - Power Supplies for Public Address, Interphone and Evacuation Alert Systems)

### Recommendation 9 – Amending CS-25 to address occupant protection from post crash fire and smoke

It is concluded that occupant protection during post-crash fire and smoke may need to be enhanced beyond what is currently afforded by CS-25 requirements. The Regulatory Impact Assessment addressed enhanced protection by the use of Cabin Water Mist systems and Passenger Smoke Hoods. However, it is concluded that prior to any regulatory change being made, further research is needed - primarily into the feasibility and cost benefit of introducing Cabin Water Mist systems.

(See Attachment 2 - Occupant Protection from Post Crash Fire and Smoke)

# Recommendation 10 – Amending CS-25 to address fire protection in remote/isolated compartments not permanently occupied during flight

Fire protection provisions, in remote or isolated compartments that are not permanently occupied in flight, are required - usually by Special Conditions. Consideration has therefore been given to amending CS-25 to reflect the fire safety precautions needed in remote or isolated compartments of varying size and location. Since this issue is already addressed by

Special Conditions the incorporation of the requirements into CS-25 will not incur additional costs to aircraft manufacturers, modifiers or operators and certification costs may even be reduced. It is therefore proposed that CS-25 be amended to incorporate a new requirement supported by guidance material to address this issue.

(See Attachment 3 - Requirements for Fire Protection in Remote/Isolated Compartments Not Permanently Occupied During Flight)

## Recommendation 11 – Amending CS-25 to address the reliability of the emergency flight deck access system

The cabin crew's ability to gain emergency access to the flight deck needs to be maintained at all times. Some emergency unlocking system designs utilise the aircraft's main electrical power for it to function, resulting in a risk of the cabin crew being unable to access the flight deck during emergency situations that involve a loss of main electrical power. Since currently the availability of the interphone system is not required to be maintained at all times. this issue will also have the potential to adversely affect the communications/coordination between the flight crew and the cabin crew. Considering that in some scenarios the consequences of not providing such access could be catastrophic, it is proposed that guidance material to CS 25.772(c) is required to ensure adequate emergency flight deck access.

(See Attachment 4 - Reliability of the Emergency Flight Deck Access System)

# Recommendation 12 – Amending CS-25 to address 'Return to Seat' sign and intelligibility of public address system in areas where the occupants are not normally seated

There is no explicit requirement within CS-25 or operational requirements for lavatories or other areas of the cabin occupied by non-seated passengers to have 'Return to Seat' signs. This and the intelligibility of the public address system (if fitted) in those areas may be particularly relevant to very large transport aircraft. Amendments to CS 25.791 and CS 25.1423 are required to ensure that such signs are installed in those areas and that emergency announcements are audible to cabin crew members in any location (e.g. Crew rest areas).

(See Attachment 5 - 'Return to Seat' Sign and Intelligibility of the Public Address System in Areas Where the Occupants are Not Normally Seated)

#### Recommendation 13 – Amending CS-25 to address external viewing means

The Regulatory Impact Assessment addressed the implications of amending CS-25 to require outside viewing means at emergency exits and to specify their minimum performance standards. However, the required level of illumination implied by FAR 25.809(a) needs further deliberation. Additionally, the requirement should not be limited to viewing windows at, or adjacent to, the exits, but should be open to the possibility of using other technologies such as external cameras. The use of external cameras may also improve flight crew awareness of external conditions for safe evacuation. It is therefore concluded that further research is needed prior to any regulatory action being taken by EASA.

(See Attachment 6 – External Viewing Means)

# Recommendation 14 – Amending CS-25 to address passenger emergency exit locator signs

The requirements for emergency exit locator signs have not presented any significant compliance issues for larger transport aeroplanes for commercial use; however, some smaller transport aeroplanes (above 10 passenger seats and up to 20 passenger seats) have experienced difficulties with compliance. The FAA SFAR No. 109 permits the use of a single exit sign to meet the requirements of 25.811(d)(1) and (2) for private use aeroplanes. It is recommended that consideration be given by EASA to review CS 25.811(d) to take into account its practicability for smaller transport category aeroplanes (regardless of their type of operation).

(See Attachment 7 - Passenger Emergency Exit Locator Sign)

#### 9 RECOMMENDATIONS- FURTHER RESEARCH

The following is a summary of the recommendations for further research resulting from the detailed evaluation of the Cabin Safety Threats and Threat Groups. The associated evaluation sheets are contained in Appendix 8 and the page number referenced at the end of each recommendation.

## Recommendation 15 – Research on the introduction of a requirement for the installation of evacuation alert systems

Some aircraft types are already equipped with evacuation alert systems. It is proposed that research be carried out to establish whether operational requirements should include a rule for all, or certain size, CS-25 aircraft to be equipped with these systems.

(See Unavailability of Power Supplies to Internal Communication Systems in Emergency Situations – page A8-2)

### Recommendation 16 – Research on improvements to cabin crew communication systems

The evaluation found that the cabin crew communication systems should be improved to enable more effective communication especially during emergency situations. It is recommended that further research be conducted to investigate the feasibility of the following potential improvements:

- i) Requiring the handsets of interphone systems (if fitted) to be installed at all cabin crew stations and to provide two-way communication amongst cabin crew stations. This may already be installed in most aeroplanes.
- ii) Requiring the public address system (if fitted) to be intelligible in all areas of the cabin.
- iii) The use of radio headsets for all cabin crew.

(See Inability of Cabin Crew to Communicate with Each Other During Emergency Situations – page A8-14)

#### Recommendation 17 – Research on cabin pressure indication and warning

The Helios Airways B737 accident has demonstrated the criticality of flight crew being adequately alerted to cabin altitude warnings. There are indications that the requirement for cabin altitude warnings should be improved from the current minimum standard (flashing light) to an aural signal and flashing light. It may be further beneficial to require a dedicated aural signal or voice signal to prevent confusion with other warnings. However, further research may be required to:

- (i) Ascertain the extent of this problem (i.e. what is the prevalence of similar incidents in other types of aeroplanes), including a survey of current cabin altitude warning systems in in-service aeroplanes.
- (ii) Ascertain the implications of requiring a dedicated aural or voice signal for cabin altitude warnings, on various aspects (e.g. design/maintenance, human factors, operations/procedures, training, etc.).

(See Inadequate Cabin Pressure Indication and Warning – page A8-20)

#### Recommendation 18 – Research on prevention methods for explosive door opening

Although the most current explosive door opening accident (Bombardier CL-600-2B19 at Chicago O'Hare Airport in 2005) could have been prevented by better procedures or communication, explosive door openings have resulted in serious and fatal injuries and there is one outstanding safety recommendation on this subject (A-02-20) that should be reviewed further. Therefore, it was concluded that further research will be required to investigate how explosive door opening occurrences can be prevented and to ensure that any solutions will not adversely affect rapid evacuation and in-flight safety.

(See Explosive Door Openings - on the Ground – page A8-24)

# Recommendation 19 – Research on turbulence detection technology, occupant protection in standing areas during turbulence, trolley restraint devices, and the effectiveness of 'firm handholds' currently provided on in-service aeroplanes

It is recommended that further research and testing be carried out in developing advanced technology for onboard turbulence detection, especially for clear air turbulence, that is affordable to the operators. Consideration should be given by EASA to investigate the feasibility of providing occupant protection in standing areas in the cabin during turbulence. Additionally, an investigation should be carried out on equipment restraint devices, especially for trolleys in use and an investigation on the effectiveness of seatbacks as firm handholds and whether there needs to be actual handholds on the seatbacks/sides.

(See Impact Protection during Flight – page A8-27)

#### Recommendation 20 – Research on windscreen fragmentation due to multiple birdstrike

It was concluded that further research is required to address windscreen fragmentation due to multiple birdstrike. In light of the recent accident to an A320 that ditched in the Hudson River, the relative likelihood of multiple birdstrike events may need to be investigated to ascertain whether extending the requirements to cover multiple birdstrike could be beneficial.

(See Windscreen Fragmentation due to Multiple Birdstrike – page A8-33)

### Recommendation 21 – Research on the effects of seat spacing on the overall dynamics of an evacuation

It is recommended that consideration be given to carrying out a research project to investigate the effects of various seat spacing dimensions on evacuation, not just on the passengers' ease of egress but also on the overall dynamics of the emergency evacuation. The investigation should take into account the projected increasing proportion of elderly people in the flying population and people from the higher body dimension percentile group.

(See Issues Associated with Seat Pitch – page A8-44)

# Recommendation 22 – Research on the economic impacts of a minimum seat pitch rule

The economic impacts of a minimum seat-pitch rule with varying seat pitch dimensions will need to be established if such a rule is to be implemented. The study should include but not be limited to, the number and size of operators adversely affected, and the effects on first cost, operating cost, and passenger fares.

(See Issues Associated with Seat Pitch – page A8-44)

#### Recommendation 23 – Research on cabin air-cleaning equipment

For in-service commercial transport aeroplanes, it is recommended that consideration be given by EASA to assess the need for using air-cleaning equipment (e.g. filters) and the feasibility of such equipment. Liaison with the FAA is strongly recommended.

(See Cabin Air Quality and Other Health Issues – page A8-48)

### Recommendation 24 – Research on the applicability of current crashworthiness standards to aeroplanes with "complex" structures and advanced materials

Materials used in the construction of aeroplanes are likely to continually change and current airworthiness requirements do not appear to cater for this. The definition of "minor crash landing" still needs to be developed to ensure the same level of safety for all aeroplanes of different sizes, configuration and materials.

Therefore, it is recommended that consideration be given by EASA to carry out further research into the appropriateness of current crashworthiness standards.

(See Future Considerations for Crashworthiness Standards – page A8-55)

### Recommendation 25 – Research on the appropriateness of current crashworthiness standards to small all-composite business jets

There is no doubt that development and manufacturing of all-composite business jets will increase in the near future. Therefore, it is recommended that consideration be given by EASA to carry out further research into the appropriateness of current crashworthiness standards to small all-composite business jets.

(See Future Considerations for Crashworthiness Standards – page A8-55)

### Recommendation 26 – Research on the extent of the risk of injuries due to fibres released from damaged composite structures

The injury risk related to fibres from damaged composite structures affecting occupants during evacuation has been identified. However, further research will be required to ascertain the extent of this risk and whether it can be mitigated by improvements in airworthiness requirements.

(See Cabin Crashworthiness – page A8-58)

# Recommendation 27 – Research on the design of overhead bins, their attachments and latches.

Evidence suggests that there is a need to improve the safety standards of overhead bins, which includes crashworthiness (detachment and failure of latches) and design to ensure safety during normal operation. It is therefore recommended that EASA carry out research into the feasibility and cost beneficial aspects of improved design standards for overhead bins, including their attachment and baggage retention both in-flight and post impact. It is also recommended that EASA give consideration to providing design guidelines related to overhead bin safety precautions, as proposed by the JAA in 2003.

(See Cabin Crashworthiness – page A8-58)

## Recommendation 28 – Research on structural designs to ensure retention of seats to the cabin floor

Although the 16g seat requirement would improve attachment of seats to the floor tracks, inadequate cabin floor strength may reduce the benefits of the improved seats. Current CS-25 and FAR 25 requirements state that floors have to be able to withstand impact forces likely to occur in "emergency landing conditions," (i.e. 9g of longitudinal static load). Stronger floors may improve the performance of 16g seats and further enhancements to those seats would likely require improved floor strength. Further research on structural design that can ensure retention of seats, in line with 16g-seat requirements, may be required. Additionally, it is recommended that consideration be given to reviewing the requirement 25.562(b) that excludes flight crew seats.

(See Inadequate Seat – Floor Strength and Floor Deformation – page A8-65)

#### Recommendation 29 – Research on protection from lower limb injuries during impact

Further research is required to investigate the mechanism of lower limb injuries during impact, taking into consideration the latest requirements for occupant protection (seats, restraint systems, etc), in order to ascertain the need for addressing lower limb injury criteria in CS-25.

(See Restraint Systems and Injury Criteria – page A8-72)

# Recommendation 30 – Research on the feasibility of taking into account possible emergency conditions during ditching approval

It is recommended that EASA give consideration to investigating the feasibility of taking into account possible emergency conditions, such as a complete loss of engine power, during ditching approval. Furthermore, the operations manual should include ditching procedures for the emergency conditions considered.

(See Optimum Ditching Parameters Cannot Be Achieved Under Certain Emergency Conditions – page A8-80)

### Recommendation 31 – Research on the explosion risks presented by various passenger emergency oxygen storage systems

It is recommended that research be carried out to establish the explosion risks presented by different passenger emergency oxygen storage systems when subjected to cabin fire or post crash impact. The research should address:-

- 1) A comparison between the risks to occupants presented by gaseous and chemical oxygen systems.
- 2) Whether large (centralised) oxygen storage vessels should be excluded from aircraft.
- 3) Whether large (centralised) oxygen storage vessels should be excluded from the pressure hull.
- 4) Whether small oxygen storage vessels located at each PSU (e.g. B787 & A350) present a greater risk than large (centralised) storage vessels.
- 5) Whether there should be a limit for the total amount of gaseous oxygen carried onboard aircraft. (Effectively requiring chemical oxygen for the passenger compartment.)

(See Oxygen System Protection from In-Flight and Postcrash Fires – page A8-90)

#### Recommendation 32 – Research on various aspects of in-flight fire protection

It is recommended that EASA give consideration to:

- 1) Addressing fire protection in hidden areas in CS-25. It is recommended that EASA continue its participation in the joint efforts of authorities and industries in this area.
- 2) Participating in the research into the likely future threats related to the increasing installation of electrical systems, the use of magnesium alloy seats, the increasing use of lithium batteries and fuel cells, the effect of lower cabin altitude on the risks of in-flight fires, and in-flight flammability properties of non-aluminum aircraft structures. Any efforts made in these areas should correspond with on-going research and initiatives by other authorities and industry.
- 3) Carrying out further research to determine the extent to which Arc Fault Interrupters should be used and the risk of any potential disbenefits that they might exhibit.
- 4) Participating in the research being carried out by the FAA and Transport Canada into providing fire suppression in hidden areas in order to ensure that any future regulatory activity in this area is harmonised with these Authorities.
- 5) Monitoring and participating where appropriate, into research and development into:
  - a. Hidden fire detection systems, for example video cameras in overhead areas and portable thermal detection cameras for use by cabin crew
  - b. Installation of discharge ports for delivering extinguishing agent from a handheld fire extinguisher.

(See In-flight Fires – page A8-93)

# Recommendation 33 – Research on different types of fire suppression systems for use in Class E cargo compartments

It was concluded that further research is required to address the threats related to the absence of a fire suppression system in Class E cargo compartments. It is suggested that further research into fire protection on cargo containers be conducted, including different types of fire suppression systems. Liaison with the FAA in addressing this issue is recommended.

(See Fires in Class E Cargo Compartments – page A8-103)

### Recommendation 34 – Research on the effects of winds and gusts on the slide operation during slide deployment

If other exits are already unavailable due to unforeseen and unavoidable circumstances (e.g. fire outside the exits), slide problems that render the remaining exits unusable can seriously affect occupants' survivability. Therefore, it is very important that the slides be capable of operating properly. Although inadequate maintenance practices or operational checks and crew error might be accountable for the issues encountered in slide/raft operations in service, there is still room for improvement in the design and approval of the system. Most of the issues can be addressed in CS-ETSO but some existing CS-25 requirements may need to be amended, particularly with regard to the slide deployment under high wind conditions. It is recommended that consideration be given by EASA to investigate the actual circumstances addressed by CS 25.810(a)1)(iv) to determine the adequacy of the requirements specifically on the subject of gusts and the effects of winds/gusts on the slide during the deployment and the associated efforts required in stabilising the slide.

(See Assist Means Reliability and Design – page A8-111)

#### Recommendation 35 – Research on slide designs to minimise injuries to evacuees

There are indications that injuries related to the use of the slide during evacuation can be addressed by improvements in slide design. It is therefore recommended that consideration be given by EASA to carry out further research on minimising evacuee injuries related to slide use by taking into account both operational and design aspects (such as minimum/maximum angle and optimum friction), with the intention on providing guidance material.

(See Assist Means Reliability and Design – page A8-111)

# Recommendation 36 – Research on the magnitude of the threats related to exit jamming and its mitigation means

There is evidence that exit jamming during emergency evacuation in the presence of postcrash fires has resulted in fatalities. However, further research is required to ascertain the magnitude of the Cabin Safety Threats related to exit jamming and the degree to which it might be mitigated by amendments to the airworthiness requirements.

(See Exit Door Failures – page A8-124)

### Recommendation 37 – Research on the technologies for locating available exits in low visibility conditions

It is evident that there needs to be a system that can assist passengers in finding available exits in low visibility conditions. Low visibility conditions are often related to the presence of smoke in the cabin that is usually associated with post-crash fire, which makes this issue even more crucial. Various systems that can mitigate this Cabin Safety Threat have been identified. It is recommended that consideration be given by EASA to carry out further research on the technologies that can be used to locate available exits, with or without cabin crew involvement, and their feasibility for emergency evacuation in low visibility conditions.

(See Evacuees Ability to Find Available Exit in a Dark/Smoke-Filled Cabin – page A8-130)

### Recommendation 38 – Research on the possible improvements to monitoring of the cabin area by the cabin crew

There is evidence that the current applicable CS-25 requirements may need to be reviewed to take into account the escalating need for improvements in monitoring the cabin area by the cabin crew. Therefore, it is recommended that consideration be given to carrying out further research, which encompasses the following:

- A survey of current commercial transport aeroplanes may need to be conducted to ascertain how, if applicable, the requirement of CS 25.785(h)(2) has been complied with.
- A review of incidents associated with cabin crew's ability to monitor cabin areas.
- A survey involving cabin crew of very large transport aeroplanes.

(See Cabin Crew Station Location – page A8-136)

### Recommendation 39 – Research to ascertain the magnitude of the threat related to cabin crew location during evacuation and its mitigation methods

Accident experience and studies have shown that cabin crew located remotely from their assigned emergency exits could adversely affect evacuation time. This threat is particularly relevant to some aircraft designs, for example the Fokker 28 and Fokker 100. The NTSB concluded that on these aircraft the aft flight attendant is seated too far from the over-wing exits, the assigned primary exits, to provide immediate assistance to passengers attempting to evacuate through the exits. This situation is not addressed by CS 25.785(h)(1). It is therefore concluded that this threat may need to be addressed by amendments to CS-25 requirements. However, further research may be required to confirm the magnitude of the threat and ascertain how the threat is best mitigated.

(See Cabin Crew Station Location – page A8-136)

### Recommendation 40 – Research to establish the appropriateness of current minimum sill height for requiring an assist means

The evidence available from accidents and research studies suggests that the requirement to jump to the ground from a height of up to  $1 \cdot 8m$  (6 feet) during evacuation, without assist means, may potentially cause serious injury or may delay the progress of an evacuation due to hesitation or unwillingness to jump. It is therefore recommended that further research should be carried out to establish whether the current height is appropriate or whether a lesser height should be specified within CS 25.810(a) and CS 25.810(d).

(See Minimum Exit Height for Requiring Assist Means – page A8-146)

### Recommendation 41 – Research on the adequacy of the terminal edge height measurements with regard to flap positions during evacuation

Since setting the flap position for evacuation is greatly dependent on flight crew action and availability or speediness of the systems for lowering the flaps, further consideration should be given to re-assessing the adequacy of CS 25.810(d) on the subject of the measurement of the height of the terminal edge with the flap in the take-off or landing position.

(See Minimum Exit Height for Requiring Assist Means – page A8-146)

## Recommendation 42 – Research on safety and effectiveness of Type III exits having no foothold

The evidence available shows that small openings such as Type III exits, when located in positions that do not have a foothold such as a wing to step down on to, can be very difficult to exit through. It may therefore be beneficial to carry out research to establish whether this type of exit feature allows safe and expedient egress.

(See Minimum Exit Height for Requiring Assist Means – page A8-146)

## Recommendation 43 – Research on the identification of potential evacuation issues on aeroplanes with multiple stairways between decks

Since multiple stairways between decks are currently only installed on one aircraft type, amendment to CS-25 requirements to address this feature may not be currently necessary and the use of a Special Condition is probably more effective. However, the subject still requires further investigation to identify all potential evacuation issues on aeroplanes with multiple stairways and to ensure that the current certification process is adequate.

(See The Use of Internal Stairways During Evacuation – page A8-154)

# Recommendation 44 – Research on the extent of the risk related to the possible jamming of a sole ditching door on aeroplanes with a passenger configuration of 35 seats or less

It was concluded that the possible jamming of a sole ditching door on aeroplanes with a passenger configuration of 35 seats or less may need to be addressed by amending CS-25 requirements. It is recommended that further investigation be carried out on this subject to assess the extent of the risk of such a scenario.

(See Issues Related to Ditching Doors – page A8-160)

# Recommendation 45 – Research into the causes of difficulties in latching open emergency exits

It is evident that difficulties have been experienced with latching open emergency exit doors during evacuations. The precise reasons are unknown, although it is possible that adverse aircraft attitude may be a contributory factor. It is recommended that further research is carried out into the causes of difficulties experienced in latching open emergency exits.

(See Emergency Exit Door Difficult to Latch Open – page A8-162)

#### **10 SUMMARY OF OTHER RECOMMENDATIONS**

The following is a summary of the recommendations for improvements that are not necessarily related to amendments to CS-25 requirements or further research. These include recommendations to review CS-ETSO, incorporating industry standards, and providing additional guidance material to CS-25. The associated evaluation sheets are contained in Appendix 8 and the page number referenced at the end of each recommendation.

### Recommendation 46 – Recommendation for incorporating industry standards into AMC and providing guidance for emergency equipment location and accessibility

It was concluded that amendments to CS-25 are not considered necessary to mitigate the Cabin Safety Threat associated with accessibility of emergency equipment. However, it is recommended that EASA give consideration to referring to existing industry standards in the AMC, in addition to providing guidelines (e.g. guidance material to CS 25.1411) as to what constitutes "readily accessible", "near to" and "directly accessible and its location is obvious" in the context of the circumstances likely to be present in emergency situations.

(See Emergency Equipment Not Easily Retrievable or Not Conveniently Located near Cabin Crew – page A8-35)

# Recommendation 47 – Recommendation for reviewing CS-ETSO or any other standards recognised by EASA to ensure adequate performance of all emergency equipment

It was concluded that amendments to CS-25 are not considered necessary to mitigate the Cabin Safety Threat associated with inadequate performance or reliability of emergency equipment. However, it is recommended that EASA review the relevant standards specified in CS-ETSO or any other standards recognised by EASA to ensure that the performance of emergency equipment is adequately addressed.

(See Inadequate Performance or Reliability of Emergency Equipment – page A8-38)

### Recommendation 48 – Recommendation for incorporating industry standards for general occupant safety (e.g. slip, trip and fall prevention) into AMC

Whilst many of the slip, trip, and fall accidents inside or from the cabin involved noncompliance with standard operating procedures or complacency, there may be aircraft design features that can reduce its risk. This may be particularly relevant to features like staircases within very large twin deck aircraft such as the A380. Additionally, there are no regulations governing the height, angle or slip resistance of the steps, or the provision of handrails for integrated airstairs. Industry standards (SAE publications) on these subjects are available. It is recommended that further deliberation be given by EASA to investigate the feasibility of the incorporation of (or referral to) such standards into airworthiness requirements.

(See General Occupant Safety – page A8-40)

## Recommendation 49 – Recommendation for providing guidelines for the installation of under-seat mounted life preservers

It is recommended that consideration be given by EASA to provide guidelines for the installation of under-seat mounted life preservers. Anthropometrics measurements and their likely future increases may need to be taken into consideration. Seat pitch may not be the only factor; other factors such as the position of the stowage and the stowage mechanism also influence ease of retrieval. It is recommended that the guidelines should consider these factors in defining the term "*easy reach of each seated occupant*" used in CS 25.1411(f)).

(See Issues Associated with Seat Pitch – page A8-44)

# Recommendation 50 – Recommendation for providing guidelines for cabin environment and cabin air quality

It is recommended that consideration be given by EASA to providing guidelines for cabin environment and cabin air quality in addition to the current provisions on ventilation rates, carbon dioxide, carbon monoxide, and ozone concentration.

(See Cabin Air Quality and Other Health Issues – page A8-48)

# Recommendation 51 – Recommendation for developing standards defining the approval criteria for Child Restraint Devices and banning the use of supplementary loop belts

It is recommended that EASA continue to develop standards defining the approval criteria for Child Restraint Devices (as ETSO-C100b) taking into account the new FAA TSO-C100c. Consideration should also be given to banning the use of supplementary loop belts, especially since conflicting legislation has been posing problems in international air operations.

(See Restraint Systems and Injury Criteria – page A8-72)

# Recommendation 52 – Recommendation for establishing liaison with the FAA regarding any future rulemaking on single-place side-facing seats

Single-place side-facing seats are no longer exclusive to private-use aeroplanes and such seating has been addressed by Special Conditions. It is likely that the installation of such seating will increase in the future and hence CS-25 may need to accommodate this. Liaison with the FAA on any future rulemaking on this subject is recommended.

(See Restraint Systems and Injury Criteria – page A8-72)

# Recommendation 53 – Recommendation for establishing standards for inflatable lapbelts (e.g. in CS-ETSO)

Inflatable lapbelts are increasingly used in Transport Category Aeroplanes and currently they require Special Conditions for their certification. It is recommended that consideration be given by EASA to establish the standards for such equipment, possibly in CS-ETSO, to ensure that they provide at least the same level of safety as conventional seatbelts or any configurations replaced by such systems (e.g. minimum distance or padding for seats behind bulkhead).

(See Restraint Systems and Injury Criteria – page A8-72)

## Recommendation 54 – Recommendation for developing a means for adopting FAA SFAR 109

Since EASA has no equivalent of an FAA SFAR, consideration should be given to developing a means for adopting the contents of SFAR 109 into the airworthiness requirements to reduce certification costs for private use aeroplanes incorporating the features addressed in the SFAR (e.g. multiple-place side-facing seats, internal doors, etc).

(See Restraint Systems and Injury Criteria – page A8-72 and Evacuation Issues Related to Internal Doors – page A8-144)

## Recommendation 55 – Recommendation for monitoring the installation of large glass structures

Depending on how prevalent the installation of large glass structures in the cabin become, CS-25 may need to be modified to ensure an adequate level of safety. Such structures may be more common in the future with the proliferation of recreational areas in very large transport aeroplanes. At present, certification using Special Conditions (currently limited to aeroplanes for private use only) may be more feasible.

(See Cabin Crashworthiness – page A8-58)

# Recommendation 56 – Recommendation for monitoring the development of flammability test methods for electrical wiring and ducting materials for incorporation in Appendix F of CS-25

The FAA is currently developing improved fire test methods and criteria for aircraft electrical wiring and ducting materials. Radiant panel tests may replace the existing Bunsen burner tests specified in Appendix F of CS-25. It is recommended that EASA give consideration to amending CS-25 to reflect any changes that may occur in FAR Part 25 in this respect.

(See In-flight Fires – page A8-93)

### Recommendation 57 – Recommendation for establishing a reporting and information management system on evacuation events

Several studies have highlighted that the data on emergency evacuation events, which includes slide usage and associated injuries, were very limited. This data unavailability makes it difficult to accurately assess the cost-benefit of any improvements made to the slide to reduce the risk of evacuee injuries. Therefore, there is a need to establish a reporting and information management system on evacuation events, not limited to accident-related evacuations but also precautionary evacuations, with sufficient details on

the performance of the emergency systems and equipment as well as any injuries and costs incurred.

(See Assist Means Reliability and Design – page A8-111)

# Recommendation 58 – Recommendation to monitor FAA actions regarding the floor level exit on cargo aeroplanes

Dependent on and bearing in mind the results of FAA deliberations, it is recommended that consideration be given by EASA to require cargo operators to designate at least one floor level door as a required emergency exit and equip the door with an evacuation slide and external marking, when appropriate.

(See Issues Related to Exits for Cargo Aeroplanes – page A8-141)

### Recommendation 59 – Recommendation for providing guidance on flight crew procedures for responding to evidence of a fire in the absence of a cockpit alert

Accident experience shows that when there is evidence of a possible fire (e.g. smoke/fumes), but the smoke detection system does not activate, the flight crew may inadvertently increase the airflow at the fire by conducting a smoke clearance procedure (ventilation), rather than carrying out a fire suppression procedure (ventilation reduction) to starve the fire of oxygen. It is therefore recommended that EASA considers adding appropriate guidance material within CS-25, regarding the inclusion within Flight Manuals and Flight Crew Operating Manuals of flight crew procedures for responding to evidence of a fire in the absence of a cockpit alert.

(See Fires in Class E Cargo Compartments – page A8-103)

#### 11 CONCLUSIONS

The study identified 235 Cabin Safety Threats from the literature review, brainstorming session, and accident review. Of these, 25 threats were considered to be not within the remits of CS-25 Cabin Safety requirements, 30 Cabin Safety Threats were considered likely to be mitigated more effectively by improvements in operational requirements (including crew training and procedures), 65 Cabin Safety Threats were considered to be already adequately addressed by CS-25 or having no practical mitigation methods.

The detailed evaluation of the remaining 115 Cabin Safety Threats (evaluated as 11 individual Cabin Safety Threats and 23 Threat Groups) resulted in:

- 7 recommendations for potential major amendments to CS-25 requirements
- 31 recommendations for further research on various subjects and
- 14 recommendations for other improvements to regulatory material including amendments to CS-25 guidance material, ETSOs etc.

A general review of the Cabin Safety requirements of CS-25 was also carried out resulting in a recommendation for 7 proposed minor amendments to CS-25.

It is concluded that improvements could be made to the Cabin Safety requirements in CS-25 (at Amendment 6) that might enhance the safety of the passengers and crew. In addition, some changes could also be made to CS-25 that might simplify the certification process without adversely affecting the level of safety. However, there are some threats that require research, prior to any amendments to CS-25, in order to ascertain the extent of the threats and to investigate potential mitigation methods.

#### **12 REFERENCES**

- 1. European Aviation Safety Agency Website <u>http://www.easa.eu.int/</u>, retrieval dates from November 2008 to February 2009.
- 2. US Federal Aviation Administration Website <u>http://rgl.faa.gov/</u>, retrieval dates from November 2008 to February 2009.
- 3. RGW Cherry & Associates Limited. (2008). Cabin Safety Research Technical Group Accident Database Issue 32.

#### APPENDIX 1 – LIST OF CS-25 REQUIREMENTS AND ADVISORY MATERIAL PERTINENT TO CABIN SAFETY

CS-25 REQUIREMENTS	RELATED AMC	RELATED FAA AC
SUPPLEMENTARY CONDITIONS		
CS 25.365 Pressurised compartment loads (paragraph (g))		
EMERGENCY LANDING CONDITIONS		
CS 25.561 General	AMC 25.561 General	
	AMC 25.561 (b)(3) Commercial Accommodation Equipment	
CS 25.562 Emergency landing dynamic conditions		
LANDING GEAR		
CS 25.721 General		
PERSONNEL AND CARGO ACCOMMODATIONS		
CS 25.772 Pilot compartment doors		
CS 25.773 Pilot compartment view (paragraphs (b), (c), (d))	AMC 25.773 Pilot compartment view	AC 25.773-1 : Pilot Compartment View Design Considerations (January 8, 1993)
CS 25.775 Windshields and windows	AMC 25.775(d) Windshields and Windows	
CS 25.783 Fuselage Doors	AMC 25.783 Fuselage Doors	AC 25.783-1A Fuselage Doors and Hatches
CS 25.785 Seats, berths, safety belts and	AMC 25.785(d) Seats and Safety Belts	
harnesses	AMC 25.785(g) Seats, Berths, Safety Belts and Harnesses	
CS 25.787 Stowage compartments	AMC 25.787(b) Stowage Compartments	
CS 25.789 Retention of items of mass in passenger and crew compartments and galleys		
CS 25.791 Passenger information signs and placards	AMC 25.791 Passenger information signs and placards	Relevant parts of AC 25-17: Transport Airplane Cabin Interiors Crashworthiness Handbook, dated 15/7/91
CS 25.793 Floor surfaces		

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#### APPENDIX 1 – LIST OF CS-25 REQUIREMENTS AND ADVISORY MATERIAL PERTINENT TO CABIN SAFETY

CS-25 REQUIREMENTS	RELATED AMC	RELATED FAA AC
CS 25.795 Security considerations.	AMC 25.795 Security considerations	FAA memorandum, Subject Information: Certification of strengthened Flight Deck Doors on Transport Category Airplanes, Original release 6 November 2001
	AMC 25.795(a)(1) Flightdeck intrusion resistance	AC 25.795-1, Flightdeck Intrusion Resistance, issue date 10 January 2002
	AMC 25.795(a)(2) Flightdeck penetration resistance	(AC) 25.795-2, Flightdeck Penetration Resistance, issue date 10 January 2002
EMERGENCY PROVISIONS		
CS 25.801 Ditching		
CS 25.803 Emergency evacuation	AMC 25.803 Emergency evacuation	Relevant parts of AC 25-17: Transport Airplane Cabin Interiors Crashworthiness Handbook, dated 15/7/91
		AC 25.803-1: Emergency Evacuation Demonstrations, dated 13/11/89
CS 25.807 Emergency exits	AMC to 25.807 and 25.813 Emergency Exit Access	
	AMC 25.807(d) Passenger Emergency Exits	
CS 25.809 Emergency exit arrangement		
CS 25.810 Emergency egress assist means and escape routes	AMC 25.810(c)(2) Emergency Evacuation	AC 20-38A Measurement of Cabin Interior Emergency Illumination in Transport Airplanes
		AC 20-47 Exterior Coloured Band around Exits on Transport Airplanes
CS 25.811 Emergency exit marking	AMC 25.811(e)(4) Emergency Exit Marking	
CS-25 REQUIREMENTS	RELATED AMC	RELATED FAA AC
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CS 25.812 Emergency lighting	AMC 25.812 Emergency lighting	Relevant parts of AC 25-17: Transport Airplane Cabin Interiors Crashworthiness Handbook, dated 15/7/91
		AC 25.812-2: Floor Proximity Emergency Escape Path Marking Systems Incorporating Photoluminescent Elements, dated 24/7/97
	AMC 25.812(b)(1) Emergency Lighting	
	AMC 25.812(b)(2) Emergency Lighting	
	AMC 25.812(e)(2) Emergency Lighting	
CS 25.813 Emergency exit access	AMC to 25.807 and 25.813 Emergency Exit Access	
CS 25.815 Width of aisle	AMC 25.815 Width of aisle	Relevant parts of AC 25-17: Transport Airplane Cabin Interiors Crashworthiness Handbook, dated 15/7/91
CS 25.817 Maximum number of seats abreast		
CS 25.819 Lower deck service compartments (including galleys)		
CS 25.820 Lavatory doors		
VENTILATION AND HEATING		
CS 25.831 Ventilation	AMC 25.831(a) Ventilation	
	AMC 25.831(c) Ventilation	
CS 25.832 Cabin ozone concentration		
CS 25.833 Combustion heating systems		
PRESSURISATION		
CS 25.841 Pressurised cabins		

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CS-25 REQUIREMENTS	RELATED AMC	RELATED FAA AC
CS 25.843 Tests for pressurised cabins		
FIRE PROTECTION		
CS 25.851 Fire extinguishers	AMC 25.851(a) Fire Extinguishers	
	AMC 25.851(a)(1) Fire Extinguishers	
	AMC 25.851(a)(2) Fire Extinguishers	
	AMC 25.851(b) Built-in Fire Extinguishers	
CS 25.853 Compartment interiors	AMC 25.853 Compartment interiors	Relevant parts of AC 25-17: Transport Airplane Cabin Interiors Crashworthiness Handbook, dated 15/7/91
		AC 25.853-1 dated 17/9/86: Flammability Requirements for Aircraft Seat Cushions
		AC 25-18: Transport Category Airplanes Modified for Cargo Service, dated 6/1/94
CS 25.854 Lavatory fire protection		
CS 25.855 Cargo or baggage compartments		
CS 25.857 Cargo compartment classification		Relevant parts of AC 25-17: Transport Airplane Cabin Interiors Crashworthiness Handbook, dated 15/7/91
		AC 25-9A: Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures, dated 6/1/94
		AC 25-18: Transport Category Airplanes Modified for Cargo Service, dated 6/1/94
CS 25.858 Cargo or baggage compartment smoke or fire detection systems		
CS 25.859 Combustion heater fire protection		
CS 25.863 Flammable fluid fire protection	AMC 25.863(a) Flammable fluid fire protection	

CS-25 REQUIREMENTS	RELATED AMC	RELATED FAA AC
CS 25.869 Fire protection: systems (paragraph (c))	AMC 25.869(c) Fire Protection for Oxygen Equipment	
ELECTRICAL SYSTEMS AND EQUIPMENT		
CS 25.1360 Precautions against injury	AMC 25.1360(a) Precautions Against Injury	
	AMC 25.1360(b) Precautions Against Injury	
CS 25.1362 Electrical supplies for emergency conditions	AMC 25.1362 Electrical supplies for emergency conditions	
SAFETY EQUIPMENT		
CS 25.1411 General		
CS 25.1415 Ditching equipment		
CS 25.1421 Megaphones		
CS 25.1423 Public address system		
MISCELLANEOUS EQUIPMENT		
CS 25.1439 Protective breathing equipment		
CS 25.1441 Oxygen equipment and supply	AMC 25.1441(d) Oxygen equipment and supply	
CS 25.1443 Minimum mass flow of supplemental oxygen		
CS 25.1445 Equipment standards for the oxygen distributing system		

CS-25 REQUIREMENTS	RELATED AMC	RELATED FAA AC
CS 25.1447 Equipment standards for oxygen dispensing units	AMC 25.1447(c) Equipment Standards for Oxygen Dispensing Units	
	AMC 25.1447(c)(1) Equipment Standards for Oxygen Dispensing Units	
	AMC 25.1447(c)(2) Equipment Standards for Oxygen Dispensing Units	
	AMC 25.1447(c)(4) Equipment Standards for Oxygen Dispensing Units	
CS 25.1449 Means for determining use of oxygen		
CS 25.1450 Chemical oxygen generators		
CS 25.1453 Protection of oxygen equipment from rupture		
MARKINGS AND PLACARDS		
CS 25.1541 General	AMC 25.1541 Markings and Placards – General	
CS 25.1557 Miscellaneous markings and placards	AMC 25.1557(a) Baggage and Cargo Compartment and Ballast Location	
CS 25.1561 Safety equipment		

Table A2-1 lists the documents related to recent EASA rulemaking activities pertinent to Cabin Safety. Documents pertaining to JAA Cabin Safety Steering Group (CSSG) activities are listed in Table A2-2. Documents related to FAA Aviation Rulemaking Advisory Committee (ARAC) and the more recent FAA rulemaking activities pertinent to Cabin Safety are listed in Table A2-3.

ISSUE DATE	RULEMAKING DOCUMENTS		
02 April 2009	TOR No. 25.057 Security Related Design Standards		
27 May 2009	TOR No. 25.039 Passenger Emergency Exits, Emergency Features and Escape Routes – Harmonisation with FAA		
13 June 2008	NPA No. 2008-18 Access through Bulkheads		
14 October 2008	CRD No. 2008-18 Access Through Bulkheads		
21 February 2006	TOR No. CS-25.045 Access Through Bulkheads		
20 May 2008	NPA No. 2008-13 Thermal/Acoustic Insulation Material		
10 November 2008	CRD No. 2008-13 Thermal/Acoustic Insulation Material		
5 July 2004	TOR No. CS-25/006 Thermal/Acoustic Insulation Blankets		
07 May 2008	NPA No. 2008-10 Class B/F Cargo Compartments		
23 June 2009	CRD No. 2008-10 Class B/F Cargo Compartments		
21 February 2006	TOR No. CS-25.041 Class B/F Cargo Compartments		
10 April 2008	NPA No. 2008-04 Type III Emergency Exit Access and Ease of Operation		
(not yet issued)	CRD No. 2008-04 Type III Emergency Exit Access and Ease of Operation		
21 February 2006	TOR No. CS-25.040 Type III Emergency Exit Access and Ease of Operation		
25 April 2006	NPA No. 04-2006 Symbolic Exit Signs And Revised Standards for Cargo Compartments		
07 June 2006	CRD No. 04-2006 Symbolic Exit Signs And Revised Standards for Cargo Compartments		
12 August 2004	TOR No. CS-25/011 Symbolic Exit Signs And Revised Standards for Cargo Compartments		
09 March 2006	NPA No. 02-2006 Doors & Mechanical Systems		
12 October 2007	CRD No. 02-2006 Doors & Mechanical Systems		
08 December 2004	TOR No. CS-25/047 Overhead Bin Safety Precautions		

### Table A2-1 Recent EASA Rulemaking Documents Pertinent to Cabin Safety

# Table A2-2 JAA CSSG Documents

ISSUE DATE	RULEMAKING DOCUMENTS		
#4 Symbolic Exit Signs			
3 March 2003	Letter - Subject: CSSG proposed comment / response document "Graphical exit signs as an alternative to red exit signs for passenger aircraft"		
#17 Access through I	Bulkheads		
August 2003	JAA CSSG - Summary Sheet # 17 Subject : Access through Bulkheads; ANPA25D-224 & 26-3 Issue: 3		
#39 Seat Distance			
3 October 2003	JAA CSSG - Summary Sheet # 39 Subject : Minimum distance between passenger seats Issue: 3		
28 February 2003	Letter - Subject: Proposed JAR 25 NPA "Airworthiness Aeroplane Cabin Manual (AACM)"		
#41 Cabin Manual			
28 February 2003	NPA 25G-xxx (CSSG proposal) Airworthiness Aeroplane Cabin Manual (AACM)		
#47 Inoperative Exits			
23 December 2002	Letter - Subject: Draft MMEL TGL "Operation with an Inoperative Exit"		
23 December 2002	CSSG DP # 47, REV. 1 Draft MMEL TGL Operation With An Inoperative Exit		
#53 Stretchers			
	Joint Aviation Authorities Administrative & Guidance Material Section Three: Certification Part Three: Interim Policies & Temporary Guidance Material Policy paper Number : INT /POL/25/XX (proposed by the CSSG) Subject : Installation of stretchers in Aircraft certified under JAR 25.562		
#54 Cargo Compartm	ents Class D to C Conversion		
27 December 2002	JAA CSSG – Summary Sheet # 54 Subject: Cargo Compartments Class D to C conversion Issue: 5		
4 December 2002	Letter - Subject: NPA 25D-320 and 26B-15 Comment Response Document		
	NPA 25D-320 Disposal Of Comments		
	NPA 26B-15 Disposal Of Comments		
#56 Overhead Bin Safety Precautions			
20 February 2003	Draft P - NPA Overhead Bin Safety Precaution (and Cover Letter)		

ISSUE DATE	RULEMAKING DOCUMENTS		
	JAA CSSG - Summary Sheet		
18 February 2003	Subject: Overhead Bin Safety Precautions Content: Advisory Material Issue: 7		
14 November 2002	JAA CSSG - Discussion Paper # 56 Subject: Overhead Bin Safety Precautions Content: Advisory Material Issue: 6		
17 April 2000	JAA CSSG - Summary Sheet # 56 Subject: Overhead Bin Safety Precautions Content: Advisory Material Issue: 5		
#59 Type and Numbe	r of Passenger Emergency Exits		
23 April 2003	NPA 25D-298 Rev.1 DRAFT (and Cover Letter)		
27 December 2002	JAA CSSG – Summary Sheet # 59 Subject: JAA adoption of FAR 25 Amdt. 88 Issue: 4		
#72 Upgrade to FAR	121 Level		
24 March 2003	NPA 26-14 Disposal Of Comments (and Cover Letter)		
27 December 2002	JAA CSSG – Summary Sheet # 72 Subject: JAR 26 new items Issue: 6		
3 December 2001	Joint Aviation Authorities NPA 26-14; Various Occupant Survivability Requirements		
#76 Passenger Use of Restraint Systems During Flight			
20 September 2000	JAA CSSG - Summary Sheet # 76 Subject: Passenger Use of Restraint Systems During Flight Issue: 7		
#77 Child Restraint Systems			
October 2003	JAA CSSG Discussion Paper # 77 Subject: Child Restraint Systems Issue: 1		
June 2003	JAA CSSG – Summary Sheet # 77 Subject: Child Restraint Systems Issue: 11		
30 August 2002	Guidance Number: TGM// Subject: Use of Child Restraint Devices in Aircraft (and Cover Letter)		
7 March 2001	Letter – Subject: CSSG Child Restraint WG – future task Ref. 200102649-1/301/MTS		

ISSUE DATE	RULEMAKING DOCUMENTS		
6 June 2000	Letter – Subject: Child Restraint System in Aviation Ref. 200004426-1/MTS		
#78 Class E Cargo Co Compartment	ompartment Essential Systems Fire Protection/Class B to F Cargo		
27 December 2002	JAA CSSG – Summary Sheet # 78 Subject: Class E essential systems fire protection Issue: 5		
27 March 2000	Draft NPA 25D-YYY Class E Cargo Compartments Essential Systems Fire Protection		
#79 Exit Accessibility	//60-feet Rule		
26 February 1999	JAA CSSG - Summary Sheet # 79 Subject: Exit Accessibility / 60' Rule Issue: Draft		
#81 Insulation Materi	als		
9 October 2003	JAA CSSG - Summary Sheet # 81 Subject: Insulation Materials Issue: 4		
10 October 2002	JAA CSSG - Summary Sheet # 81 Subject: Insulation Materials Issue: 3		
	Insulation Materials Working Group (CSSG #81)		
10 October 2002	Dissent About the Admissibility of Interpretative Material in NPA 25 TBD and NPA 26 TBD Entitled Improved Flammability Standards for Thermal/Acoustic Insulation Materials Used in Large Aeroplanes		
	Draft NPA 25D-345 and Draft NPA 26-17		
	Improved Flammability Standards for Thermal/Acoustic Insulation Materials Used in Large Aeroplanes		
	(and Cover Letter)		
	Letter – Subject: Final Draft NPA "Improved Flammability Standards for Thermal/Acoustic Insulation Materials Used in Large Aeroplanes", Letter to JAA by Detlef Hayner dated 10 October 2002		
#82 FAA/JAA Policy Letters/Memoranda			
22 June 2001	JAA CSSG - Summary Sheet # 82 Subject: FAA/JAA Policy Letters / Memoranda Issue: 5		
#83 Type III Exits			
28 February 2003	CSSG Draft - NPA 25D - 270A		
	Improved Operation of and Access to Type III Exits		
	(and Cover Letter)		
	Appendix to NPA 25D-270A - Part 1 Appendix to NPA 25D-270A - Part 1		
	Unified Submission of the Dissenting Position to ARAC Cabin Safety Harmonization Working Group On Behalf of Members Representing AFA,		

ISSUE DATE	RULEMAKING DOCUMENTS
	APFA, ETF, IAM, IBT, and ITF, in conjunction with SCISAFE.
	FAR/JAR 25.813(c)
	Appendix to NPA 25D - 270A - Part 2
	Unified Submission of the Dissenting Position of the Members Representing AEA, AECMA, AIA, Airbus, ATA, The Boeing Company and GAMA
	FAR/JAR 25.813(c)
	Appendix to NPA 25D - 270A - Part 3
	CSHWG Report and Team Member Positions
General	
16 January 2004	An inventory of work to assist the transition to EASA Issue 3

#### Table A2-3 Recent FAA/ARAC Rulemaking Documents Pertinent to Cabin Safety

ISSUE DATE	RULEMAKING DOCUMENTS
July 13, 2007	Docket No. FAA-2007-28250: Special Requirements for Private Use Transport Category Airplanes; NPRM
January 5, 2007	Docket No. FAA-2006-26722: Security Related Considerations in the Design and Operation of Transport Category Airplanes; NPRM
2005	ANM-2003-115-30 Disposition of Public Comments on Draft Policy Statement ANM-03-115-30, Side-Facing Seats on Transport Category Airplanes
August 26, 2005	Docket No. FAA-2005-22045: FAA-Approved Child Restraint Systems
October 27, 2004	Docket no. FAA-2002-11346: 14 CFR Parts 25 and 121 Miscellaneous Cabin Safety Changes; Final Rule
July 2, 2004	Docket no. FAA-2002-13438: Public Address System; Trim Systems and Protective Breathing Equipment; Final Rule <sup>1</sup>
May 3, 2004	Docket no. FAA-2003-14193: Design Standards for Fuselage Doors on Transport Category Airplanes; Final Rule <sup>1</sup>
July 31, 2003	Docket No. FAA-2000-7909: Improved Flammability Standards for Thermal/Acoustic Insulation Materials Used in Transport Category Airplanes
June 19, 2003	Docket no. FAA-2002-11346: Lower Deck Service Compartments on Transport Category Airplanes; Final Rule <sup>1</sup>
2002	Aviation Rulemaking Advisory Committee Transport Airplane and Engine Issue Area Design for Security Harmonization Working Group Task 1 – Amendment 97 to Annex 8
2001	Aviation Rulemaking Advisory Committee Transport Airplane and Engine Issue Area Cargo Standards Harmonization Working Group Task 1 – Main Deck Class B Cargo Compartments
2000	Aviation Rulemaking Advisory Committee Transport Airplane and Engine Issue Area General Structures Harmonization Working Group Task 7 – Fuselage Doors
2000	Aviation Rulemaking Advisory Committee Transport Airplane and Engine Issue Area Seat Testing Harmonization Working Group Task 2 – Passenger Seat Safety
November 26, 1999	Aviation Rulemaking Advisory Committee Occupant Safety Issue Area Cabin Safety Harmonization Working Group Task 2 - Passenger Information Signs and Placards

<sup>&</sup>lt;sup>1</sup> Harmonisation item (FAA adopted the "more stringent" JAR-25 requirements)

ISSUE DATE	RULEMAKING DOCUMENTS
November 26, 1999	Aviation Rulemaking Advisory Committee Occupant Safety Issue Area Cabin Safety Harmonization Working Group Task 1 – Stowage Compartments

The primary objectives of the review of certification documents were to identify requirements that have presented problems in the certification process in the past and to identify whether new standards will be required for new technology or designs. This review was used in conjunction with the evaluation of proposed major amendments to CS-25 in Phase III and Phase IV of the study. Additionally, Cabin Safety threats were also identified as part of Phase II of the study.

#### EASA Certification Review Item Documents

According to EASA MB Decision no. 7-2004, Certification Review Items "shall mean a document that is used to track and record the resolution of a certification subject which requires clarification or interpretation or represents a major technical or administrative issue."

EASA has provided a number of Cabin Safety related Certification Review Item (CRI) documents issued during the period 2001-2009 for this study. The summaries of the CRIs are shown in Table A3-1 (for Special Conditions/Deviations), Table A3-2 (for Interpretative Material and Means of Compliance), and Table A3-3 (for Equivalent Safety Findings).

EASA prescribes Special Conditions for a product if the related airworthiness code does not contain adequate or appropriate safety standards for the product, because:

- 1) The product has novel or unusual design features relative to the design practices on which the applicable airworthiness code is based; or
- 2) The intended use of the product is unconventional; or
- 3) Experience from other similar products in service or products having similar design features, has shown that unsafe conditions may develop.

Since the data consisted of a small sample, the result of this review was only used as supporting data and not as the main means of determining the certification issues that need to be addressed.

# APPENDIX 3 – SUMMARY OF THE REVIEW OF CERTIFICATION DOCUMENTS Table A3-1 Summary of Relevant EASA Special Conditions/Deviations

SUBJECTS	APPLICABLE REQUIREMENTS	NO. OF SPECIAL CONDITIONS
Installation of a "groom station"	FAR 25.561, 25.857(e), 25.783, 25.785, 25.787, 25.801, 25.803, 25.807, 25.809, 25.811, 25.812, 25.813, 25.815, 25.851, 25.853, 25.1439, 25.1447	2
Seats with non-traditional, large, non-metallic panels	CS 25.853(d); Appendix F part IV & V	2
Type C passenger exits	CS 25.783(h), 25.785(h), 25.807(a)(8), 25.807(d)(2), 25.810(a)(1)(ii), 25.813(a), 25.813(b)	2
Crew rest compartments	CS 25.785, 25.789, 25.791, 25.812, 25.831, 25.851, 25.853, 25.858	2 (1 is a draft)
Access to class C cargo compartment in flight	JAR 25.855(a),(c),(h), 25.857(c)	1
Access to class E cargo compartment in flight	CS 25.855, 25.857, 25.1309, 25.1439, 25.1443	1
Composite fuselage in-flight fire/flammability resistance	CS 25.853(a)	1
Emergency exit arrangement - outside viewing	JAR 25.809(a)	1
Extendable length escape system	JAR 21.16, 25.561 (b), 25.810, 25.1301, 25.1309	1
Fire detection and protection in passenger cabin	CS 25.853, 25.854, 25.855, 25.857, 25.858	1
Fire protection of essential systems/equipment within class E cargo compartments	CS 25.855	1
Fire protection of thermal and acoustic insulation material	JAR 21.16, 25.853	1
High altitude operation	JAR 25.831, 25.841	1
Incorporation of Inertia Locking Device in dynamic seats	JAR 25.562, 25.785	1
Installation of courier area on freighter aircraft*	CS 25.855	1
Installation of suite-type seating	JAR 25.785(h)(2), JAR25.813 (e)	1
Installation of trolley stowage/lift systems with proximity to upper deck staircase	JAR 25.789, 25.1301, 25.1309, Part 21 §21A16B	1
Isolated compartments*	CS 25.785, 25.811, 25.812, 25.831, 25.851, 25.853, 25.858, 25.1411, 25.1447, 25.1541	1

SUBJECTS	APPLICABLE REQUIREMENTS	NO. OF SPECIAL CONDITIONS
Medical stretcher installation	JAR 25.158, 25.561, 25.625, 25.785, 25.789, 25.791, 25.803, 25.813, 25.815, 25.853, 25.1301, 25.1438, 25.1441, 25.1453, 25.1447, 25.1524, 25.1541	1
Post crash fire - composite fuselage construction	CS 25.601, 25.603	1
Side-facing single occupancy seats*	CS 25.562(a), 25.785(b)	1
Stairways between decks	JAR 21.16, 25.811, 25.812, 25.813	1
Emergency exit marking (size and location)	JAR 25.811(d)(1)(2)(3), 25.812(b)(1)	1
Application of heat release and smoke density requirements to seat materials **	JAR 25.853(a)(1) Change 13	1
Firm handhold **	JAR 25.785(d) Change 13	1
Installation of door between passenger compartments **	25.813(e)	1
Side-facing divans (Sofas) **	CS 25.562(a), 25.785(b)	1

\* Draft only \*\* Template only

#### Template only

### Table A3-2 Summary of Relevant EASA Interpretative Material/Means of Compliance

SUBJECTS	APPLICABLE REQUIREMENTS	NO. OF IM/MOC
Occupant injury considerations relating to the head up display system	CS 25.561, 25.562, 25.571(e)(1), 25.601, 25.773, 25.775, 25.777, 25.785(b), (d) and (k), 25.789, 25.809, 25.1301, 25.1303, 25.1309, 25.1316, 25.1321, 25.1322, 25.1323, 25.1333, 25.1381, 25.1541, 25.1543	4
Fire extinguishing systems for use in class C compartments	JAR 25.851(b), 25.857	2
Direct View compliance method	CS 25.785(h)(2)	2
Escape slides operation in wind conditions with the engines running	JAR 25.810	2
Installation of glass panels in the cabin*	JAR 25.561, 25.601, 25.603, 25.613, 25.775, 25.785, 25.841	2
Requirement for Cold Soak testing, and assessment with other environmental conditions including wind, for emergency egress assist means stowed in non pressurised compartment	JA R25.810, 25.1309	2
Simultaneous deployment of all escape systems on aircraft	JAR 25.1301(d)	1

SUBJECTS	APPLICABLE REQUIREMENTS	NO. OF IM/MOC
Compliance with Head Injury Criterion (HIC) for front row seats	JAR 25.562(c)(5)	1
Ditching certification	JAR 25.801, 25.807 (e)	1
Door exterior band marking	CS 25.811(f)(1) & (2)	1
Emergency evacuation	JAR 25.803	1
Emergency provisions and equipment required per deck	JAR 25.783, 25.803, 25.807, 25.812, 25.813, 25.851, 25.1411, 25.1447	1
Over wing Type A exit	JAR 25.810, 25.1309	1
Fire detection and protection in passenger cabin	JAR 25.853, 25.854, 25.855, 25.857, 25.858	1
Fuselage doors	JAR 25.783 PNPA 25D-301	1
High elevation airfield operation	JAR 25.841(a),(b)(6), 25.1447(c)(1)	1
Oxygen outlets in the galley work areas	JAR 25.1447 (c)(3)	1

\* Draft only

#### Table A3-3 Summary of Relevant EASA Equivalent Safety Findings

SUBJECTS	APPLICABLE REQUIREMENTS	NO. OF EQUIVALENT SAFETY FINDINGS
Allowable carbon dioxide concentration in aeroplane cabins and cabin ozone concentration	JAR 25.831(b)(2), 25.832	1
Installation of doors between passenger compartments	JAR 25.813(e), 25.813(f)	1
Fuselage doors	JAR 25.783 PNPA 25D-301	1
Packs off operation	JAR 25.831(a)	1
Photo-luminescent exit identifiers	JAR 25.812(b)(1)(ii), 25.812(b)(2), 25.812(i)	1

#### FAA Certification Documents

#### FAA Special Conditions Documents

An FAA Special Condition is a rulemaking action that is specific to an aircraft type and often concerns the use of new technology that the Code of Federal Regulations do not yet address. Special Conditions are an integral part of the Certification Basis and give the manufacturer permission to build the aircraft, engine or propeller with additional capabilities not referred to in the regulations.

A total of 62 Special Conditions relevant to Cabin Safety which were issued by the FAA during the period 2000–2009 have been identified using the FAA Regulatory and Guidance Library website. Table A3-4 summarises the subjects and the number of the Special Conditions reviewed. The applicable requirements are not annotated in Table A3-4 since the FAA considers the applicable airworthiness regulations do not contain adequate or appropriate safety standards for addressing the potential hazards that may be introduced by the new technology.

The review found that "Seats with inflatable lapbelts" and "Crew rest compartment" were the most frequent subjects that required a Special Condition in the period analysed.

SUBJECTS	NO. OF SPECIAL CONDITIONS
Seats with inflatable lapbelts	9
Crew rest compartment	9
Certification of cooktops	7
Seats with non-traditional, large, non-metallic panels	6
Side-facing single occupancy seats	5
Lithium battery installations	5
Service/cargo compartment	3
Child restraint system	2
Crashworthiness of aeroplanes with complex configuration or new material	2
Reinforced flightdeck bulkhead	2
Fire protection for aircraft with multiple electrical equipment bays	2
Extendable length escape system	1
Stairways between decks	1
Emergency exit arrangement - outside viewing	1
Flotation and ditching	1
Escape systems installed in non-pressurized compartments	1
Escape systems inflation systems	1
Flight-accessible class C cargo compartment	1
Overhead cross aisle stowage compartments	1
Large non-structural glass in the passenger compartment	1
Composite fuselage in-flight fire/flammability resistance	1

Table A3-4 Summary of Relevant FAA Special Conditions (2000-2009)

#### FAA Equivalent Level of Safety Documents

FAA Equivalent Level of Safety Findings are made when literal compliance with a certification regulation cannot be shown and compensating factors exist which can be shown to provide an equivalent level of safety.

A total of 70 Equivalent Level of Safety (ELOS) documents relevant to Cabin Safety which were issued by the FAA during the period 2000–2008 have been identified using the FAA Regulatory and Guidance Library website.

Some of the ELOS are not applicable to CS-25 Amdt. 5 requirements. The differences between FAR 25 and CS-25 have been taken into account in reviewing the ELOS. Subjects that have required more than one ELOS application are shown in Table A3-5.

#### Table A3-5 Subjects Requiring More Than One ELOS Application (2000-2008)

Subject	Equivalent CS-25 (Amdt. 5) Requirements	No. of ELOS Issued
Passenger emergency exit locator sign above the aisle (or aisles) near each passenger emergency exit, or at another overhead location	CS 25.811(d)(1)	9
Emergency exit locator sign and emergency exit marking sign size	CS 25.812(b)(1)	8
Warning for when a safe or preset cabin pressure altitude limit is exceeded	CS 25.841(b)(6)	7
Passenger emergency exit marking sign next to each passenger emergency exit	CS 25.811(d)(2)	4
Passageway width	CS 25.813(a)	4
Installation of doors between passenger compartments	CS 25.813(e)	4
Means to maintain a clear portion of the windshield during precipitation conditions (in particular heavy rain at speeds up to 1.5 $V_{\rm SR1}$ )	CS 25.773(b)(1)	3
Type and number of emergency exit	CS 25.807(d)(1)	3
Sign on each bulkhead or divider that prevents fore and aft vision along the passenger cabin to indicate emergency exits beyond and obscured by the bulkhead or divider	CS 25.811(d)(3)	3
Class C cargo compartment smoke detector system	CS 25.857(c)(1)	3
Exit above waterline	CS 25.807(e)(2)	2
Marking of operating instruction for all Type II and larger passenger emergency exits	CS 25.811(e)(4)	2
Obstruction of the projected opening of the exit	CS 25.813(c)(1)	2
Passenger aisle width	CS 25.815	2

#### FAA Exemption Documents

An FAA Exemption is a petition for a request to the FAA by an individual or entity asking for relief from the requirements of a regulation in effect. The FAA's response to the petition is one of the following: granted, partially granted or denied.

A total of 177 granted and partially granted Exemptions relevant to Cabin Safety which were issued by the FAA during the period 2000–2008 have been identified using the FAA Regulatory and Guidance Library website.

The differences between FAR 25 and CS-25 Amdt. 5 have been taken into account in reviewing the Exemptions. The five most frequent subjects for which Exemptions have been requested and granted are shown in Table A3-6.

Subject	Equivalent CS- 25 (Amdt. 5) Requirements	Total No. Petitions	Original Petitions	Extension of Petitions
Firm handhold (mostly on freighter and executive interior configuration)	CS 25.785(j)	52	45	7
Occupant protection for stretchers and side-facing divans (mostly on medical and executive interior configuration)	CS 25.785(b)	45	31	14
Carriage of supernumeraries on freighter aircraft	CS 25.857(e)	41	34	7
Installation of door between passenger compartments (mostly on executive interior configuration)	CS 25.813(e)	38	36	2
Oxygen-dispensing unit connected to oxygen supply terminals immediately available to each occupant, wherever seated (mostly on freighter aircraft)	CS 25.1447(c)(1)	38	30	8

#### Table A3-6 Most Frequent Subjects with Granted Exemption (2000-2008)

Since the data from the FAA was comprehensive, the results of the review could give an indication of:

- Requirements that need to be evaluated to facilitate the certification process (for example, the requirements for passenger emergency exit locator sign location or for firm handhold);
- Required additional standards to cater for new designs or new technologies, especially those that are likely to be used more extensively in the future (for example, seats with non-traditional, large, non-metallic panels).

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION
20071216C	16-Dec-07	CANADAIR RJ200-ER	N918SW	O'HARE INTERNATIONAL A/P, CHICAGO, ILLINOIS, U.S.A.
20071107A	07-Nov-07	B737-200	ZS-OEZ	CAPE TOWN, SOUTH AFRICA
20071012A	12-Oct-07	CANADAIR RJ700	N368CA	DENVER, COLORADO, U.S.A.
20070818A	18-Aug-07	AVRO RJ100	HB-IYU	LONDON CITY AIRPORT, LONDON, U.K.
20070807A	07-Aug-07	EMB145LR	N810HK	KNOX, INDIANA, U.S.A.
20070802A	02-Aug-07	B737-724	N13716	PANAMA CITY, PANAMA
20070712A	12-Jul-07	B777-232	N865DA	ATLANTA, GEORGIA, U.S.A.
20070710A	10-Jul-07	B737-232	N332DL	TUNICA AIR CENTER, TUNICA, MISSISSIPPI, U.S.A.
20070708C	08-Jul-07	B737-800	N929AN	MCALESTER, OKLAHOMA, U.S.A.
20070627A	27-Jun-07	B747-422	N120UA	SYDNEY, AUSTRALIA
20070625A	25-Jun-07	B747-267B	B-HIH	STOCKHOLM/ARLANDA A/P, SWEDEN
20070603B	03-Jun-07	B757-251	N523US	DENVER, COLORADO, U.S.A.
20070428A	28-Apr-07	ATR72-212	N407AT	SAN JUAN, PUERTO RICO
20070412C	12-Apr-07	CANADAIR RJ200-LR	N8905F	CHERRY CAPITAL A/P, TRAVERSE CITY, MICHIGAN, U.S.A.
20070412B	12-Apr-07	B757-200	N525UA	LOS ANGELES, CALIFORNIA, U.S.A.
20070407A	07-Apr-07	CANADAIR RJ200-LR	N77181	LAKE MICHIGAN, MICHIGAN, U.S.A.
20070329A	29-Mar-07	DC9-83	N877GA	ORLANDO SANFORD INTL A/P, SANFORD, FLORIDA, U.S.A.
20070315A	15-Mar-07	B767-300	N662UA	CHICAGO, ILLINOIS, U.S.A.
20070307A	07-Mar-07	B737-497	PK-GZC	ADI SUCIPTO AIRPORT, YOGYAKARTA, INDONESIA
20070223A	23-Feb-07	B777-200	N779AN	(NEAR) JAPAN
20070218A	18-Feb-07	EMB170	N862RW	CLEVELAND HOPKINS INTL A/P, CLEVELAND, OHIO, U.S.A.
20070204A	04-Feb-07	DC8-71F	HK-4277	MIAMI INTL A/P, MIAMI, FLORIDA, U.S.A.
20070201A	01-Feb-07	B737-5U3	PK-GGD	SOEKARNO-HATTA INTL A/P, JAKARTA, INDONESIA

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION
20061128A	28-Nov-06	ATR72	HL-5229	JEJU INTL A/P, SOUTH KOREA
20061116B	16-Nov-06	B757-27A	B-27015	99 NM SOUTH OF JEJU ISLAND, SOUTH KOREA
20061110A	10-Nov-06	B717-200	N956AT	MEMPHIS INTERNATIONAL AIRPORT, TENNESSEE, U.S.A.
20061011A	11-Oct-06	MD90-30	N906DA	DENVER INTL AIRPORT, DENVER, COLORADO, U.S.A.
20060916A	16-Sep-06	B737-700	N793SA	HASTINGS, NEBRASKA, U.S.A.
20060912A	12-Sep-06	B737-319	ZK-NGJ	AUCKLAND INTERNATIONAL AIRPORT, AUCKLAND, NEW ZEALAND
20060908B	08-Sep-06	EMB170	N864RW	LA GUARDIA INTL AIRPORT, NEW YORK, U.S.A.
20060905A	05-Sep-06	B757-232	N622DL	LUIS MUNOZ MARIN INTL A/P, SAN JUAN, PUERTO RICO
20060831A	31-Aug-06	DHC8-402	HL-5254	GIMHAE INTL A/P, SOUTH KOREA
20060827C	27-Aug-06	CANADAIR RJ100	N431CA	BLUE GRASS AIRPORT, LEXINGTON, KENTUCKY, U.S.A.
20060727A	27-Jul-06	B737-300	N529AU	PITTSBURGH INTL A/P, PENNSYLVANIA, U.S.A.
20060724A	24-Jul-06	EMB135LR	N703MR	NEWARK, NEW JERSEY, U.S.A.
20060708A	08-Jul-06	A310-324	F-OGYP	IRKUTSK, SIBERIA, RUSSIA
20060707B	07-Jul-06	A319-131	N839UA	MASONVILLE, COLORADO, U.S.A.
20060704A	04-Jul-06	MD81	JA-8499	70NM NORTHEAST OF TOYOTA, JAPAN
20060620A	20-Jun-06	DC9-83	N961TW	O'HARE INTL A/P, CHICAGO, ILLINOIS, U.S.A.
20060617A	17-Jun-06	B767-300	N653UA	WASHINGTON DULLES INTL AIRPORT, DULLES, VIRGINIA, U.S.A.
20060615A	15-Jun-06	B737-300	OO-TND	NOTTINGHAM EAST MIDLANDS A/P, U.K.
20060609A	09-Jun-06	A321-100	HL-7594	20 M SE OF ANYANG VOR, SOUTH KOREA
20060608A	08-Jun-06	B737-300	N403TZ	LAGUARDIA AIRPORT, NEW YORK, NEW YORK, U.S.A.
20060530A	30-May-06	EMB170	N651RW	DULLES INTL A/P, VIRGINIA, U.S.A.
20060513A	13-May-06	EMB145LR	N653AE	WINCHESTER, VIRGINIA, U.S.A.

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION
20060512A	12-May-06	EMB145LR	N275SK	BOSTON, MASSACHUSETTS, U.S.A.
20060430A	30-Apr-06	CANADAIR RJ900	N909FJ	MCCARRAN INTL AIRPORT, LAS VEGAS, NEVADA, U.S.A.
20060425A	25-Apr-06	B777-233ER	N789AN	DALLAS FORT WORTH INTL AIRPORT, DALLAS, TEXAS, U.S.A.
20060419A	19-Apr-06	B777-222ER	N216UA	SHANGHAI, CHINA
20060415A	15-Apr-06	CL600-2B19	N934EV	FRONT ROYAL, VIRGINIA, U.S.A.
20060319A	19-Mar-06	AVRO RJ100	HB-IXS	ZURICH AIRPORT, ZURICH, SWITZERLAND
20060315A	15-Mar-06	B757-222	N518UA	CHEYENNE, WYOMING, U.S.A.
20060225A	25-Feb-06	B757-232	N697DL	LOGAN INTL AIRPORT, BOSTON, MASSACHUSETTS, U.S.A.
20060207A	07-Feb-06	DC8-71F	N748UP	PHILADELPHIA, PENNSYLVANIA, U.S.A.
20051226A	26-Dec-05	MD83	N979AS	SEATTLE, WASHINGTON, U.S.A.
20051219A	19-Dec-05	B747-400	VT-AIM	LOS ANGELES, CALIFORNIA, U.S.A.
20051214A	14-Dec-05	B727-2S2F	N213FE	MEMPHIS INTERNATIONAL AIRPORT, MEMPHIS, TENNESSEE, U.S.A.
20051208A	08-Dec-05	B737-700	N471WN	CHICAGO MIDWAY INT AP, CHICAGO, ILLINOIS, U.S.A.
20051128B	28-Nov-05	DC10	N359FE	O'HARE INTERNATIONAL AIRPORT, CHICAGO, ILLINOIS, U.S.A.
20051119A	19-Nov-05	B737-800	N734MA	UNIVERSITY PARK AIRPORT, STATE COLLEGE, PENNSYLVANIA, U.S.A.
20051117A	17-Nov-05	SAAB 2000	HB-IZZ	LUGANO AIRPORT, SWITZERLAND
20051106B	06-Nov-05	B777-200	N781AN	LONDON HEATHROW AIRPORT, LONDON, U.K.
20051030B	30-Oct-05	B737-900	N317AS	CALGARY INTL A/P, ALBERTA, CANADA
20051026A	26-Oct-05	CL600-2C10	N391CA	CINCINNATI/NORTHERN KENTUCKY INTL AIRPORT, KENTUCKY, U.S.A.
20051022B	22-Oct-05	B737-832	N378DA	300 MILES NORTHWEST OF HAMILTON, BERMUDA
20051012A	12-Oct-05	B737-3H4	N624SW	PHOENIX SKY HARBOR INTL AIRPORT, PHOENIX, ARIZONA, U.S.A.

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION
20051007A	07-Oct-05	DHC8-311	G-BRYW	ABERDEEN AIRPORT, ABERDEEN, SCOTLAND, U.K.
20051003A	03-Oct-05	EMB170	N650RW	DULLES, VIRGINIA, U.S.A.
20050918A	18-Sep-05	A321-231	N583NK	FT LAUDERDALE HOLLYWOOD INTL A/P, FT LAUDERDALE, FL, U.S.A.
20050829B	29-Aug-05	DHC8-202	N363PH	PORTLAND INTL AIRPORT, PORTLAND, OREGON, U.S.A.
20050820A	20-Aug-05	B757-33N	N557TZ	CHICAGO MIDWAY INTL AIRPORT, CHICAGO, ILLINOIS, U.S.A.
20050814A	14-Aug-05	B737-300	5B-DBY	GRAMMATIKO, GREECE
20050808C	08-Aug-05	EMB145LR	N10575	NEWARK, NEW JERSEY, U.S.A.
20050802A	02-Aug-05	A340-313	F-GLZQ	LESTER B PEARSON INTL AIRPORT, TORONTO, CANADA
20050714A	14-Jul-05	B747-400	HL-7472	ABOVE BORNEO ISLAND (KEVOK POINT)
20050711A	11-Jul-05	B767-232	N113DA	20 NM NE OF CHARLOTTE, NORTH CAROLINA, U.S.A.
20050627A	27-Jun-05	B727-230	N357KP	SAN DIEGO INTNL AIRPORT, SAN DIEGO, CALIFORNIA, U.S.A.
20050615A	15-Jun-05	ATR42-300	N42NC	ANCHORAGE, ALASKA, U.S.A.
20050612B	12-Jun-05	CL600-2B19	N960SW	LOS ANGELES INTL AIRPORT, LOS ANGELES, CALIFORNIA, U.S.A.
20050611A	11-Jun-05	JETSTREAM 41	ZS-NRI	DURBAN INT'L AIRPORT, SOUTH AFRICA
20050610C	10-Jun-05	AVRO RJ85	N530XJ	WILL ROGERS WORLD AIRPORT, OKLAHOMA CITY, OKLAHOMA, U.S.A.
20050610B	10-Jun-05	A319-114	N302NB	SCOTTSBLUFF, NEBRASKA, U.S.A.
20050608A	08-Jun-05	SAAB SF340A	N40SZ	DULLES INT'L AIRPORT, VIRGINIA, U.S.A.
20050607A	07-Jun-05	MD11-F	N205UP	LOUISVILLE INT'L AIRPORT, KENTUCKY, U.S.A.
20050605A	05-Jun-05	B757-223	N602AN	NEW CHICAGO, INDIANA, U.S.A.
20050531A	31-May-05	CL600-2B19	N417AW	CHICAGO O'HARE INTL AIRPORT, CHICAGO, ILLINOIS, U.S.A.
20050513A	13-May-05	MD88	N949DL	DENVER, COLORADO, U.S.A.

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION
20050510C	10-May-05	DC9-51	N763NC	ST PAUL INTERNATIONAL AIRPORT, MINNEAPOLIS, MINNESOTA, U.S.A
20050510B	10-May-05	A319-114	N368NB	ST PAUL INTERNATIONAL AIRPORT, MINNEAPOLIS, MINNESOTA, U.S.A
20050429A	29-Apr-05	B737-400	N727SW	LITTLE ROCK, ARKANSAS, U.S.A.
20050415A	15-Apr-05	B737-800	EI-DAC	MURCIA SAN JAVIER AIRPORT, SPAIN
20050320A	20-Mar-05	EMB135LR	N733KR	RALEIGH DURHAM INTL AIRPORT, RALEIGH, NORTH CAROLINA, U.S.A.
20050311B	11-Mar-05	CL600-2B19	N8932C	GENERAL MITCHELL INTL AIRPORT, MILWAUKEE, WISCONSIN, U.S.A.
20050311A	11-Mar-05	B777	N790AN	EZEIZA INTL AIRPORT, BUENOS AIRES, ARGENTINA
20050306C	06-Mar-05	B757-232	N6710E	GENERAL EDWARD LAWRENCE LOGAN INTL A/PORT BOSTON, U.S.A.
20050306A	06-Mar-05	A310-308	C-GPAT	NEAR VARADERO, CUBA
20050302A	02-Mar-05	B777-200	N78008	NEWARK LIBERTY INTL A/P, NEW JERSEY, U.S.A.
20050211A	11-Feb-05	SAAB SF340B	N394AE	LOS ANGELES, CALIFORNIA, U.S.A.
20050117A	17-Jan-05	B737-247	N373DL	CINCINNATI NORTHERN KENTUCKY INTL AIRPORT, KENTUCKY, U.S.A.
20050108A	08-Jan-05	B737-724	N16732	GUNNISON CRESTED BUTTE REG. A/PORT, GUNNISON, U.S.A.
20041229B	29-Dec-04	CANADAIR RJ700	N506MJ	AUSTIN, TEXAS, U.S.A.
20041216A	16-Dec-04	SD360	N748CC	OSHAWA MUNICIPAL AIRPORT, ONTARIO, CANADA
20041201B	01-Dec-04	GULFSTREAM IV	G-GMAC	TETERBORO AIRPORT, TETERBORO, NEW JERSEY, U.S.A.
20041130A	30-Nov-04	MD82	PK-LMN	ADI SUMARMO AIRPORT, SOLO, INDONESIA
20041128B	28-Nov-04	CL600-2A12	N873G	MONTROSE REGIONAL AIRPORT, COLORADO, U.S.A.
20041128A	28-Nov-04	B737-406	PH-BTC	BARCELONA, SPAIN
20041104A	04-Nov-04	B737-37Q	G-ODSK	MANCHESTER AIRPORT, MANCHESTER, U.K.
20041020A	20-Oct-04	B747	N709CK	OVER LAKE MICHIGAN, MI, U.S.A.

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION	
20041018A	18-Oct-04	A320-232	B-22310	TAIPEI SUNGSHAN AIRPORT, TAIWAN	
20040929A	29-Sep-04	B767-232	N109DL	CARIBBEAN SEA	
20040913A	13-Sep-04	B737-3H4	N601WN	LOS ANGELES, CALIFORNIA, U.S.A.	
20040831A	31-Aug-04	B747-400	JA-8083	HANAMAKI, JAPAN	
20040813A	13-Aug-04	CV580	N586P	COVINGTON, KENTUCKY, U.S.A.	
20040811B	11-Aug-04	A330-300	HL-7720	25000 FT OVER GWANGJU AREA, SOUTH KOREA	
20040721C	21-Jul-04	MD83	EC-FTS	ALICANTE AIRPORT, SPAIN	
20040721A	21-Jul-04	CL600	N995CA	SNOW HILL, VIRGINIA, U.S.A.	
20040717A	17-Jul-04	A319	N812AW	FLAT ROCK, VIRGINIA, U.S.A.	
20040715A	15-Jul-04	MD82	N585AA	SHERIDAN, ILLINOIS, U.S.A.	
20040706A	06-Jul-04	L1011-385-3	CS-TMR	AMSTERDAM AIRPORT SCHIPHOL, NETHERLANDS	
20040604A	04-Jun-04	B737-7H4	N757LV	LIBERAL, KANSAS, U.S.A.	
20040526A	26-May-04	MD82	N573AA	NEAR ST. LOUIS, MISSOURI, U.S.A.	
20040519A	19-May-04	DHC8-402	LN-WDA	20 NM W-NW OF SANDEFJORD A/P, NORWAY	
20040509A	09-May-04	ATR72	N438AT	SAN JUAN, PUERTO RICO	
20040414A	14-Apr-04	B737-700	N448WN	BEACH HAVEN, NEW JERSEY, U.S.A.	
20040410A	10-Apr-04	B737-300	N662SW	ST. LOUIS, MISSOURI, U.S.A.	
20040301B	01-Mar-04	B757-200	N516UA	JANESVILLE, WISCONSIN, U.S.A.	
20040226A	26-Feb-04	B747-300	TF-ATJ	OVER ATLANTIC OCEAN TROPICS	
20040225A	25-Feb-04	B737-210C	C-GNWN	EDMONTON, ALBERTA, CANADA	
20040105A	05-Jan-04	F70	OE-LFO	MUNICH, GERMANY	
20040102A	02-Jan-04	A320	CS-TQE	MADEIRA AIRPORT, MADEIRA, PORTUGAL	
20040101A	01-Jan-04	MD81	JA-8297	TOKUNOSHIMA AIRPORT, JAPAN	
20031225A	25-Dec-03	B727-223	3X-GDO	COTONOU, BRUNEI DARUSSALAM	
20031222A	22-Dec-03	B737-NG	G-EZJM	AMSTERDAM AIRPORT SCHIPHOL, AMSTERDAM, NETHERLANDS	
20031218A	18-Dec-03	DC10-10F	N364FE	MEMPHIS, TENNESSEE, U.S.A.	

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION
20031214A	14-Dec-03	CL600-2B19	N445AW	MIAMI, INTERNATIONAL AIRPORT, MIAMI, FLORIDA, U.S.A.
20031202A	02-Dec-03	CL600-2B19	N916CA	JOHN F. KENNEDY INTL AIRPORT, JAMAICA, NEW YORK, U.S.A.
20031114A	14-Nov-03	B747-422	N178UA	SAN FRANCISCO, CALIFORNIA, U.S.A.
20031112A	12-Nov-03	SAAB 340B	N442XJ	MINNEAPOLIS, MINNESOTA, U.S.A.
20031101A	01-Nov-03	B737-500	N956UA	DENVER, COLORADO, U.S.A.
20031016A	16-Oct-03	A319-112	N764US	TAMPA, FLORIDA, U.S.A.
20031007B	07-Oct-03	B777-200ER	JA-709A	SAN FRANCISCO INTL A/P, SAN FRANCISCO, CALIFORNIA, U.S.A.
20031007A	07-Oct-03	B777-22B	N222UA	SAN FRANCISCO INTL A/P, SAN FRANCISCO, CALIFORNIA, U.S.A.
20031004A	04-Oct-03	B737	N972AN	BOSTON LOGAN INTERNATIONAL AIRPORT, MASSACHUSETTS, U.S.A.
20030927A	27-Sep-03	EMB145	N733KR	LA GUARDIA ARIPORT, FLUSHING, NEW YORK, U.S.A.
20030921A	21-Sep-03	DHC8-202	N455YV	PHOENIX, ARIZONA, U.S.A.
20030904A	04-Sep-03	F28-100	N1450A	FLUSHING, NEW YORK, U.S.A.
20030902B	02-Sep-03	DORNIER 328- 300	N413FJ	HEBRON, KENTUCKY, U.S.A.
20030902A	02-Sep-03	MD82	N454AA	JAMAICA, NEW YORK, U.S.A.
20030816A	16-Aug-03	B737-800	N329TZ	WOOSTER, OHIO, U.S.A.
20030815A	15-Aug-03	B737-33V	HB-III	(NEAR) GENEVA, SWITZERLAND
20030807A	07-Aug-03	MD81	N814ME	GREELEY, COLORADO, U.S.A.
20030806A	06-Aug-03	A340-300	D-AIGK	HOUSTON, TEXAS, U.S.A.
20030803A	03-Aug-03	MD82	N7527A	CHARLOTTE, NORTH CAROLINA, U.S.A.
20030801A	01-Aug-03	B717-200	N970AT	ATLANTA, GEORGIA, U.S.A.
20030722A	22-Jul-03	B757-251	N504US	WADSWORTH, OHIO, U.S.A.
20030718A	18-Jul-03	A330-342	В-НҮА	REPORTING POINT NOBEN, MANILLA FIR
20030717A	17-Jul-03	B777-222	N779UA	CHICAGO, ILLINOIS, U.S.A.
20030702B	02-Jul-03	B747-438	VH-OJU	SYDNEY AIRPORT, NEW SOUTH WALES, AUSTRALIA

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION
20030624A	24-Jun-03	EMB135KL	N839AE	BOSTON LOGAN INTERNATIONAL AIRPORT, MASSACHUSETTS, U.S.A.
20030623A	23-Jun-03	B757-232	N633DL	TAMPA, FLORIDA, U.S.A.
20030622A	22-Jun-03	CANADAIR RJ100	F-GRJS	BREST, FRANCE
20030618A	18-Jun-03	EMB145LR	N294SK	TAYLOR, FLORIDA, U.S.A.
20030617A	17-Jun-03	MD88	TC-ONP	GRONINGEN AIRPORT EELDE, NETHERLANDS
20030616B	16-Jun-03	A320	C-GTDK	BRISTOL, U.K.
20030612A	12-Jun-03	MD82	N451AA	FORT WORTH, TEXAS, U.S.A.
20030605A	05-Jun-03	A320-321	N644AW	PAYSON, ARIZONA, U.S.A.
20030602B	02-Jun-03	EMB120ER	N299UX	DENVER INTERNATIONAL AIRPORT, DENVER, COLORADO, U.S.A.
20030602A	02-Jun-03	A319-111	N910FR	DENVER, COLORADO, U.S.A.
20030526B	26-May-03	A321-231	G-MIDJ	CRUISE AT FL340, 70NM SOUTH- EAST OF VIENNA, AUSTRIA
20030524A	24-May-03	B737-300	N343SW	AMARILLO, TEXAS, U.S.A.
20030521A	21-May-03	SAAB 340B	N277MJ	FLUSHING, NEW YORK, U.S.A.
20030520A	20-May-03	B757-223	N962AA	SANTA ANA, CALIFORNIA, U.S.A.
20030507B	07-May-03	CL600-2B19	N484CA	BOSTON, MASSACHUSETTS, U.S.A.
20030507A	07-May-03	B767-300	N650UA	NEW MARKET, VIRGINIA, U.S.A.
20030424A	24-Apr-03	DORNIER 328- 300	N427FJ	ROANOKE, VIRGINIA, U.S.A.
20030422A	22-Apr-03	MD88	N974DL	DENVER, COLORADO, U.S.A.
20030421A	21-Apr-03	B757-222	N504UA	LITHONIA, GEORGIA, U.S.A.
20030417A	17-Apr-03	F27-600	N730FE	PORT TOWNSEND, WASHINGTON, U.S.A.
20030416A	16-Apr-03	MD82	N452AA	DFW AIRPORT, TEXAS, U.S.A.
20030409B	09-Apr-03	SD330	N805SW	DU BOIS, PENNSYLVANIA, U.S.A.
20030406A	06-Apr-03	B737-924	N71411	PALESTINE, TEXAS, U.S.A.
20030405A	05-Apr-03	A319-111	N917FR	PUEBLO, COLORADO, U.S.A.
20030326A	26-Mar-03	B717-200	N957AT	FLUSHING, NEW YORK, U.S.A.

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION	
20030319A	19-Mar-03	ATR42-300	N216AT	SANTO DOMINGO, DOMINICAN REPUBLIC	
20030312A	12-Mar-03	B747-412	9V-SMT	AUCKLAND, NEW ZEALAND	
20030308A	08-Mar-03	F27-500	N712FE	KINGSTON, NORTH CAROLINA, U.S.A.	
20030301A	01-Mar-03	ATR72-212	N642AS	ATLANTA, GEORGIA, U.S.A.	
20030225A	25-Feb-03	B777-223	N790AN	MIAMI, FLORIDA, U.S.A.	
20030208A	08-Feb-03	ATR72-212	N448AM	SAN JUAN, PUERTO RICO	
20030119A	19-Jan-03	B757-251	N550NW	FLUSHING, NEW YORK, U.S.A.	
20030117B	17-Jan-03	F28-1000	HC-BMD	QUITO, ECUADOR	
20030117A	17-Jan-03	F50	PH-FZE	MELILLA, SPAIN	
20030112A	12-Jan-03	B737-800	PH-HZB	ROTTERDAM, NETHERLANDS	
20030108B	08-Jan-03	DHC8-401	N409QX	MEDFORD, OREGON, U.S.A.	
20030106A	06-Jan-03	EMB145LR	N16571	CLEVELAND, OHIO, U.S.A.	
20021128A	28-Nov-02	A320	N324US	MINNEAPOLIS, MN, U.S.A.	
20021109A	09-Nov-02	MD82	N452AA	LA GUARDIA, U.S.A.	
20021106C	06-Nov-02	MD82	N479AA	ORLANDO, FL, U.S.A.	
20021106B	06-Nov-02	F50	LX-LGB	NIEDERANVEN, LUXEMBOURG	
20021102A	02-Nov-02	F27-500	G-ECAT	SLIGO, IRELAND	
20020914C	14-Sep-02	B747	TF-ATH	MADRID, SPAIN	
20020907B	07-Sep-02	A340	EC-IDF	MADRID, SPAIN	
20020828A	28-Aug-02	A320-231	N635AW	PHOENIX SKY HARBOR INT'L AIRPORT, ARIZONA, U.S.A.	
20020811A	11-Aug-02	B747-256	EC-DNP	JOHN F. KENNEDY INTERNATIONAL AIRPORT, NEW YORK, U.S.A.	
20020726B	26-Jul-02	B727	N497FE	TALLAHASSEE, U.S.A.	
20020602A	02-Jun-02	B757	N694DL	FAIRFIELD, IL, U.S.A.	
20020529A	29-May-02	B757	N626DL	THE WILLIAM B HARTSFIELD ATLANTA INTL, U.S.A.	
20020513A	13-May-02	B767-300	C-GHML	TORONTO, CANADA	
20020501A	01-May-02	B747-422	N182UA	PACIFIC OCEAN	
20020422A	22-Apr-02	B767-224	N68160	ATLANTIC OCEAN	

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION	
20020418A	18-Apr-02	B757	N516AT	SPRINGFIELD, MO, U.S.A.	
20020416A	16-Apr-02	HS748	ZS-OLE	PILANESBERG, SOUTH AFRICA	
20020415B	15-Apr-02	A319-114	N325NB	RENO, NV, U.S.A.	
20020415A	15-Apr-02	B767	B-2552	PUSAN, SOUTH KOREA	
20020401A	01-Apr-02	B747	G-BNLS	ATLANTIC OCEAN	
20020331A	31-Mar-02	MD11-11	N809DE	CHARLOTTE, NC, U.S.A.	
20020322A	22-Mar-02	DC10	N234NW	INTERNATIONAL WATERS	
20020227B	27-Feb-02	B737-8AS	EI-CSA	STANSTED AIRPORT, U.K.	
20020219A	19-Feb-02	B737	N24736	BEAUMONT, TX, U.S.A.	
20020124A	24-Jan-02	DC9	N754NW	INDIANAPOLIS INTL, U.S.A.	
20020114B	14-Jan-02	B737-200	PK-LID	PEKANBARU, INDONESIA	
20020106A	06-Jan-02	B737-400	D-AHLJ	FUERTEVENTURA, SPAIN	
20011228A	28-Dec-01	B747-128	N3203Y	ANCHORAGE, ALASKA, U.S.A.	
20011130A	30-Nov-01	MD82	N488AA	LONDON, ONTARIO, CANADA	
20011120A	20-Nov-01	B727-233	N277FE	MEMPHIS, TENNESSEE, U.S.A.	
20011029A	29-Oct-01	B757-223	N640A	DULLES, VIRGINIA, U.S.A.	
20011016B	16-Oct-01	EMB120	N120AX	BETHAL, ALASKA, U.S.A.	
20011016A	16-Oct-01	EMB145LR	N825MJ	ROANOKE, VIRGINIA, U.S.A.	
20011013A	13-Oct-01	ATR42-320	N34820	EN ROUTE NEWARK, NJ, U.S.A.	
20011003A	03-Oct-01	F100	N1448A	DALLAS FORT WORTH AIRPORT, U.S.A.	
20010915A	15-Sep-01	F100	PT-MRN	70NM FROM BELO HORIZONTE, BRAZIL	
20010907B	07-Sep-01	B767-332	N194DN	BUENOS AIRES, ARGENTINA	
20010905A	05-Sep-01	B777-236	G-VIIK	DENVER INTERNATIONAL AIRPORT, DENVER, COLORADO, U.S.A.	
20010830A	30-Aug-01	EMB135	N25504	RICHMOND, VIRGINIA, U.S.A.	
20010829A	29-Aug-01	CASA 235	EC-FBC	NEAR MALAGA AIRPORT, SPAIN	
20010825A	25-Aug-01	B737-3G7	N306AW	KANSAS CITY, U.S.A.	
20010824C	24-Aug-01	A330-243	C-GITS	LAJES, AZORES, PORTUGAL	
20010820A	20-Aug-01	A320-232	N605AW	NEEDLES, CALIFORNIA, U.S.A.	

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ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION
20010809B	09-Aug-01	B737-500	N512SW	KLAMATH FALLS, OREGAN, U.S.A.
20010809A	09-Aug-01	B717-200	N2417F	MASCOUTAH, ILLINOIS, U.S.A.
20010804A	04-Aug-01	B737-200	C-FRYG	NEAR CAYO LARGO DEL SUR, CUBA
20010725A	25-Jul-01	DC9-51	N780NC	DETROIT, MICHIGAN, U.S.A.
20010721A	21-Jul-01	MD81	LN-RMT	NEAR HELSINKI, FINLAND
20010711A	11-Jul-01	B757-232	N644DL	SAN FRANCISCO, CALIFORNIA, U.S.A.
20010702A	02-Jul-01	L382G	N401LC	LAKE MINCHUMINA, ALASKA, U.S.A.
20010628A	28-Jun-01	B757-200	TF-FIJ	COPENHAGEN A/P, DENMARK
20010615C	15-Jun-01	A320	N661AW	SAN DIEGO, CALIFORNIA, U.S.A.
20010605C	05-Jun-01	F27-500	G-CEXF	JERSEY AIRPORT, CHANNEL ISLANDS, JERSEY
20010605B	05-Jun-01	B757-200	N563UA	Kokomo, Indiana, U.S.A.
20010605A	05-Jun-01	B757-200	N750AT	ATLANTA, GEORGIA, U.S.A.
20010528A	28-May-01	B737-301	N349US	TOCCOA,GEORGIA, U.S.A.
20010523A	23-May-01	F100	N1419D	DALLAS FORT WORTH AIRPORT, U.S.A.
20010522B	22-May-01	B737-210C	C-GNWI	YELLOWKNIFE, CANADA
20010513A	13-May-01	A300-600	TU-TAG	JOHANNESBURG, SOUTH AFRICA
20010510A	10-May-01	MD81	EC-FXI	LIVERPOOL AIRPORT, LIVERPOOL, U.K.
20010426B	26-Apr-01	DC8-71F	N8076U	NASHVILLE, TENNESSEE, U.S.A.
20010426A	26-Apr-01	ATR42-300	N223AT	ATLANTIC OCEAN
20010419B	19-Apr-01	A320-232	N654AW	RATON, NEW MEXICO, U.S.A.
20010418A	18-Apr-01	A321-211	G-VOLH	FUNCHAL, MADEIRA, PORTUGAL
20010417A	17-Apr-01	B737-200	N253UA	JACKSONVILLE, FLORIDA, U.S.A.
20010409C	09-Apr-01	DORNIER 328- 100	N423JS	SPRINGFIELD, VIRGINIA, U.S.A.
20010409B	09-Apr-01	B737-800	N3731T	BOSTON, MASSACHUSETTS, U.S.A.
20010404D	04-Apr-01	B737	C-GDCC	ST. JOHNS INTERNATIONAL AIRPORT, ST JOHNS, CANADA
20010401A	01-Apr-01	B737-400	VH-TJX	MELBOURNE AIRPORT, AUSTRALIA

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION	
20010321B	21-Mar-01	L188	G-LOFD	PRESTWICK, SCOTLAND, U.K.	
20010319B	19-Mar-01	EMB120	N266CA	WEST PALM BEACH, FLORIDA, U.S.A.	
20010317A	17-Mar-01	A320-200	N357NW	DETROIT, MICHIGAN, U.S.A.	
20010306B	06-Mar-01	DC10	N375FE	BOSTON, MASSACHUSETTS, U.S.A.	
20010306A	06-Mar-01	DHC8-102	N822PH	PORTLAND, OREGAN, U.S.A.	
20010303A	03-Mar-01	B737-400	HS-TDC	BANGKOK, THAILAND	
20010301A	01-Mar-01	DHC8-311	G-BRYO	PLYMOUTH, ENGLAND, U.K.	
20010227A	27-Feb-01	SD360	G-BNMT	GRANTON HARBOUR, U.K.	
20010225A	25-Feb-01	EMB120	N288SW	MONTEREY, CALIFORNIA, U.S.A.	
20010207A	07-Feb-01	A320	EC-HKJ	BILBAO A/P, SPAIN	
20010206A	06-Feb-01	F28-100	N1457B	BOSTON, MASSACHUSETTS, U.S.A.	
20010203A	03-Feb-01	B737-832	N3735D	BOSTON, MASSACHUSETTS, U.S.A.	
20010115A	15-Jan-01	DHC8-300	B-15235	CHINMEN SHANGYI AP, CHINMEN ISLAND, TAIWAN	
20010108A	08-Jan-01	CANADAIR RJ100	N784CA	DETROIT, MICHIGAN, U.S.A.	
20001224A	24-Dec-00	DC10-10	N132AA	FAAA AIRPORT, TAHITI	
20001129B	29-Nov-00	DC9-32	N826AT	HARTSFIELD ATLANTA INTL A/P, ATLANTA, GEORGIA, U.S.A.	
20001129A	29-Nov-00	DC9-82	N3570A	DULLES, VIRGINIA, U.S.A.	
20001120B	20-Nov-00	ATR72	N630AS	ASHEVELLE, NORTH CAROLINA, U.S.A.	
20001120A	20-Nov-00	A300	N14056	MIAMI, FLORIDA, U.S.A.	
20001115B	15-Nov-00	B757-236	OY-GRL	NEAR COPENHAGEN, DENMARK	
20001105A	05-Nov-00	B747-200	TJ-CAB	PARIS CHARLES DE GAULLE, FRANCE	
20001104A	04-Nov-00	B767-300	N173DZ	PORTLAND, OREGON, U.S.A.	
20001031B	31-Oct-00	B747-412B	9V-SPK	CHIANG KAI-SHEK AP, TAIWAN	
20001022A	22-Oct-00	DHC8-Q400	LN-RDG	COPEHAGEN AIRPORT, KASTRUP, DENMARK	
20000927B	27-Sep-00	CV580	C-GFHH	LA GRANDE 4, QUEBEC, CANADA	
20000920A	20-Sep-00	B767-300	N172DZ	DUBLIN, GEORGIA, U.S.A.	

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION	
20000823B	23-Aug-00	B757-200	N657AM	GULF OF MEXICO, GM, U.S.A.	
20000808A	08-Aug-00	DC9-32	N838AT	GREENSBORO PIEDMONT-TRIAD INT AP, NORTH CAROLINA, U.S.A	
20000527A	27-May-00	DHC8-Q400	LN-RDB	AALBORG AIRPORT, AALBORG, DENMARK	
20000525A	25-May-00	SD330-200	G-SSWN	PARIS CDG AIRPORT, FRANCE	
20000520A	20-May-00	B737-500	N522SW	NASHVILLE, TENNESSEE, U.S.A.	
20000426A	26-Apr-00	DC9-41	SE-DOM	COPENHAGEN AIRPORT, KASTRUP, DENMARK	
20000310A	10-Mar-00	ATR72	N636AS	ATHENS, GEORGIA, U.S.A.	
20000305A	05-Mar-00	B737-300	N668SW	BURBANK, CALIFORNIA, U.S.A.	
20000227A	27-Feb-00	B747-100/200	G-BDXL	PROVIDENCE, RI, U.S.A.	
20000113A	13-Jan-00	SD360	HB-AAM	MARSA EL BREGA, LIBYA	
19991112A	12-Nov-99	ATR42-300	F-OHFV	PRISTINA (25NM NORTH OF), KOSOVO	
19991107A	07-Nov-99	F100	I-ALPL	BARCELONA AIRPORT, BARCELONA, SPAIN	
19990923A	23-Sep-99	B747-438	VH-OJH	BANGKOK, THAILAND	
19990917A	17-Sep-99	MD88	N947DL	CINCINNATI/N. KENTUCKY INT AP, COVINGTON, KENTUCKY, U.S.A	
19990914A	14-Sep-99	B757-204	G-BYAG	GIRONA AIRPORT, SPAIN	
19990909A	09-Sep-99	DC9-31	N993Z	NASHVILLE AIRPORT, TENNESSEE, U.S.A.	
19990824A	24-Aug-99	MD90-30	B-17912	HUALIEN AIRPORT, TAIWAN	
19990822A	22-Aug-99	MD11	B-150	HONG KONG INTERNATIONAL AIRPORT, HONG KONG	
19990715A	15-Jul-99	A300-600ER	N80057	JOHN F. KENNEDY INTL AIRPORT, JAMAICA, NEW YORK, U.S.A.	
19990601A	01-Jun-99	MD82	N215AA	NATIONAL AIRPORT, LITTLE ROCK, ARKANSAS, U.S.A.	
19990422A	22-Apr-99	B727-23	ZS-IJE	LANSERIA, JOHANNESBURG, SOUTH AFRICA	
19990405B	05-Apr-99	B737-200	PK-RIL	HASANUDDIN AIRPORT, UJUNGPANDANG, SOUTH SULAWESI, INDONESIA	
19981226A	26-Dec-98	MD88	N907DE	DFW AIRPORT, TEXAS, U.S.A.	

ADB REF.	DATE	AIRCRAFT TYPE	AIRCRAFT REG.	LOCATION	
19981203A	03-Dec-98	HS748-2A	C-FBNW	IQALUIT AIRPORT, IQALUIT, NWT, CANADA	
19981101B	01-Nov-98	B737-200	EI-CJW	HARSTFIELD INTERNATIONAL AIRPORT, ATLANTA, GEORGIA, U.S.A.	
19981025A	25-Oct-98	ATR42-300	N143DD	LUIS MUNOZ MARIN INTL, AP., SAN JUAN, PUERTO RICO	
19981004A	04-Oct-98	B767-332	N1200K	SAO PAULO, BRAZIL	
19990902A	02-Sep-98	MD-11	HB-IWF	PEGGY'S COVE, NOVA SCOTIA	
19980806A	06-Aug-98	HS748	C-GTAD	KASABONIKA, ONTARIO, CANADA	
19980521A	21-May-98	A320-212	G-UKLL	IBIZA AIRPORT, BALEARIC ISLANDS, SPAIN	
19980507A	07-May-98	DC9-32	N948VV	NEAR CALHOUN, GEORGIA, U.S.A.	
19980418A	18-Apr-98	B747-200	N623FF	ATLANTIC OCEAN, U.S.A.	
19980330B	30-Mar-98	B727-212	C-FRYS	FORT LAUDERDALE, FLORIDA, U.S.A.	
19980330A	30-Mar-98	HS748 SER 2B	G-OJEM	STANSTED AIRPORT, LONDON, U.K.	
19980209B	09-Feb-98	SD360	G-BLGB	STORNAWAY, U.K.	
19980209A	09-Feb-98	B727-223	N845AA	O'HARE INTERNATIONAL AIRPORT, CHICAGO, ILLINOIS, U.S.A.	

#### **APPENDIX 5 – CABIN SAFETY THREATS NOT WITHIN CS-25 CABIN SAFETY REMITS**

As part of the initial review of Cabin Safety threats, 25 were identified as being outside of the remit of CS-25 Cabin Safety requirements. They consist of firefighting/rescue operation issues (Table A5-1), and fuel tank crashworthiness and fuel flammability (Table A5-2).

# Table A5-1 Cabin Safety Threats Related to Firefighting/Rescue Operation Issues

ID	CABIN SAFETY THREATS	IDENTIFIED FROM
R01	Aircraft's location in difficult terrain/vegetation or in the vicinity of structures /buildings which impede firefighting efforts by firefighting/rescue services	Accident review (2 accidents)
R02	Organisational issues of firefighting/rescue services which impede firefighting/ rescue efforts	Accident review (5 accidents)
R03	Inadequate equipment of the firefighting/rescue services	Accident review (3 accidents)
R04	Inadequate equipment training of firefighting/rescue services personnel	Accident review (1 accident)
R05	Ineffective/inadequate firefighting/rescue efforts due to insufficient personnel	Accident review (4 accidents)
R06	Inadequate/no communication between flight crew and ARFF/Tower	Accident review (3 accidents)
R07	Rescue/firefighting services having difficulty in reaching accident site (locked gate, no access road)	Accident review (5 accidents)
R08	Evacuees having difficulty in moving away from the aircraft due to environmental conditions (e.g. deep mud)	Accident review (1 accident)
R11	Rescue/firefighting personnel unfamiliar with aircraft	Accident review (2 accidents)
R12	Difficulty in rescue operations due to aircraft cabin disruption	Accident review (1 accident)
R13	Rescue vehicles/equipment posing danger to evacuees	Accident review (1 accident)
R14	No confirmation on the total number of passengers that could affect the conduct of rescue efforts	Accident review (2 accidents)
S05	Difficulty in extinguishing fires involving composite structures	Literature review and/or brainstorming
Z02	Inaccurate or unavailable aircraft diagram for rescue and firefighting services	Accident review (2 accidents)
C02	Rescue/firefighting services having difficulty in locating the accident site	Accident review (7 accidents)
C03	Failure of Aircraft Radio or Difficulty in Contacting Tower Following a Crash or Emergency Landing	Accident review (3 accidents)
R09	Evacuation during heavy snow/rain	Accident review (4 accidents)
R10	Hostile external environment in water (temperature, wind, sea condition, other threats)	Accident review (1 accident)
AA05	Evacuees' contact with fuel, oil, hydraulic fluid, etc in water	Literature review and/or brainstorming

#### **APPENDIX 5 – CABIN SAFETY THREATS NOT WITHIN CS-25 CABIN SAFETY REMITS**

# Table A5-2 Cabin Safety Threats Related to Fuel Tank Crashworthiness and FuelFlammability

ID	CABIN SAFETY THREATS	IDENTIFIED FROM
FC01	Ground pool fire (causing thermal injuries to evacuees outside of aircraft)	Accident review (7 accidents)
FC02	Fuel tank explosion following a crash landing	Accident review (1 accident)
FC03	Changes of fuel flammability properties associated with the use of new types of fuel (e.g. bio fuel)	Literature review and/or brainstorming
FC04	Increased severity of post-crash fire due to the increased amount of fuel carried on bigger/longer- range aeroplanes	Literature review and/or brainstorming
S04	Increased severity of post-crash fire due to the use of hydrogen or other fuel carried on board the aeroplane for fuel cell APUs	Literature review and/or brainstorming
R36	Fuel tank explosion (not crash related)	Accident review (1 accident)

# APPENDIX 6 – CABIN SAFETY THREATS FOR MITIGATION BY OPERATIONS REQUIREMENTS

The following table contains identified Cabin Safety threats that are likely to be mitigated more effectively by improvements in operations requirements, crew training, or procedures.

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)
G03	Emergency Equipment Locations Varying Amongst Aircraft of the Same Make and Model	Literature review <sup>1,2,3</sup>	(Not applicable)
Y12	Evacuation Commencing with Engine Still Running	Accident review (4 accidents) ADB Ref. 20051030B 20030623A 20000927B 19990824A	(Not causing direct injuries)
GB04	Incorrect Brace-for-Impact Positions Illustrated in Safety Cards	Accident review (1 accident) ADB Ref. 20050802A Literature review <sup>4</sup>	(Unknown)
E01	In-Flight Fire/Explosion from Items/Dangerous Goods Carried into Cabin by Passengers	Accident review (1 accident) ADB Ref. 19990824A	Serious injuries Fatal injuries
GB03	No Brace-for-Impact Commands or Instructions Given to Passengers	Accident review (4 accidents) ADB Ref. 20050802A 20010829A 19981203A 19981101B	(Unknown)
U07	Not All available Exits Used Based On Crew's assumption that Not All Exits are Needed	Accident review (4 accidents) ADB Ref. 20050415A 20030617A 20030117A 19981226A	(Not causing direct injuries)
V01	Evacuation Hampered by Elderly or Disabled Passengers	Accident review (2 accidents) ADB Ref. 20030617A 20010824C	(Not causing direct injuries)

# APPENDIX 6 – CABIN SAFETY THREATS FOR MITIGATION BY OPERATIONS REQUIREMENTS

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)
Y05	Incorrect or Lack of Instructions to Evacuees for Using the Slide (This threat relates to passenger safety cards, passenger briefing, and instructions from cabin crew at the top of the slide. The main issues are conflicting/inconsistent/nil information on how to carry infants and how to sit on the slide.)	Accident review (3 accidents) ADB Ref. 20060319A 20010510A 19990923A	(Unknown)
Y30	Passengers Hesitate in Using Upper Deck Slides	Literature review <sup>5</sup>	(Not applicable)
CA02	Incorrect or Insufficient Instruction On Using Life Vest or Flotation Device	Accident review (2 accidents) ADB Ref. 20010824C 20000113A	None
R15	Crew's Lack of Understanding of the Dangers of Hypoxia	Accident review (1 accident) ADB Ref. 20050814A	(Not causing direct injuries)
R21	Lack of Communication/Information between Crewmembers (Procedural Issues) during an In-Flight Emergency	Accident review (4 accidents) ADB Ref. 20050814A 20050306A 20020322A 20000113A	(Not causing direct injuries)
R22	Lack of Communication/Information between Crewmembers (Procedural Issues) during/Prior to Evacuation	Accident review (5 accidents) ADB Ref. 20030702B 20020227B 20010115A 20000927B 19981025A	
R23	Flight Crew Decision Not to Carry Out an (Immediate) Evacuation Based On Unconfirmed Information	Accident review (2 accidents) ADB Ref. 20060912A 19990923A Literature review <sup>6</sup>	
# APPENDIX 6 – CABIN SAFETY THREATS FOR MITIGATION BY OPERATIONS REQUIREMENTS

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)
R25	Passengers' Difficulty in Understanding Cabin Crew's Instructions due to Language	Accident review (6 accidents) ADB Ref. 20050802A 20041128A 20030617A 20020415A 20010824C 20001224A	(Not causing direct injuries)
R26	Cabin Crew Actions Do Not Comply with Evacuation Procedure	Accident review (2 accidents) ADB Ref. 20030702B 19990824A	(Not causing direct injuries)
R27	Inadequate Cabin Crew Training	Accident review (4 accidents) ADB Ref. 20030622A 20030326A 20020227B 20001031B	(Not causing direct injuries)
R28	Insufficient Cabin Crew Instruction to Passengers during Evacuation	Accident review ADB Ref. (1 accident) 20030617A	(Not causing direct injuries)
R29	Evacuees Attempting to Collect (or Collecting) Cabin Baggage during Evacuation	Accident review (13 accidents) ADB Ref. 20060912A 20051117A 20050802A 20041128A 20031218A 20030702B 20030617A 20010824C 19990923A 19990822A 19981101B 19980521A 19980209A	(Not causing direct injuries)
R30	Evacuees Carrying Baggage onto Evacuation Slides or Through Emergency Exits during Evacuation	Accident review (5 accidents) ADB Ref. 20060912A 20051208A 20050802A 20030702B 19990923A Literature review <sup>7</sup>	Serious injuries

# APPENDIX 6 – CABIN SAFETY THREATS FOR MITIGATION BY OPERATIONS REQUIREMENTS

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)
R31	Passenger Opening Exit without Assessing External Hazards	Accident review (2 accidents) ADB Ref. 20041128A 19990601A	Serious injuries
R32	Evacuees Remaining in the Vicinity of the Aircraft and/or Allowed to Re-Enter Aircraft	Accident review (2 accidents) ADB Ref. 20030617A 20020227B	None
R35	Unruly passenger behaviour	Accident review (1 accident) ADB Ref. 20000520A	Serious injuries
R38	Occupants Not Belted during Impact	Accident review (1 accident) ADB Ref. 19990822A	Fatal injuries
R39	Evacuation/Deplaning Using Other Assist Means (e.g. Ladder)	Accident review (2 accidents) ADB Ref. 20070218A 20021102A	None
R40	Rapid Decompression due to Puncture of the Fuselage (Not Uncontained Engine Failure)	Accident review (2 accidents) ADB Ref. 20051226A 20050513A	None
R44	Cabin Crew Clothing or Apparel Adversely Affecting the Performance of Safety Duties	Accident review (1 accident) ADB Ref. 20001031B	(Not causing direct injuries)
R48	Aircraft Flotation Time Is Reduced due to Opening of a Non-Ditching Emergency Exit (Below Waterline) or Water Barrier Not Properly Installed	Literature review <sup>8,9</sup>	(Not applicable)
GA14	Hot Fluids and Drinks Spilt onto Occupants during In-Flight Meal Service	Accident review (1 accident) ADB Ref. 20040831A	Minor injuries
W01	Insufficient or Inconsistent Information On Emergency Exit and Assist Means in Safety Card or Manual	Accident review (2 accidents) ADB Ref. 20050802A 19980330A	(Not causing direct injuries)

# APPENDIX 6 – CABIN SAFETY THREATS FOR MITIGATION BY OPERATIONS REQUIREMENTS

 <sup>1</sup> Cosper, D.K. & McLean, G.A. (1998) DOT/FAA/AM-98/19, Analysis of Ditching and Water Survival Training Programs of Major Airframe Manufacturers and Airline. Washington, D.C.: Office of Aviation Medicine.
 <sup>2</sup> Asmayawati, S., Butcher, N, & Cherry, R. (2009) CAA Paper 2009/01 Cabin Crew Fire Training – Training Needs Analysis. Gatwick: UK Civil Aviation Authority.

<sup>3</sup> National Transportation Safety Board. (1991) *Flight Attendant Training and Performance During Emergency Situations, Special Investigation Report NTSB/SIR-92/02.* Washington D.C.: NTSB

<sup>4</sup> Sperber, M. & Bancken, M. (2006) *Protective Brace/Safety Positions for Passengers and Cabin and Cockpit Crew in Emergency Landing Conditions or Aborted Take-Off, FE no. L-3/2006 – 50.0319/2006.* Cologne: Federal Ministry of Transport, Building and Urban Affairs

<sup>5</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16 October 1998.

<sup>6</sup> Communication Problems Contribute to Misperceptions of Evacuation Urgency, Flight Safety Foundation – Cabin Crew Safety, Vol. 38 No. 2, March – April 2003

<sup>7</sup> Attempts to Retrieve Carry-on Baggage Increase Risks During Evacuation, Flight Safety Foundation – Cabin Crew Safety, Vol. 39 No. 3, May – June 2004 <sup>8</sup> Federal Aviation Administration, *Equivalent Level of Safety Finding for Cessna New Model 680 FAA Project* 

<sup>8</sup> Federal Aviation Administration, *Equivalent Level of Safety Finding for Cessna New Model 680 FAA Project* #TC2548WI-T, ELOS Memo # TC2548WI-T-AG-1

<sup>9</sup> Federal Aviation Administration, Equivalent Level of Safety (ELOS) Finding for Raytheon Model 4000, FAA Project Number TC1258WI-T, ELOS Memo # TC1258WI-T-A-6

<sup>10</sup> Vigilance in Aircraft Galley and Service Procedures Preserves Margin of Safety, Flight Safety Foundation – Cabin Crew Safety, Vol. 34 No.1, January – February 1999

# Table A7-1 Cabin Safety Threats that are considered adequately addressed by CS-25 Cabin Safety Requirements

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
GA08	On-Board Accidents Related to Contact with Projecting or Hot Items, Electrical Shock, Operation of Lifts etc	Literature review <sup>1</sup>	None within the period reviewed	25.785(k), 25.819(g), 25.1360(a) and (b)	Following the fatal accident to a flight attendant on board a DC-10 in 1981, the NTSB has issued safety recommendations regarding the operation of lifts. CS 25.819(g) has now provided safety measures to prevent such accidents and there have been no further accidents or incidents recently. Protection from projecting objects (from seats) is provided by CS 25.785(k), and protection from electrical shock by CS 25.1360(a) and AMC 25.1360(a). Sufficient protection from burns is provided by 25.1360(b) and AMC 25.1360(b) (see related proposed minor amendment in Section 4.2 of the report).
BB03 BB05 BB04	Oxygen Masks Do Not Deploy Delay in Oxygen Masks Deployment Failure of Oxygen System	Accident review (1 accident) ADB Ref. 20010824C	None	25.1447 (b) and (c)	The oxygen system failures identified during the accident review were caused by manufacturing or installation/maintenance defects. It is considered that CS-25 is adequate.
BB09	Insufficient Protection from Aircraft Cabin Decompression in Altitudes Higher than 40,000 ft	Brainstorming	(Not applicable)	25.1441(d)	Although the requirements for oxygen equipment in 25.1443(b) and (c) only apply to up to and including 40,000 ft, CS 25.1441(d) states that " <i>The oxygen flow rate and the oxygen equipment for aeroplanes for which certification for operation above 12192 m (40 000 ft) is requested must be approved. (See AMC 25.1441(d).)"</i> This requirement is considered adequate for protection from hypoxia. In 1999, CAMI <sup>2</sup> carried out a study on the physiological issues related to cabin decompression during high-altitude flight (60,000 – 80,000 ft) and strategies for protecting passengers

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
					and crewmembers. It was concluded that a combination of protective systems, which included an increased structural integrity of the cabin, a repressurisation system, and an optimally designed supplemental oxygen system for crew and passengers, may be necessary. However, these protective systems were considered cost-prohibitive and there may not be many commercial aircraft operating at such altitudes. Therefore, the amendment of CS-25 requirements is currently not immediately required.
IB05	Difficulty in Communicating Whilst Wearing Smoke Hood (Cabin Crew)	Accident review (1 accident) ADB Ref. 20050802A Literature review <sup>3</sup>	(Not the cause of direct injuries)	25.1439(b)	In accident ADB Ref, 20050802A (Toronto A340), a cabin crew member donned a smoke hood due to the presence of a significant amount of black smoke in her station. She subsequently removed it because the passengers could not hear/understand what she was saying to them. An in-flight smoke incident on a DHC8-400 (4 August 2005) resulted in a UK AAIB Recommendation 2007-006, which recommended a review of the current training requirements for cabin crew members in the use of smoke hoods to mitigate the communications difficulties and to improve the ability of crew members to communicate while wearing smoke hoods. The issue of difficulties in communicating whilst using the smoke hood was found in a study <sup>3</sup> , and it was recommended that cabin crew training should address this subject.

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
					<ul> <li>applicable Operating Regulations, the following apply:</li> <li>(3) Equipment, including portable equipment, must allow communication with other crewmembers while in use. Equipment available at flight crew assigned duty stations must enable the flight crew to use radio equipment.</li> </ul>
					adequate and hence it is recommended that this threat should be addressed by training requirements.
IA04	Difficulty in Using PA System/Interphone Whilst Oxygen Mask is Worn by Flight Crew	Accident review (1 accident) ADB Ref. 20000808A Literature review <sup>3</sup>	Minor injuries	25.1439(b), 25.1447(a) and (c)(2)(ii):	In accident ADB Ref. 20000808A, the first officer removed his oxygen mask to address the passengers on the PA system and exposed himself to the smoke. He was treated for smoke inhalation after evacuating the aircraft. CS 25.1439 (b) states that:
					For protective breathing equipment required by sub-paragraph (a) of this paragraph or by the applicable Operating Regulations, the following apply: (3) Equipment, including portable equipment, must allow communication with other crewmembers while in use. Equipment available at flight crew assigned duty stations must enable the <u>flight crew</u> to use radio equipment.
					Also in CS 25.1447(a) and (c)(2)(ii): <i>a)</i> There must be an individual dispensing unit for each occupant for whom supplemental oxygen is to be supplied. Units must be designed to cover the

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
					<ul> <li>nose and mouth and must be equipped with a suitable means to retain the unit in position on the face. Flight crew masks for supplemental oxygen must have provisions for the use of communication equipment.</li> <li>(c)(2) Each flight-crew member on flight deck duty must be provided with demand equipment. In addition, each flight-crew member must be provided with a quick-donning type of oxygen dispensing unit, connected to an oxygen supply terminal, that is immediately available to him when seated at his station, and this is designed and installed so that it (see AMC 25.1447 (c)(2)) – (ii) Allows, while in place, the performance of normal communication functions.</li> <li>CS-25 requirements on this subject are considered adequate. This threat might be best mitigated through crew training.</li> </ul>
FA08	In-Flight Fire from Passenger Smoking	Literature review <sup>3</sup>	(Not applicable)	25.791(a) and (d), 25.853(f) and (g), 25.854(a) and (b)	A review of UK CAA Mandatory Occurrence Reports (for UK registered commercial aeroplanes only) in the period 2002-2006 found 39 occurrences of passenger smoking in flight, 12 of which had caused a minor in-flight fire <sup>3</sup> . Although the frequency of occurrence may not be considered acceptable, the protection against this threat provided by the applicable CS-25 requirements (as well as OPS.GEN.130 and OPS.CAT.130 requirements) is considered adequate.
D01	Smoke in Cabin and/or Cockpit during Flight	Accident review (3 accidents) ADB Ref. 20001129A	Minor injuries	25.831(d)	The CS-25 requirement is found to be adequate. In only one of the accidents, 3 crewmembers and 5 passengers (of 63 occupants) received minor injuries from smoke inhalation.

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ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
		20001115B 20000808A			
D03	Failure to Isolate Passenger Cabin from Cargo Compartment in the Event of Fire/Smoke	Review of certification documents: ELOS Memo # AT5124AT-T-A-6; CRI: 190/D-30	(Not applicable)	25.855(h)(2), 25.857(b)(2), (c)(3), and (e)(4)	This threat is predominantly related to the installation of doors on a cargo compartment to enable access in flight. The ELOS and CRI were approved with the installation of a cockpit indication that the cargo compartment door is open, which provides the necessary information to the flight crew to know when the cargo compartment isolation requirements of 25.857 are met. Additionally, the Flight Manual should ensure that the crew will not charge fire inhibiting agents into the cargo area until the occupants have left and the door is closed and latched. In the future, if the installation of cargo compartment doors for in-flight access becomes more common, the design features mentioned above may need to be incorporated into CS 25.857 as a requirement. However, since such installations appear to be relatively infrequent at the present time, amendment to CS-25 is not considered necessary and addressing the subject with a CRI is considered sufficient.
FA02	Cargo Compartment Fire Detection Systems Not Providing Timely Warning	Accident review (1 accident) ADB Ref. 20060207A	(Not the cause of direct injuries)	25.858(a)	In the accident ADB Ref. 20060207A, the fire was detected by the aeroplane's smoke and fire detection system after the fire breached a cargo container, at which time, it proceeded to spread. The smoke detection system installed on the accident aircraft was certificated to the 5-minute detection time limit specified in the FAA's March 1965 letter to Boeing. Current FAR/CS 25.858 requires a 1-minute detection time, which is

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Appendix 7 Page A7-5

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
					considered adequate. <b>However</b> , the performance requirements for detection of fire inside cargo compartments may need to be reviewed. The FAA has been investigating the effects of cargo and cargo containers on airflow around smoke and fire detection sensors and reviewing the TSO for cargo containers, which resulted from NTSB Recommendation A-07-98.
FB05 FB07	Fire Penetration by Fuselage Burnthrough (causing thermal injuries) Fire Penetration through Burnthrough of Windows (causing thermal injuries)	Accident review (1 accident) ADB Ref. 20031218A <sup>a</sup>	(Unknown)	CS 25.856(b)	The recently issued CS-25 Amendment 6 includes the introduction of CS 25.856 (b), which requires that on newly manufactured aircraft thermal acoustic insulation located in the lower half of the fuselage must resist flame penetration for 4 minutes. This additional burnthrough protection is not required in the upper fuselage, nor for uninsulated parts of the lower fuselage on cost/benefit grounds. EASA has recently commissioned a study on burnthrough resistance of fuselage <sup>4</sup> which evaluated the adequacy of CS 25.856 (b) Amdt. 6. This study included a RIA which recommended rulemaking activity following research that is necessary to determine the achievable fire penetration time for the cabin windows. It is considered that this issue is being adequately dealt with by EASA and therefore does not need to be addressed further in this evaluation.

<sup>&</sup>lt;sup>a</sup> There may be other accidents that featured a fuselage burnthrough event within the period analysed; however the accident report of this accident is the only one that explicitly stated that there was an evidence of a burnthrough.

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
E04	Security Threats Related to Passengers Being Able to Access Cargo/Baggage in Flight	Review of certification documents: ELOS Memo # AT5124AT-T-A-6; CRI: 190/D-30	(Not applicable)	25.857(c)	This threat was identified from the review of certification documents. There has been an ELOS and a CRI for the installation of a door in the partition panel between a Class C cargo compartment and the passenger compartment, which enables entry to the cargo compartment in flight. This threat is also conceivable in aeroplanes with Class A and B cargo compartments. It was concluded that since in-flight access, especially to Class A and B cargo compartments, is required for firefighting, this threat is best mitigated by stricter security measures at airports. Additionally, smaller aeroplanes and aeroplanes used for private operations are less likely to be the target of terrorists. It should be noted that approval of the installation of a door for in-flight access to other cargo
					compartment classes in larger aeroplanes (if applicable), especially in commercial operations, should take into account the likelihood of this threat.
E05	Security Related Design Considerations	Review of rulemaking activities (FAA): Docket No. FAA– 2006–26722; Notice No.06–19 - Security Related Considerations in the Design and Operation of Transport Category Airplanes	(Not applicable)	25.795	The FAA has issued a Final Rule on this subject (FAR 25 Amendment 25-127), which addresses the survivability of systems, cargo compartment fire suppression, smoke and fumes protection (in the cabin and flight deck), least risk bomb location and design, protection of pilot compartment from penetration by small arms fire or shrapnel, and interior design to deter hiding of dangerous articles and improve searching. EASA has issued NPA 2009-07 (rulemaking task 25-57) to address security related design standards.

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Appendix 7 Page A7-7

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
TB03	Cargo Items Shifted during Impact Sequence (hitting occupants)	Accident review (2 accidents) ADB Ref. 20050802A 20001031B	Minor injuries	25.561(c)(1)(i), 25.787(a)(1)	The current applicable requirements are considered adequate and the risk is assessed to be relatively low.
SB02	Passenger Seat Failures/Distortion Following Impact	Accident review (4 accidents) ADB Ref. 20020415A 20010829A 19990914A 19990601A	Minor injuries Serious injuries	25.562(a) and (b), 25.785(b) and (f)	An FAA Final Rule on 16g seats was published on 17 May 1988 and became effective 16 June 1988 (FAR 25.562 Amendment 25-64). This is already adopted in CS-25. On 27 September 2005, FAA then published a Final Rule which requires transport category aeroplanes type-certificated after 1 January 1958 manufactured on and after 27 October 2009, that are used in Part 121 passenger-
SB06	Cabin Crew Jumpseat Failures/Distortion Following Impact	Accident review (2 accidents) ADB Ref. 20001031B 20000305A	Minor injuries Serious injuries		carrying operations, to have 16g seats for passengers and cabin crew. It is understood that EASA plans to issue an Advanced Notice of Proposed Amendment with similar content in 2009, leading to a final rule in late 2010 or early 2011.
SB05	Flight Crew Seat Failures/Distortion Following Impact	Accident review (1 accident) ADB Ref. 20040509A	Serious injuries	25.561(d), 25.562(a), 25.785(b) and (f)	In the Findings section of the accident report, it was stated that: at some point during the accident sequence, the captain cockpit seat failed when it was subjected to vertical loads that exceeded those required for certification.
					Although flight crew seats have less stringent requirements than cabin seats, the accident review has not found any evidence that this is a significant issue. Flight crew seat detachment from the floor and flight deck floor deformation are discussed in 'Inadequate Seat-Floor Strength and Floor Deformation'.

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
W02	Emergency Lighting/Exit Marking Obscured by Displaced Cabin Fittings/Equipment	Accident review (1 accident) ADB Ref. 19990601A	(Not the cause of direct injuries)	25.1541(b)(2)	In this accident the "EXIT" sign located to the left of the 1R door, near the floor, was obscured by a galley unit that was displaced aft. A section of aisle lighting strip was intact and obscured by the forward galley unit that had shifted inboard.
					CS 25.1541(b) states that: Each marking and placard prescribed in sub- paragraph (a) of this paragraph- (2) May not be easily erased, disfigured, or obscured.
					The requirement is considered adequate and there has only been one such occurrence in the period reviewed.
W07	Passengers Unaware of Exit Locations	Accident review (1 accident) ADB Ref. 20030622A	(Not the cause of direct injuries)	25.811	The accident report stated that "During the evacuation, some passengers headed toward the rear of the cabin, whereas the pre-takeoff safety demonstrations and the safety instructions clearly indicate that the CRJ-100 is not fitted with rear exits."
					The requirement for emergency exit marking is considered adequate. The operator had complied with the operations regulations to ensure that the information is conveyed to the passengers. Additionally, appropriate cabin crew commands should be able to resolve this issue.
W12	Passengers Do Not Understand Graphical (Symbolic) Exit Sign	Literature review	(Not applicable)	25.811(g)	There is no evidence from in-service experience that passengers can misunderstand symbolic exit signs. As mentioned in NPA No. 04-2006 'Symbolic Exit Signs And Revised Standards for Cargo Compartments', the symbolic exit signs are adopted from internationally recognised symbols used in

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
					buildings. The NPA states that it has been shown that the proposed symbols, already recognised world-wide in buildings, will increase passenger comprehension and thus enhance safety levels.
W05	Cabin Crew Cannot Find the Emergency Light Switch	Accident review (1 accident) ADB Ref. 19981203A	(Not the cause of direct injuries)	25.812(f)(1)	The requirement 25.812(f)(1) states that "The lights must be operable manually from the flight crew station and from a point in the passenger compartment that is readily accessible to a normal cabin crewmember seat."
					Since this occurrence is only identified in one accident (one type of aircraft) there is insufficient evidence to conclude that the requirement is not adequate.
W06	Flight Deck Door Blocked by Shifted Objects or Detached Cabin Fittings	Accident review (3 accidents) ADB Ref. 20010115A 20000927B 19981203A	(Not the cause of direct injuries)	25.787(a)(3) 25.772(a) and (b)	In ADB Ref. 20000927B, the first officer had difficulty opening the door between the cockpit and the passenger cabin because it was blocked by an object that likely shifted during the runway excursion In ADB Ref. 19981203A, the cargo in the forward baggage compartment shifted on impact, blocking access to the port over-wing exit and the
V11	Flight Deck Door Cannot Be Opened or Difficult to Open Following a Crash	Accident review (1 accident) ADB Ref. 20050510C			crew/freight door. The flight crew evacuated through the sliding windows in the cockpit. In ADB Ref, 20010115A, the First Officer could not open the cockpit door because it was obstructed by the sagging ceiling above L1 aisle. He did not, however use the emergency methods.
					On aircraft with a passenger seating capacity of 20 or more, exit capability for the flight crew is also required in the flight deck. It is also required to provide means to enable flightcrew

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ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
					members to directly enter the passenger compartment from the pilot compartment if the cockpit door becomes jammed. The applicable requirement is considered adequate.
V02	Seatback Not in Upright Position	Accident Review (1 Accident) ADB Ref. 20051208A	(Not the cause of direct injuries)	25.807(a) and (b), 25.813(a), (b), and (c), 25.817	Only four accidents were identified in the accident review relating to these threats. Three related to seatback trays obstructing evacuation and one related to reclined seats obstructing evacuation. At the time of this study. EASA is engaged in the
V04	Seatback Trays in Down Position Obstructing Evacuation Route	Accident Review (3 Accidents) ADB Ref. 20051208A, 20041128A and	(Not the cause of direct injuries)		rulemaking process to improve access to Type III exits. (NPA No 2008-04 which also covers ease of operation of Type III exits). It is considered that this NPA adequately addresses the threats identified in the accident review.
V14	Insufficient Aisle Width for Immediate Evacuation	19990914A			EASA has also considered the need for regulatory change concerning access through bulkheads (NPA No 2008-18). The conclusion of the regulatory impact assessment is to do nothing.
V15	Width for Immediate Evacuation Through Type III Exits				There is not enough evidence of the remaining threats to warrant further evaluation in order to consider recommendation for amendment of CS-25
V16	Insufficient Width between Monuments for Immediate Evacuation				or further research.
V17	Insufficient Assist Space for Immediate Evacuation				
V21	High Number of Seats Per				
V22	The Increasing Human Size				
	Capability Associated with				

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ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
X15	Seat Pitch, Aisle Width, Passageway Width, Exit Size, etc Obstruction of Exit Opening by Seat Components				
X16	Exit Step Up or Step Down Distance too High				
X09	Exit Door Blocked by Spilled Galley Items or Metal Food Containers or Cart	Accident review (1 accident) ADB Ref. 20060708A	(Not the cause of direct injuries)	25.561(c)(1)(iii), 25.787(a)(3) and (b), 25.789	In this particular accident, the metal food containers fell and blocked the exit as a result of the aeroplane's collision with barriers. In an NTSB study on emergency evacuations <sup>5</sup> , in the 28 cases for which questionnaires were distributed, only two flight attendants reported galley items obstructing passenger evacuation.
					It was concluded that the requirements to mitigate this threat are considered adequate.
V07	Spilled Galley Contents On Evacuation Route(s)	Accident review (1 accident) ADB Ref. 19980806A	Minor injuries	25.787(a)(3)	The risk of this threat is found to be relatively low and the current applicable requirement is considered adequate.
X10	Exit(s) Cannot Be Used due to Aircraft Attitude	Accident review (6 accidents) ADB Ref. 20040101A 20020828A 20020114B 20001224A 20001105A 19991107A	(Not the cause of direct injuries)	25.810(a)(1)(iii) and (e)(2)	All of these accidents, with the exception of ADB Ref. 20001224A which rested on sloping terrain, involved the collapse or detachment of one or more landing gears. Such circumstances are already addressed in CS 25.810(a)(1)(iii) and (e)(2). In these accidents, cabin crew chose not to use those exits to avoid the risk of injuries to evacuees due to the (likely) steep slope of the slide. This was understandable since none of these accidents had life-threatening circumstances such as post-crash fire.

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
X03	Passengers Have Difficulty Opening Type III Exit (No Jamming)	Accident review (2 accidents) ADB Ref. 19990601A 19981101B	(Not the cause of direct injuries)	25.809(c)	These issues are being addressed by current rulemaking activity. EASA is in the process of amending CS-25 on Type III Exits (NPA No 2008- 04). The objective is to increase evacuation performance by improving access to, and automatic disposal of. Type III exit hatches.
X08	Overwing Exit Hatch Left inside the Cabin	Accident review (1 accident) ADB Ref. 19990601A	(Not the cause of direct injuries)		
X12	Difficulty in Opening Exit Door with Airstair	Accident review (1 accident) ADB Ref. 19981203A	(Not the cause of direct injuries)	25.810(e)	In this accident, the stowed airstairs had dislodged on impact and partially blocked the exit door. However, the flight attendant was able to access the handle and open the door.
					The requirement is considered adequate and the findings of the accident review did not warrant a further evaluation.
W09	Insufficient Type or Number of Emergency Exits	Brainstorming	(Not applicable)	25.807(a) and (d)	The study did not identify this risk in the accident review, although lack of emergency exits related to door non-operation and other circumstances (hazards near exits) was identified.
					The Proposed JAA NPA 25.298 introduces the FAA Amendment 25-88, revising the standards for Emergency Exits. Rev. 1 of this NPA introduces a difference with FAR Amendment 25-88, which is the prohibition of non-floor level over wing exits in airplanes with more than 299 passengers. EASA will be developing the RIA for this subject.
AA04	Insufficient Capacity of Emergency Exits (Type/Size, Number, Location) for Evacuating during Ditching	Review of certification documents:	(Not applicable)	25.807(e)	The accident review did not find any ditching events where the type/size, number, or location of ditching emergency exits was considered insufficient.

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ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
		ELOS Memo # TC1258WI-T-A-6, TC2548WI-T-AG-1			Taking into account that the frequency of ditching in the period analysed was relatively low (8 water- related events in the 326 accidents evaluated), the level of safety achieved by the current applicable requirements was found acceptable. A threat that may be related to this is 'Issues Related to Ditching Doors' (AA02), which has been evaluated further.
R51	Injuries Sustained by Evacuees while Using Escape Rope	Accident review (1 accident): ADB. Ref. 20031218A	Minor injuries	25.810(a)(2)	It is unlikely that there are any more features that can significantly enhance the safety of the flight crew escape rope. Additionally, the nature of the injuries in this case was minor and only affected flight crew. Therefore the risks are considered low.
CB01 CB02	Liferaft Fails to Deploy/Inflate Liferaft Fails to Stay Inflated	Literature review <sup>67</sup>	(Not applicable)	25.1415(b)	Although these threats originated from in-service experience (possibly during maintenance), the accident review did not find any events associated with the threats.
					must be approved. The standard for slide rafts is defined in CS-ETSO-C69c and for liferafts in CS-ETSO-2C70a.
CB03	Insufficient Number of Liferafts/Slide Rafts	Literature review <sup>8</sup> .	(Not applicable)	25.1411(d)(1), 25.1415(b)(1)	The issue regarding the provision of life rafts in addition to the slide rafts on Very Large Transport Aeroplanes was raised at the VLTA Conference at Noordwijkerhout in 1998 <sup>8</sup> . The Conference concluded that "the workshop is unsure of the need of such additional rafts, taking into consideration that ditching is an improbable event (looking at the last 30 years) and will likely be even more improbable for future airplanes. A careful review of the issue may lead to judgment instead of having these additional rafts, that the weight saved then

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Appendix 7 Page A7-14

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	APPLICABLE CS-25 CABIN SAFETY REQUIREMENTS	DISCUSSIONS
					being used for another safety device".
					The accident review did not find any accident (non- VLTA) where this threat was present. It was concluded that the applicable CS-25 requirements, as well as OPS.CAT.420, are adequate.
CA01	Difficulty in Using (Donning	Accident review	None	25.1415(b),	In this accident, the threat had no effect on safety
	Design	ADB Ref.		25.1415(e)	and the evacuation of the airplane took place
	Ŭ	20001224A			calmly and with no rush. It should be noted that it is
					conditions, it could have been a factor leading to
<b></b>					panic.
CA04/ CA05	Failure of or ineffective Life Vest/Flotation Devices	Literature review	(Not applicable)		The accident review did not find any recent occurrence of threats CA04/CA05, or CA06. In a
CA06	Ineffective Infant Life	Literature review <sup>10</sup>	(Not applicable)		CAMI study <sup>3</sup> , threat CA04/CA05 was identified in the 1989 USAir Flight 5050 accident.
	Preservers				The applicable CS-25 requirements require
					approval of the vests and fiolation devices. This approval is based on CS-ETSO-72c (Individual
					Flotation Devices'). The CS-25 requirements are
					considered adequate.

# APPENDIX 7 – CABIN SAFETY THREATS ADEQUATELY ADDRESSED BY CS-25 REQUIREMENTS OR HAVING NO PRACTICAL MITIGATION METHODS Table A7-2 Cabin Safety Threats that are considered having no practical mitigation methods

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	RATIONALE
GB08	Separated Parts of Aircraft (e.g. Engine, Propeller) Penetrating Cabin during Impact Sequence	Accident review (1 accident) ADB Ref. 20000927B	None	It is considered that there would be no practical way of addressing this threat.
V12	Presence of Water in Cabin during Evacuation (Not Ditching)	Accident review (1 accident) ADB Ref. 19990822A	None	It is considered that there would be no practical way of addressing this threat. Additionally the risk related to this threat is considered low.
GB02	Non-Specific Injuries Sustained during Impact	Accident review (17 accidents): ADB Ref. 20070218A 20061128A 20051208A 20050802A 20040509A 20040105A 20040101A 20031222A 20030622A 20030622A 20030117A 20020415A 20020415A 20010108A 19990923A 19990914A 19990822A 19980806A 19980209A	Minor injuries Serious injuries Fatal injuries	Further evaluation is not possible since there was not enough information on the nature of the impact injuries. Other more specific impact-related threats and the associated CS-25 requirements addressing various impact protections for occupants have been evaluated further (see 'Restraint Systems and Injury Criteria', 'Cabin Crashworthiness', 'Inadequate Seat-Floor Strength and Floor Deformation').

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	RATIONALE
Y01	Non-Specific Injuries Sustained during Evacuation	Accident review (21 accidents)	Minor injuries Serious injuries	The accident review identified 21 accidents where non-specific injuries were sustained during evacuation. The injuries ranged from minor to serious. Without knowing the nature of the injuries and the cause it is not considered possible to identify and evaluate the associated threats.
X01	Exit Cannot Be Used due to Obstruction by Interior Disruption	Accident review (1 accident)	(This non- availability of exit	These threats could not have been avoided due to the nature of the impact and/or fire in these accidents.
	or internal Fire	20060708A	has contributed to fire/smoke fatalities/injuries)	Internal fire is partially addressed in the discussion of the threat group 'Occupant Protection from Smoke Inhalation and Thermal Injuries During Post- Crash Fires'
X05	Exit Cannot Be Used due to External Fire or Other Hazards (e.g. Debris)	Accident review (4 accidents) ADB Ref. 20050802A 20040509A 20031218A 20020114B	(The non- availability of exits in these accidents did not contribute to fatalities or injuries)	
H02	Leakage of Aircraft System Fluid into Cabin	Accident review (2 accidents) ADB Ref. 20050610C 19990822A	Minor injuries	ADB Ref. 20050610C – This accident on an Avro RJ-85 (high wing) aircraft involved hydraulic fluid leakage within the upper cabin, including spray and mist, which caused minor injury to a number of passengers in 3 rows, inluding breathing and eye irritation. The leak was attributed to a fatigue failure in a hydraulic line caused by a manufacturing defect.
				ADB Ref. 19990822A – This accident involved a major impact where the fuselage became inverted and suffered significant crushing damage to the upper fuselage. Fuel and hydraulic fluid leaked into the cabin.
				Notwithstanding the hazardous nature of hydraulic fluid, especially when in a mist form, it is considered impractical to regulate within CS-25 to mitigate against leakage resulting from a manufacturing defect or severe aircraft impact damage.

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	RATIONALE
X07	Exit Door Cannot Be Opened or Is Difficult to Open due to Direct	Accident review (1 accident)	(Not a cause of direct injuries)	The aft galley (2L) door could not be used because of impact damage from the runway 22L approach lighting system.
	Impact Damage	ADB Ref. 19990601A		It is considered that currently there would be no practical way of addressing this threat.
X11	Exit Door Cannot Be Opened or Is Difficult to Open Because of Its Proximity to the	Accident review (4 accidents) ADB Bef	(Not a cause of direct injuries)	In these accidents, the aircraft came to rest against trees, an airport fence, and ground.
	Ground/Structures/Vegetation	20041201B 20030117A 20020114B 20001031B		It is considered that currently there would be no practical way of addressing this threat.
SB03	Injurious Contact with Seat Components during Impact Sequence	Accident review (1 accident) ADB Ref. 19990601A	Minor injuries	The accident review identified one accident where injuries were noted from impact with arm rests. This was the 1999 MD-82 accident at Little Rock, USA, which involved a substantial impact where the aircraft broke into three sections. He [seat 7E pax] thinks his ribs were injured by the arm rests on the seat. He [seat 22D pax] hit the armrests and bruised his ribs
				Minor injuries are inevitable in some impacts and their occurrence would ultimately depend on the degree of impact. CS 25.785(k) requires projecting objects on seats to be padded to prevent injury during normal flight. This type of protection would undoubtedly prevent injury during many minor impacts. It would however be impractical and not cost beneficial to design armrests on aeroplane seats that prevented minor injury (bruising) during all impacts.
V09	Disrupted Cabin Floor On Evacuation Route	Accident review (1 accident) ADB Ref. 19990923A	(Not a cause of direct injuries)	The accident report states that a cabin crew member noted that the galley floor between doors L1 and R1 had been deformed upward. The accident report does not state that this has caused an evacuation impediment. There is not enough evidence to warrant further evaluation in order to consider recommendation for amendment of CS-25 or further research.

ID	CABIN SAFETY THREATS	IDENTIFIED FROM	EXTENT OF INJURIES (FROM ACCIDENT REVIEW)	RATIONALE
J03	Occupants' Crumple Zone Compromised by Fuselage Distortion Following Impact	Accident review ADB Ref. (1 accident)	Minor injuries	The cabin wall on the right fuselage next to seats 1K through 5K was deformed inboard The crown of the fuselage was crushed downwards resulting in head injuries to many of the persons onboard. 45 head injuries
	1999082	19990822A	19990822Á	In this accident, the aeroplane came to rest inverted. The three fatalities on this accident were not related to the compromised cabin space. There is not enough information to determine the extent of injuries this threat might have caused.
				There is not enough evidence to warrant further evaluation in order to consider recommendation for amendment of CS-25 or further research.
R50	Evacuation Taking More Than 90 Seconds (Non-Specific)	Accident review (9 accidents) ADB Ref. 20060912A 20051208A 20051030B 20050802A 20050510C	None	Most of these accidents did not feature life-threatening circumstances and hence it was considered acceptable to conduct the evacuation at a slower rate to minimise the risk of injuries. There is not enough evidence to warrant further evaluation in order to consider recommendation for amendment of CS-25 or further research.
		20050510B 20041128A 20030617A 19980330B		
R12	Difficulty in Rescue Operations due to Disruption of Aircraft Cabin	Accident review (1 accident) ADB. Ref. 19990822A	(Unknown)	From the description of the accident, the nature and forces of the impact were most likely beyond that specified in the requirements for minimising cabin disruption.

<sup>&</sup>lt;sup>1</sup> Vigilance in Aircraft Galley and Service Procedures Preserves Margin of Safety, Flight Safety Foundation – Cabin Crew Safety Vol. 34 No. 1, January – February 1999 <sup>2</sup> Garner, R.P. (1999). Concepts Providing for Physiological Protection After Aircraft Cabin Decompression in The Altitude Range of 60,000 to 80,000 Feet ASL, DOT/FAA/AM-99/4. Washington, D.C.: US Department of Transportation

<sup>3</sup> Asmayawati, S., Butcher, N, & Cherry, R. (2009) CAA Paper 2009/01 Cabin Crew Fire Training – Training Needs Analysis. Gatwick: UK Civil Aviation Authority.

<sup>4</sup> RGW Cherry & Associates (2009) Burnthrough Resistance of Fuselage, 4207/R/000456/KK Issue 5, Prepared for the European Aviation Safety Agency

<sup>5</sup> National Transportation Safety Board. (2000) Safety Study – Emergency Evacuation of Commercial Airplanes, NTSB/SS-00/01. Washington, D.C.: NTSB

<sup>6</sup> Civil Aviation Safety Authority Australia, AD/EMY/31, Airworthiness Directives for Aerazur Life Raft Type 606 (Falcon 900), 9/96 (Ref. DGAC AD 96-112(AB))

<sup>7</sup> Federal Aviation Administration, Airworthiness Directives; Air Cruiser Company Emergency Evacuation Slide/Raft System AD 2004-03-01

<sup>8</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16 October 1998

<sup>9</sup> Cosper, D.K. & McLean, G.A. (1998) DOT/FAA/AM-98/19, Analysis of Ditching and Water Survival Training Programs of Major Airframe Manufacturers and Airline. Washington, D.C.: Office of Aviation Medicine

<sup>10</sup> Funkhouser, G.E & Fairlie, G. W. (1991) *Donning Times and Flotation Characteristic of Infant Life Preservers: Four Representative Types, DOT/FAA/AM-91/6.* Washington, D.C.: Office of Aviation Medicine

4208/R/000454/KK Issue 6 Dec-2009

**APPENDIX 8 – CABIN SAFETY THREATS EVALUATED IN DETAIL** 

# **EVALUATION SHEETS**

#### Cabin Safety Threat:

# 1. Unavailability of Power Supplies to Internal Communication Systems in Emergency Situations

IA01 / Failure of Communication System between Flight Crew and Cabin Crew during an In-Flight Emergency

IA02 / Failure of PA system during an In-Flight Emergency

IB01 / Failure in PA system during/Prior to Evacuation

IB02 / Failure in Communication System between Cabin Crew and Flight Crew (Interphone or Evacuation Alarm System) during/Prior to Evacuation

R20 / Occupants Unaware of Cautions/Warning due to Failure of Communication/ Announcement System during Flight

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

The only CS-25 requirement applicable to this threat is for the PA system, as follows:

CS 25.1423 A public address system required by operational rules must –

(a) Be powerable when the aircraft is in flight or stopped on the ground, after the shutdown or failure of all engines and auxiliary power units, or the disconnection or failure of all power sources dependent on their continued operation, for –

(1) A time duration of at least 10 minutes, including an aggregate time duration of at least 5 minutes of announcements made by flight and cabin crew members, considering all other loads which may remain powered by the same source when all other power sources are inoperative; and

(2) An additional time duration in its standby state appropriate or required for any other loads that are powered by the same source and that are essential to safety of flight or required during emergency conditions.

(FAR 25.1423 was introduced in 1989 and is effective for aircraft manufactured after November 27 1990)

Note: CS 25.1362 'Electrical supplies for emergency conditions' is not applicable to communications systems. AC 25.1362-1 states "Emergency Services. The emergency services which may require an electrical supply include fuel shut-off valves, hydraulic shut-off valves, and engine/APU fire extinguisher systems."

Other requirements related to this threat are under EU-OPS, as follows:

EU-OPS 1.690 Crew member interphone system

(a) An operator shall not operate an aeroplane with a maximum certificated take-off mass exceeding 15 000 kg or having a maximum approved passenger seating configuration of more than 19 unless it is equipped with a crew member interphone system except for aeroplanes first issued with an individual certificate of airworthiness before 1 April 1965 and already registered in a Member State on 1 April 1995.

EU-OPS 1.695 Public address system

(a) An operator shall not operate an aeroplane with a maximum approved passenger seating configuration of more than 19 unless a public address system is installed.

The table illustrates the variation in the requirements for each of the systems:

Communication System	Requirement for Aircraft to be Equipped with System	Requirement for System to be Powerable following Engine/APU Fail or Off	Requirement for System to be Powerable following Battery Bus Fail or Off
Interphone	EU-OPS 1.690	No	No
		Requirement	Requirement
PA System	EU-OPS 1.695	CS 25.1423	No
			Requirement
Evacuation	No	No	No
Alert	Requirement	Requirement	Requirement

#### Accident Experience and Safety Recommendations

The review of accidents has highlighted that unavailability of power to the aircraft internal communication systems has occurred frequently at critical times during an emergency situation. This has affected the ability of the cabin and flight crew to initiate and execute emergency procedures in the most expeditious and effective manner. This threat occurred in 16 accidents in the period reviewed.

Brief details of the most recent accidents are shown in the table below and are representative of the problems that occurred with the internal communications systems during the earlier accidents.

ADB Ref	A/C Type (First Flight)	Aircraft Pre/Post CS 25.1423	Resume
20060912A <sup>1</sup> Auckland, New Zealand	B737-300 ZK-NGJ (1999)	Post	In-flight power failure to PA system, intercom and call button following Battery Bus failure. Evacuation after landing due to smoke in cabin. No aircraft impact. Due to this unavailability of communication systems, the communications between flight crew and cabin crew, amongst cabin crew, and between crew and passengers had to be carried out face-to-face.
20051208A <sup>2</sup> Chicago, U.S.A.	B737-700 N471WN (2004)	Post	Post crash power failure to PA system. Moderate impact after a landing overrun. The PA system was unavailable for cabin crew direction of the evacuation. One cabin crew expected the PA not to work due to aircraft power failure and therefore did not try. Another tried to use the PA and did not know it was not working until advised by a passenger that no sound was coming through.
20050802A <sup>3</sup>	A340	Post	Post crash power failure to PA system, EVAC COMMAND and EVAC ON alert. Landing overrun followed by moderate impact, fire and evacuation. The PA operated for a short time

Toronto, Canada	F-GLZQ (1999)		allowing three announcements including one evacuation announcement, but then failed. The EVAC COMMAND function failed to work when operated by the chief purser to notify the flight crew. The EVAC ON function failed to work when operated by the flight crew in order to activate the evacuation alert to the cabin crew. The accident report cites the vulnerable location of the PA system emergency power in the avionics bay as the reason.
20030617A <sup>4</sup> Groningen, Netherlands	MD88 TC-ONP (1997)	Post	Post crash failure of PA system. Rejected takeoff, overrun, moderate impact and evacuation. One passenger heard a PA announcement soon after the aircraft stopped but it was unintelligible. The Purser stated the PA system did not work after the crash.
20030524A <sup>5</sup> Amarillo, U.S.A	B737-300 N343SW (1989)	Pre	Post crash failure of PA system and Radio. Runway excursion during landing and moderate impact. No evacuation was necessary.
20020114B <sup>6</sup> Pakanbaru, Indonesia	B737-200 PK-LID (1969)	Pre	Post crash failure of PA system power. Aborted take-off, overrun, moderate impact and evacuation. When the pilot in command realised the emergency situation he shouted "EMERGENCY, EVACUATE" several times since there was no electrical power available.

The following table lists the safety recommendations related to this threat group. Also included in the table are a safety finding pertinent to the subject and a safety recommendation relevant but outside the scope of the accident review period:

ADB Ref	Safety Recommendations
20001031B <sup>7</sup>	Aviation Safety Council Taiwan Recommendations
Taipei,	To SIA:
Taiwan	Modify the emergency procedures to establish an alternate method for initiating the
B747-400	emergency evacuation command in the event of a PA system malfunction. (3.2-[26]) -ASC- ASR-02-04-09
9V-SPK	To the Boeing company:
	Develop a means to reduce failure of PA systems during survivable accidents and provide modified systems to operators. (3.2-[26]) -ASC-ASR-02-04-39
	To US FAA & JAA:
	Initiate rulemaking actions to require the installation, on Boeing aircraft, of public address systems that continue to function following survivable accidents. (3.2-[26]) -ASC-ASR-02-04-55 & 59
19990923A <sup>8</sup>	Safety Recommendation R20000231
Bangkok, Thailand	The ATSB recommends that the FAA and JAA review the design requirements for high capacity aircraft to ensure the integrity of the cabin interphone and passenger address
B747-400	systems, particularly with respect to cabin/flight deck communications, in the event of runway overruns and other relatively common types of events which result in landing gear
VH-OJH	and lower fuselage damage.
20050802A <sup>3</sup>	Findings as to Risks
Toronto,	8. The emergency power for both the public address (PA) and EVAC alert systems are located in the avionics bay. A less vulnerable system and/or location would reduce the risk

Canada	of these systems failing during a survivable crash.	Τ
A340		
F-GLZQ		
Incident to EMB190 <sup>9</sup> 15/01/2008 (not within review period)	UK AAIB Safety Recommendation 2009-019: It is recommended that Embraer modify the functioning of the interphone systems of Embraer 190 family aircraft to provide crew with the facility to make both normal and emergency calls when the aircraft is supplied only with emergency electrical power.	

#### Research and Rulemaking Activities

In 1995, the TSB published a document entitled A Safety Study of Evacuations of Large, Passenger-Carrying Aircraft<sup>10</sup>. Twenty-one occurrences involving emergency evacuations were reviewed. In 8 of the 21 occurrences, the aircraft's PA system was inoperable or inaudible following the accident. As a result, cabin crew and/or passengers did not hear the initial command to evacuate and/or did not hear other emergency instructions. The onset of these evacuations was delayed, placing the safety of passengers and crew at risk. One of the recommendations resulting from this safety study is as follows:

The Department of Transport review the adequacy of power supplies and standard operating procedures for PA systems in an emergency for all Canadian operators of large passenger aircraft. (A95-04)

Communication issues during emergency situations associated with loss of power to internal communication systems have been cited in a safety study carried out by the National Transportation Safety Board<sup>11</sup> and re-iterated in a presentation on the challenge of emergency and abnormal situations for flight attendants<sup>12</sup>. Following the safety study, the NTSB issued the following recommendation:

Require all newly manufactured transport-category airplanes operating under Title 14 Code of Federal Regulations Part 121 to be equipped with independently powered evacuation alarm systems operable from each crewmember station, and establish procedures and provide training to flight crews and flight attendants regarding the use of such systems. (A-00-90)

Communication is even more crucial on very large transport aeroplanes, due to the increased number of cabin crew, number of exits and number of possible scenarios for evacuation in comparison to the smaller aeroplanes. The VLTA conference in Noordwijkerhout<sup>13</sup> recommended that:

It is recommended that a means of enhancing communication between cabin crew members and between cabin and flight crew be pursued.

#### Discussion

#### 1) Interphone system

Aircraft configured with greater than 19 passenger seats or greater than 15,000 kg MTOW are required by EU-OPS 1.690 to be equipped with an interphone system allowing communications between flight deck crew and cabin crew.

EU-OPS 1.690 clearly intends the interphone to be operational during emergency situations since it requires the interphone system to " have a means for the recipient of a call to determine whether it is

a normal call or an emergency call ... "

However, CS-25 does not require the interphone system to be powerable when the engines or APU are off, as it does for the PA system. This means that aircraft compliant with CS-25 could potentially have non-functioning interphone systems as a result of engine shutdown or failure following emergency landing or impact, at a time when two way communications between the flight deck and cabin are most vital to establish the need for an evacuation. It is normal for the aircraft commander to initiate evacuation, but it is often the cabin crew who first recognise the need for evacuation, because either they have sight of an external fire or fire has entered the passenger compartment. Without an interphone system the ability of the cabin crew to notify the captain is severely degraded.

Similarly, following total engine failure in flight, two way communications between the flight deck and passenger compartment could be lost, degrading preparations for ditching or emergency landing. This threat is exacerbated by the requirement for locked cockpit doors.

Unlike the interphone system, CS-25 requires PA systems to be powerable when the engines and APU are off. This would usually be achieved by powering the PA system from the switchable battery bus instead of the generator bus, as on the Boeing 737. There appears to be no obvious reason why an interphone system could not be powered in a similar way to the PA system.

#### 2) PA system

The primary reasons for using the PA system during emergency situations are to initiate an emergency evacuation and for the flight crew to call 'Brace for Impact'.

It is logical that CS 25.1423 requires the PA system to be powerable in the event of engines and APU not running (FAR 25.1423 was introduced in 1989 and is effective for aircraft manufactured after 27 November 1990). This requirement caters for an in-flight loss of engines and APU and the possible need to shut down engines after an emergency landing or impact. It is likely that on the majority of aircraft types, the PA system is powered from the switchable battery bus, as on the Boeing 737.

However, in several accidents reviewed over the period 1998 to 2007 inclusive, there was no power available to the PA system immediately after emergency landing or impact when the crew were faced with an evacuation situation. In one accident, (Toronto A340, ADB Ref. 20050802A), the PA system received power for only enough time for three messages to be broadcast.

The accident review shows that a potential reason for the loss of a PA system's power supply is fuselage impact damage. In some accidents, the power supplies to the PA systems failed despite there being relatively low levels of impact damage to the fuselages.

Additionally, it is possible for the power to the communications systems to be switched off by the flight crew; this occurred in at least one accident. The precise reason for loss of power was not given for some accidents and for others, where the aircraft was manufactured prior to 25.1423 becoming effective, the PA system was not required to be powered following engine and APU shutdown. One example of in-flight failure of the battery bus, which removed the power supply to the PA system, was evident in the accident review.

#### 3) Evacuation Alert System

Evacuation alert systems are not currently required by operational requirements or CS-25. However, it is evident from the review of accidents, that on some aircraft types these systems have been introduced and airline operating procedures specify their use for initiating evacuations. It is therefore logical that the power supplies to the evacuation alert systems should be available when required in an emergency. For this reason it is considered that the power supply to the evacuation alert system should have equal status and availability to that for the PA system.

It may be beneficial for all CS-25 aircraft beyond a certain size to be equipped with evacuation alert

systems. However, since an evacuation alert system duplicates the capabilities of the interphone and PA system in establishing the need and commanding an evacuation, further research would be necessary to determine the benefits.

#### Proposed Potential Solutions

i) 'Impact Tolerant' Power Supply to Internal Communication Systems

The current reliance on powering the communications systems from the aircraft battery bus may not provide the most impact tolerant power source. To remedy this, it is likely that a dedicated power source could be installed for internal communications systems, having a location optimised to resist damage from crash impact. The power source and its electrical distribution wiring could also be crash hardened.

ii) Radio Headsets for Cabin Crew

The use of radio headsets by cabin crew has been suggested as a potential solution to resolve crew communication problems. Such a system would usually employ headsets individually powered by batteries, which might initially be seen as a method for overcoming aircraft power unavailability. However, more research would be required to investigate its feasibility and cost/benefit. Additionally, this does not address issues related to PA system. This subject is discussed further in 'Inability for Cabin Crew to Communicate with Each Other During Emergency Situations'.

#### **Conclusions and Recommendations**

1) PA, Interphone and Evacuation Alert System (if fitted) Power Supplies

Given the importance of the availability, during emergency situations, of the service interphone, PA system and evacuation alert system (if fitted), it is proposed that the integrity of the power supplies to these systems should be improved. This will require amendment of CS-25. It is recommended that this proposal be considered for evaluation via a Regulatory Impact Assessment.

A new rule will be required for the power supplies to the interphone system and evacuation alert system (if fitted). A revision to the existing rule CS 25.1423 for the PA system may be required.

The final wording of the rules will be required such that the systems:-

- 1) Are powerable when the aircraft is in flight or stopped on the ground, after the shutdown or failure of all engines and auxiliary power units, or the disconnection or failure of all other power sources.
- 2) Have power supplies and EWIS located and installed to minimise the likelihood of power interruption in the event of impact damage to the fuselage.

In effect, this means that a dedicated power supply would be necessary for these communications systems.

2) Evacuation Alert System

Some aircraft types are already equipped with evacuation alert systems. It is proposed that research be carried out to establish whether operational requirements should include a rule for all, or certain size, CS-25 aircraft to be equipped with these systems.

<sup>&</sup>lt;sup>1</sup> The Transport Accident Investigation Commission New Zealand, *Report 06-003 Boeing 737-319 ZK-NGJ* electrical malfunction and subsequent ground evacuation Auckland International Airport 12 September 2006

<sup>2</sup> National Transportation Safety Board, *Runway Overrun and Collision Southwest Airlines Flight 1248 Boeing* 737-7H4, N471WN Chicago Midway International Airport Chicago, Illinois December 8, 2005, NTSB/AAR-07/06

PB2007-910407 <sup>3</sup> Transportation Safety Board of Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005 Dutch Safety Board, Runway overrun Onur Air Runway overrun after rejected take-off of the Onur Air MD-88,

registration TC-ONP, at Groningen Airport Eelde on 17 June 2003 <sup>5</sup> National Transportation Safety Board, Aircraft Accident Brief FTW03MA160, Southwest Airlines Flight 2066, Boeing 737-300, N343SW, Amarillo, Texas, Date: May 24, 2003

National Transportation Safety Committee, Department of Communications Republic Of Indonesia, Aircraft Accident Report KNKT/02.01/03.03.011, PT. Lion Air, Boeing 737-200 PK-LID, Sultan Syarif Kasim II Airport, Pekanbaru, Riau, 14 January 2002

Aviation Safety Council Taiwan, Crashed on a partially closed runway during takeoff, Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, Chiang Kai Sek Airport, Taoyuan, Taiwan, October 31, 2000

Australian Transport Safety Bureau, Investigation Report 199904538, Boeing 747-438, VH-OJH, Bangkok,

*Thailand* <sup>9</sup> UK Air Accidents Investigation Branch, *AAIB Bulletin No: 1/2009, Ref: EW/C2009/01/03, EMB-190, G-FBEH,* 

15 January 2009, Overhead Edinburgh <sup>10</sup> Transportation Safety Board of Canada (1995) A Safety Study of Evacuations of Large, Passenger-Carrying Aircraft, Report Number SA9501. Retrieved November 2008 from http://www.tsb.gc.ca/eng/rapportsreports/aviation/etudes-studies/sa9501/sa9501.asp

National Transportation Safety Board (2001) Safety Study - Emergency Evacuation of Commercial Airplanes, NTSB/SS-00/01. Washington D.C.: NTSB <sup>12</sup> Nora C. Marshall (2009) *The Challenge of Emergency and Abnormal Situations for Flight Attendants*.

Washington, D.C.: National Transportation Safety Board.

<sup>13</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16 October 1998

#### Cabin Safety Threat:

#### 2. Issues Associated with Secured Flightdeck Doors

IA05 / Communication Problems Related to Secured Flightdeck Door during Flight

IB04 / Communication Problems Related to Secured Flightdeck Door during/Prior to Evacuation

IA06 / Cabin Crew Could Not Access Flightdeck in the Event of Flight Crew Incapacitation

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

The following are CS-25 requirements applicable to this issue:

25.772 For an aeroplane that has a lockable door installed between the pilot compartment and the passenger compartment: -

(a) For aeroplanes with passenger seating configuration of 20 seats or more, the emergency exit configuration must be designed so that neither crewmembers nor passengers require use of the flight deck door in order to reach the emergency exits provided for them; and

(b) Means must be provided to enable flightcrew members to directly enter the passenger compartment from the pilot compartment if the cockpit door becomes jammed.

(c) There must be an emergency means to enable a crewmember to enter the pilot compartment in the event that the flight crew becomes incapacitated.

There is no guidance material for the above requirements.

The JAA Policy Paper on Flightcrew Compartment Access issued 20 November 2001<sup>14</sup> listed several operational considerations. The following operational considerations are of particular relevance to this ssue:

- Communication between flight deck/cabin crew and cabin crew/flight deck in normal, abnormal and emergency situations (including flight deck intrusion and pilot incapacitation)
- Procedures in case one flight crew member leaves the flight deck for, health, safety, security or crew rest reasons
- Evacuation procedures, in particular if the Public Address/Cabin Interphone system is broken or unserviceable

#### Accident Experience and Safety Recommendations

#### 1) Difficulties in communications

Accident experience has shown that generally a locked flightdeck door has degraded communications between the flight crew and the cabin crew especially during emergency situations. The following excerpt from the report on the accident involving Alaska Airlines B737-900 at Calgary International Airport on 30 October 2005 reflects this issue:

... the request of the cabin crew for a direct discussion of the problem, the first officer released the flightdeck door lock. Due to the noise level in the cabin, the flight attendants could not hear the lock release, and the flightdeck door remained closed. [Findings:] The closed flightdeck door likely reduced the effectiveness of communications between the cabin and flight deck crews, and prevented the pilots from directly assessing the amount of smoke in the cabin. (ADB Ref. 20051030B)<sup>15</sup>

The situation was also found in an incident involving a DHC-8-400 near Leeds, West Yorkshire, UK, on 4 August 2005<sup>16</sup>, where a high workload in an in-flight smoke incident had prevented the flight crew from communicating with the cabin crew for some time. The cabin crew commented that

"delays in obtaining a response from the flight deck to cabin emergency calls at times had caused concern as to the state of the flight crew".

Although it could not be determined whether any of the cabin crew members in the Helios Airways B737 accident (ADB Ref. 20050814A<sup>17</sup>) attempted to contact the flight crew or enter the flight deck after passenger oxygen masks deployment, it is possible that the secured flightdeck door contributed in the events leading to the eventual crash of the aeroplane.

The occurrences mentioned above did not involve any failure of the interphone system, and yet communication difficulties were already evident. In an incident to a B737-436 in Clacton<sup>18</sup>, the interphone system was rendered unserviceable by the damage to the wiring. Having discovered smoke and other indications of fire, both the flight crew and cabin crew were initially hampered in their efforts to deal with the incident promptly due to their inability to communicate with each other across the locked flightdeck door.

With the current requirements, the failure of the interphone system is likely to occur as a result of the loss of electrical power on the aircraft, either as a result of the flight crew being required to switch certain power buses off in an emergency or as a result of engine failure or crash impact. Accident/incident experience demonstrates that there is a significant risk of system failure or intentional power disconnection affecting the operability of the interphone system, as listed below:

- In-flight: the failure of battery bus in flight (B737-300 accident at Auckland Airport<sup>19</sup>, B737-33V near Lyons<sup>20</sup>), damaged wiring (B737-436 incident in Clacton<sup>18</sup>), and loss of main electrical supply (EMB-190 incident overhead Edinburgh<sup>21</sup> and Avro 146-RJ100 incident at Edinburgh Airport<sup>22</sup>)
- Post-impact: loss of main electrical supply shut off or damaged following impact (Paris B737-200<sup>23</sup>, Hua Lien MD-90-30<sup>24</sup>, Bangkok B747-438<sup>25</sup> and Toronto A340<sup>26</sup> accidents)

CS-25 does not require power to the interphone to be preserved when the aircraft has a degraded main electrical supply, nor does it require the emergency flightdeck door unlocking facility (from cabin) to be powered in these circumstances. Flightcrew incapacitation (or suspicion of flightcrew incapacitation) would heighten the need for cabin crew to enter the flightdeck using the emergency unlocking mechanism that is usually electrically operated. However, as in the incident to an EMB-190 cited below, power for the unlocking system may be unavailable for the same reason that power is unavailable to the interphone.

The following two incidents featured a scenario involving difficulties with the interphone system combined with a locked flightdeck door in emergency situations:

(1) EMB-190, G-FBEH, Overhead Edinburgh, 15 January 2009<sup>21</sup>

In the course of the 'Electrical System Fire or Smoke' procedure, the flight crew disarmed the emergency lighting, deployed the Ram Air Turbine (RAT) and then selected off the Integral Drive Generators (IDGs), which are the engine-driven sources of main electrical power. This caused all the cabin lighting to extinguish...

The SCCM attempted to call the flight crew on the cabin interphone system, by pressing the PILOT call button. The green light above the button illuminated, but the flight crew did not answer. Despite repeated attempts, using handsets in both the forward and rear galleys, the SCCM could not establish communication with the pilots in this way.

The "smoke" diminished and eventually ceased. Nonetheless, the cabin crew became concerned at the darkness in the cabin, the unexplained noise from the forward part of the aircraft, and the lack of communication with the flight crew. They became concerned either that the flight crew might have become incapacitated or that a serious emergency had developed in the flight deck. After some minutes they decided to attempt to access the flight deck using the emergency flight deck access system, but this, too, did not function.

Concern amongst the cabin crew continued until the commander made a public address announcement explaining that the aircraft was diverting to Newcastle; the cabin crew then recognised that their concerns were unfounded.

Following this incident, the UK AAIB issued Safety Recommendation 2009-020:

It is recommended that Embraer immediately notify all operators, of the Embraer 190 family of aircraft, to inform flight and cabin crew of the functioning of the flight deck access system when the aircraft is supplied only with emergency electrical power.

### (2) Avro 146-RJ100, G-CFAE, Edinburgh Airport, 11 January 2006<sup>22</sup>

Prior to starting the second engine on an aircraft with an unserviceable Auxiliary Power Unit (APU), the engine rpm was not increased on the operating engine, as required. Once the start was initiated, the increased load on the operating generator resulted in the operating engine going into a sub-idle condition. The engine was then over-fuelled and the result was a jet-pipe fire, which was reported to the flight crew by a ground handler. The operating generator also went off-line, leaving the battery as the sole source of electrical power for the aircraft. The cabin crew could not establish communications with the flight crew, who were completing the engine fire drill, and were unable to open the locked flightdeck door. With visual indications of an engine fire, the cabin crew initiated an emergency evacuation of the passengers.

The incident was initiated by the flight crew not following the correct procedure for engine start with the APU not available. However, the subsequent loss of normal electrical power resulted in no effective liaison between the flight and cabin crew. The investigation revealed a lack of knowledge regarding the communications system in degraded electrical conditions, which the company has taken action to rectify. The communication difficulties were compounded by the cockpit door being locked, with no means of operating it from the cabin. The situation required the flight crew to unlock the door or for the cabin and flight crews to establish communications. With the flight crew dealing with the reported engine fire, unlocking of the door was not their first priority. With no communication between the flight and cabin crew, the purser made the correct decision to evacuate the aircraft. The investigation has highlighted the essential need for any new procedure, such as locking the cockpit door, to be properly evaluated to ensure that security requirements do not have an unduly adverse effect on safety aspects.

### 2) Issues related to flight crew incapacitation in-flight

The incidents to an EMB-190 on 15 January 200921 and a DHC-8-400 on 4 August 200516 above highlight the need for a method by which the flight crew can confirm to the cabin crew that they are not incapacitated when they are unable to do so via verbal communication. The AAIB Bulletin on the DHC-8-400 incident mentioned triple activation of the seat belt audio alert in the cabin as a code from the flight crew. Some doors are fitted with two 'peepholes', one allowing the pilots to look into the cabin (as required by the operations requirements) and one allowing the cabin crew to look into the flight deck. Therefore, in the absence of any verbal communication, the cabin crew could at least visually check on the state of the pilots on the flight deck. Whilst means for monitoring, from either pilot's station, the entire door area outside the flightdeck to identify persons requesting entry and to detect suspicious behaviour or potential threat is required by EU OPS 1.1255, there is no requirement for means for cabin crew to check the flightdeck area in case of flight crew incapacitation.

Additionally, CS 25.772(c) does not require the emergency means to enter the flightdeck from the cabin to be operable when the main electrical supply is not available. If there is an in-flight fire/smoke incident within the flight deck, which could incapacitate the flight crew and at the same time cause or require disconnection of the main electrical supply, it may be impossible for the cabin crew to assist the flight crew.

### Research and Rulemaking Activities

Procedures have been used to prevent incapacitation of all flight crew due to common factors such as food or drink poisoning. There could be other factors such as hypoxia<sup>27</sup>, cabin air contamination with noxious fumes or smoke, or windscreen failure (e.g. due to maintenance error<sup>28</sup> or bird impact exceeding the standards provided by the airworthiness requirements<sup>29</sup>).

A study by the Australian Transport Safety Bureau<sup>30</sup> attempted to gain an appreciation of the potential magnitude of the hazards identified in the case of pilot incapacitation in 30 to 59 seat aircraft that included a problematic installation of a hardened cockpit security door. The study found

that in the period January 2000 to July 2005, there had been 43 reports of flight crew incapacitation during the period studied, or an average of about 8 incidents per year. The causes of the pilots' incapacitation varied, but included: the temporary loss of vision as a result of a lightning strike; physical illness, including stomach cramps and nausea; the lodgement of a foreign object in a pilot's eye; and incapacitation as a result of the contamination of the flight compartment. In one instance, both pilots became incapacitated. In many of the reported incidents, a cabin crew member was required to enter the flight compartment to render assistance while the remaining pilot ensured the continued safe conduct of the flight.

The following is the abstract of a study on flight crew incapacitation in flight carried out by CAMI<sup>31</sup>:

Although it is not known when the first accident due to pilot in-flight medical incapacitation occurred, a recent survey showed that almost one-third of all pilots who responded had experienced an incapacitation requiring another crewmember to take over their duties, with safety of flight significantly threatened in 3% of cases. The importance of in-flight medical incapacitation and impairment can be better understood when it is realized that each in-flight medical incapacitation or impairment could potentially lead to an aircraft accident. We studied in-flight medical incapacitations and impairments in U.S. airline pilots from 1993 through 1998. We defined in-flight medical incapacitation as a condition in which a flight crewmember was unable to perform any flight duties and impairment as a condition in which a crewmember could perform limited flight duties, even though performance may have been degraded. We found 39 incapacitations and 11 impairments aboard 47 aircraft during the six-year period. All pilots were males. The average age for incapacitations was 47.0 years (range 25 to 59 years). The average age for impairments was 43.3 years (range 27 to 57 years). The inflight medical event rate was 0.058 per 100,000 flight hours. The probability that an inflight medical event would result in an aircraft accident was 0.04. Incapacitations significantly increased with age, with more serious categories in the older age groups. The most frequent categories of incapacitation were loss of consciousness, cardiac, neurological, and gastrointestinal. Safety of flight was seriously impacted in seven of the 47 flights and resulted in two non-fatal accidents.

#### **Conclusions and Recommendations**

The cabin crew's ability to gain emergency access to the flightdeck needs to be maintained at all times. Some emergency unlocking system designs utilise the aircraft's main electrical power for it to function, resulting in a risk of the cabin crew being unable to access the flightdeck during emergency situations that involve a loss of main electrical power. Since currently the availability of the interphone system is not required to be maintained at all times, this issue will also have the potential to adversely affect the communication/coordination between the flight crew and cabin crew. Considering that in some scenarios the consequences of not providing such access could be catastrophic, an amendment to CS-25 may be required.

<sup>&</sup>lt;sup>14</sup> Joint Aviation Authorities, JAA Policy Paper on Flightcrew Compartment Access Door Design and the associated Changes in Operational Procedures, 20 November 2001

<sup>&</sup>lt;sup>15</sup> Transportation Safety Board of Canada, Aviation Investigation Report A05W0222, Engine Torching, Alaska Airlines Inc. Boeing 737-900 N317AS, Calgary International Airport, Alberta, 30 October 2005

<sup>&</sup>lt;sup>16</sup> UK Air Accidents Investigation Branch, *AAIB Bulletin No: 4/2007, Ref: EW/C2005/08/10, Bombardier DHC-8-400, G-JECE, 4 August 2005, Near Leeds, West Yorkshire* 

<sup>&</sup>lt;sup>17</sup> Hellenic Republic Ministry of Transport and Communications, Air Accident Investigation & Aviation Safety Board (AAIASB), *Aircraft Accident Report, Helios Airways Flight HCY522, Boeing 737-31S at Grammatiko, Hellas on 14 August 2005, 11/2006* 

<sup>18</sup> UK Air Accidents Investigation Branch, AAIB Bulletin No: 6/2004, Ref: EX/C2002/11/02, Boeing 737-436, G-DOCH, 8 November 2002, Near Clacton, Essex

<sup>19</sup> The Transport Accident Investigation Commission New Zealand, *Report 06-003 Boeing 737-319 ZK-NGJ* electrical malfunction and subsequent ground evacuation Auckland International Airport 12 September 2006

<sup>20</sup> UK Air Accidents Investigation Branch, AAIB Bulletin No: 4/2006, Ref: EW/A2005/03/02 Boeing 737-33V, G-EZYN, 22 March 2005, Near Lyons, France

<sup>21</sup> UK Air Accidents Investigation Branch, AAIB Bulletin No: 1/2009, Ref: EW/C2009/01/03, EMB-190, G-FBEH, 15 January 2009, Overhead Edinburgh

<sup>22</sup> UK Air Accidents Investigation Branch, AAIB Special Bulletin No: 1/2007, Ref: EW/C2006/01/01, Avro 146-RJ100, G-CFAE, 11 January 2006, Edinburgh Airport

<sup>23</sup> Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile, *Accident on 5 November 2000 at Paris Charles de Gaulle (95) to the Boeing 747-200 registered TJ-CAB operated by Cameroon Airlines* 

<sup>24</sup> Aviation Safety Council, Accident Investigation Report ASC-AAR-00-11-001, UIA 873, B-17912, MD-90-30 cabin explosion and fire during landing roll Hua-Lien, Taiwan, August 24th, 1999

<sup>25</sup> Australian Transport Safety Bureau, *Investigation Report 199904538, Boeing 747-438, VH-OJH, Bangkok, Thailand* 

<sup>26</sup> Transportation Safety Board of Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005

<sup>27</sup> Hellenic Republic Ministry of Transport & Communications – Air Accident Investigation & Aviation Safety Board (AAIASB), Aircraft Accident Report 11/2006 – Helios Airways Flight HCY522, Boeing 737-31S at Grammatiko, Hellas on 14 August 2005
 <sup>28</sup> UK Air Accidents Investigation Branch, Aircraft Accident Report 1/92 – Report on the accident to BAC One-

<sup>28</sup> UK Air Accidents Investigation Branch, Aircraft Accident Report 1/92 – Report on the accident to BAC One-Eleven G-BJRT over Didcot, Oxfordshire on 10 June 1990

 <sup>29</sup> National Transportation Safety Board, NTSB Identification SEA03FA024, Accident occurred on Horizon Airlines Bombardier DHC-8-401, registration: N409QX on January 08, 2003 in Medford, OR, USA
 <sup>30</sup> Australian Transport Safety Bureau (2005) Operational and flight safety implications of the installation of

 <sup>30</sup> Australian Transport Safety Bureau (2005) Operational and flight safety implications of the installation of hardened cockpit security doors in passenger aircraft having a seating capacity of 30 seats or more ATSB Transport Safety Investigation Report, Aviation Occurrence Report 200504018 – Final. Canberra: ATSB
 <sup>31</sup> DeJohn, C.A., Wolbrink, A.M., and Larcher J.G. (2004) *In-Flight Medical Incapacitation and Impairment of U.S.*

Airline Pilots: 1993 to 1998, DOT/FAA/AM-04/16. Oklahoma City: FAA Civil Aerospace Medical Institute
## Cabin Safety Threat:

# 3. Inability of Cabin Crew to Communicate with Each Other During Emergency Situations (IB03)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 does not require the installation of communication means amongst cabin crew for use in normal or emergency situations. However, aircraft configured with more than 19 seats are required by EU-OPS 1.690 to be equipped with an Interphone and by EU-OPS 1.695 to be equipped with a public address (PA) system which has to meet the requirements of CS 25.1423. Aircraft configured with more than 60 passenger seats are required by EU-OPS 1.810 to carry megaphone(s) for use during emergency evacuation.

EU-OPS 1.690 Crew member interphone system

(a) An operator shall not operate an aeroplane with a maximum certificated take-off mass exceeding 15 000 kg or having a maximum approved passenger seating configuration of more than 19 unless it is equipped with a crew member interphone system except for aeroplanes first issued with an individual certificate of airworthiness before 1 April 1965 and already registered in a Member State on 1 April 1995.

(b) The crew member interphone system required by this paragraph must:

1. operate independently of the public address system except for handsets, headsets, microphones, selector switches and signalling devices;

2. provide a means of two-way communication between the flight crew compartment and:

(i) each passenger compartment;

(ii) each galley located other than on a passenger deck level; and

(iii) each remote crew compartment that is not on the passenger deck and is not easily accessible from a passenger compartment;

3. be readily accessible for use from each of the required flight crew stations in the flight crew compartment;

4. be readily accessible for use at required cabin crew member stations close to each separate or pair of floor level emergency exits;

5. have an alerting system incorporating aural or visual signals for use by flight crew members to alert the cabin crew and for use by cabin crew members to alert the flight crew;

6. have a means for the recipient of a call to determine whether it is a normal call or an emergency call; and

7. provide on the ground a means of two-way communication between ground personnel and at least two flight crew members.

EU-OPS 1.695 Public address system

(a) An operator shall not operate an aeroplane with a maximum approved passenger seating configuration of more than 19 unless a public address system is installed.

(b) The public address system required by this paragraph must:

1. operate independently of the interphone systems except for handsets, headsets, microphones, selector switches and signalling devices;

2. be readily accessible for immediate use from each required flight crew member station;

3. for each required floor level passenger emergency exit which has an adjacent cabin crew seat, have a microphone which is readily accessible to the seated cabin crew member, except that one microphone may serve more than one exit, provided the proximity of the exits allows unassisted verbal communication between seated cabin crew members;

4. be capable of operation within 10 seconds by a cabin crew member at each of those stations in the compartment from which its use is accessible; and

5. be audible and intelligible at all passenger seats, toilets and cabin crew seats and work stations.

CS 25.1423 Public address system

A public address system required by operational rules must –

(a) Be powerable when the aircraft is in flight or stopped on the ground, after the shutdown or failure of all engines and auxiliary power units, or the disconnection or failure of all power sources dependent on their continued operation, for –

(1) A time duration of at least 10 minutes, including an aggregate time duration of at least 5 minutes of announcements made by flight and cabin crew members, considering all other loads which may remain powered by the same source when all other power sources are inoperative; and

(2) An additional time duration in its standby state appropriate or required for any other loads that are powered by the same source and that are essential to safety of flight or required during emergency conditions.

(b) The system must be capable of operation within 3 seconds from the time a microphone is removed from its stowage by a cabin crew member at those stations in the passenger compartment from which its use is accessible.

(c) Be intelligible at all passenger seats, lavatories, and cabin crew member seats and work stations.

(d) Be designed so that no unused, un-stowed microphone will render the system inoperative.

(e) Be capable of functioning independently of any required crewmember interphone system.

(f) Be accessible for immediate use from each of two flight-crew member stations in the pilot compartment.

(g) For each required floor-level passenger emergency exit which has an adjacent cabin crew member seat, have a microphone which is readily accessible to the seated cabin crew member, except that one microphone may serve more than one exit, provided the proximity of the exits allows unassisted verbal communications between seated cabin crew members

(FAR 25.1423 was introduced in 1989 and is effective for aircraft manufactured after November 27 1990)

EU-OPS 1.810 Megaphones

An operator shall not operate an aeroplane with a maximum approved passenger seating configuration of more than 60 and carrying one or more passengers unless it is equipped with portable battery-powered megaphones readily accessible for use by crew members during an emergency evacuation, to the following scales:

1. For each passenger deck:

Passenger seating configuration	Number of megaphones required
61 to 99	1
100 or more	2

2. For aeroplanes with more than one passenger deck, in all cases when the total passenger seating configuration is more than 60, at least one megaphone is required.

#### Accident Experience and Safety Recommendations

The accident review found 4 accidents where related to this threat. Extracts from the accident reports describing the events are as follows:

Cabin crew made three announcements via the PA system before it stopped working. The first PA made by cabin crew was a direct PA stating "Everything is OK - Remain Seated." The aft purser immediately made a second direct PA, in French only, stating "Door 4 left, I see flames, fire. I am evacuating door 4 right - I am evacuating." The chief purser did not hear the aft purser's PA concerning the fire. Other cabin crew heard the PA. The chief purser was subsequently told by the forward purser that there was a fire. The third and final announcement made using the PA system was the command to evacuate the aircraft made by the chief purser. The chief purser attempted to repeat the command to evacuate, but the PA system was no longer working.

The forward purser knew that opened exit L2 was unusable because of the fire outside and because the slide had not deployed. However, when the aircraft came to a stop, he realized that the chief purser was not aware that the aircraft was already on fire. He rushed over to him and advised him that an evacuation was required. This action likely enabled the evacuation to begin sooner. In doing so, he did not have time to close the exit door and left the open exit unattended for an undetermined period of time.

The chief purser did not hear the aft purser's PA concerning the fire. Other cabin crew heard the PA. The chief purser was subsequently told by the forward purser that there was a fire. After the chief purser gave the command to evacuate, he pressed the EVAC/CMD button on the FAP. The purpose of activating the evacuation alert system is to ensure that all cabin crew know that they are to initiate an evacuation immediately. When the chief purser pushed the EVAC/CMD button, it did not illuminate. (ADB Ref 20050802A)32

The three cabin attendants located in the aft part of the cabin stated that they did not receive any orders to start the evacuation. (ADB Ref 20030617A)33

The L1P and R1P cabin crewmembers reported that they were unaware that the disembarkation had commenced until they heard the sound of evacuation slides being

activated. (ADB Ref 19990923A)<sup>34</sup>

At the time of the explosion, the evacuation signal was not relayed from the cockpit to the flight attendants in the front section. They concluded that the PA was off because there was no power available and the evacuation path was packed with passengers. They did not have time to reach the portable loudspeaker located in the bin above the seats of the first row. Since the aircraft was not equipped with an Evacuation Signal Panel, the flight attendants in the rear section did not receive the evacuation order. (ADB Ref 19990824A)<sup>35</sup>

As a result of the accident investigations, one Safety Recommendation was made:

[Safety Recommendation To UNI AIR]. The installation of an emergency [alert] system or easily accessible loudspeakers to improve the communications between the front and the rear section of the aircraft. (ASC-ASR-00-11-003).

### **Research and Rulemaking Activities**

A research project carried out for the UK CAA on Cabin Crew Fire Training<sup>36</sup> identified a number of communication issues. Comments from a cabin crew survey include:

"When communicating, it would be useful for all stations interphone so at least someone in the opposite end of the cabin on a large aircraft to listen in on what is being told to the flight crew, and this could be passed to crew in the forward part... especially if a divert is possible as they can start to secure etc.." (Cabin Crew – UK)

"I think the communicator should get all information to be related to the flight crew, from his/her own, first-hand, observations and from speaking to the fire fighter directly. The information passed to the flight crew will then be accurate. I find that, during training scenarios, the information, being passed from crew to crew becomes a bit like Chinese Whispers and the information gets altered along the way. I really noticed this during my recent SEP refresher..." (Cabin Crew – UK)

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

#### Discussion

## 1) Existing Requirements (Inter-Cabin Communications)

#### a) Interphone

Aircraft configured with more than 19 passenger seats are required by EU-OPS 1.690 to be equipped with a crew interphone system. No requirements are given in CS-25. EU-OPS 1.690 defines the communication paths to be provided by the interphone system. There are no requirements for two way interphone communication between cabin crew stations. However on some aircraft types, the B737 and F50 for example, the interphone system does provide two way communications between the forward and rear cabin crew stations despite not being required to do so. (The full extent of aircraft types having this capability has not been determined in this study.)

## b) PA System

Aircraft configured with more than 19 passenger seats are required by EU-OPS 1.695 to be equipped with a PA system. Rules governing power supply, location, accessibility, availability and intelligibility are given in CS 25.1423. EU-OPS 1.695 overlaps with CS 25.1423 to some extent.

CS 25.1423 states that a PA system microphone is required to be readily accessible to a cabin crew

member seated at each floor level emergency exit and must be intelligible at all passenger seats, lavatories, and cabin crew member seats and work stations. These locations are very specific and may no longer be appropriate to large aircraft with complex interiors. For example there are no requirements for the PA system to be intelligible in stairways, lifts or crew rest compartments, nor adjacent to non-floor level emergency exits.

### c) Megaphone

EU-OPS 1.810 requires aircraft configured with more than 60 seats to be equipped with megaphone(s) that are easily accessible to crew members for use during an emergency evacuation.

#### 2) Cabin Crew Communication Problems in an Emergency Situation

The two main emergency scenarios requiring cabin crew to cabin crew communication are emergency evacuation and in-flight emergency, such as smoke or fire in the cabin.

Accident evidence, most notably the A340 accident at Toronto in 2005 (ADB Ref 20050802A) demonstrates that communication problems between cabin crew can affect the progress of an evacuation. In this accident, following an overrun impact, a fire started outside the rear of the aircraft before it stopped. The chief purser, located at the forward end, used the PA system to announce that everything was OK and to remain seated. (This statement would have been based solely on his knowledge of the situation at the forward end of the cabin). However, the aft purser was aware of a fire outside the left rear of the cabin and used the PA system to alert the remaining cabin crew of the fire and to say he was evacuating. The chief purser did not hear the message. The forward purser did hear the message and left an unusable open exit unattended to advise the chief purser. The chief purser then gave the command to evacuate using the PA system.

This demonstrates the following problems with existing communication systems:

- (a) In an emergency situation the PA system may not be audible or intelligible. (This may be caused by background noise from moving or panicking passengers.) Additionally, the information conveyed through the PA system that is intended for cabin crew members may cause unnecessary panic among passengers.
- (b) Cabin crew may be forced to move away from manning an exit to access a microphone or carry out face-to-face communication.

The interphone could potentially be used during evacuation, However:-

- (a) An interphone call is unlikely to be noticed.
- (b) The interphone system is not required to provide communication between cabin crew members (although it may do on some aircraft).
- (c) Only one interphone handset is required in a passenger compartment (although some aircraft may have several in a compartment).

#### **Proposed Potential Solutions**

i) Improvements to the Interphone System

Improvements to the interphone system and its associated power supply, including the requirement for communication between cabin crew and handsets at all cabin crew stations, could be beneficial during in-flight emergencies and evacuations. However, the benefit might be limited because the handsets would still not be accessible from everywhere in the cabin.

#### ii) Improvements to the PA System

The current CS-25 requirements do not require the PA system to be intelligible in areas such as stairways, lifts or crew rest compartments, nor adjacent to non-floor level emergency exits. Consideration should be given to amending CS-25 to include these areas and it is probable that the majority of aircraft are already compliant. It may be more appropriate if CS-25 were less specific, instead requiring the PA system to be intelligible at every location within the cabin that is accessible during flight. This would then cater for very large aircraft with complex interiors. However, this would only provide one-way communication to cabin crew members.

#### iii) Cabin Crew Radio Headsets

Portable, battery powered radio (wireless) headsets worn by the cabin crew would enable communications between cabin crew members whilst in any location within the cabin. Consideration needs to be given to whether such systems could be used in both normal and emergency conditions. Consideration would also need to be given to whether the headset system should interface with the aircraft PA system and interphone, although this could add complexity and cost. Other issues to explore are interference with aircraft systems, protocol/procedures, and design (e.g. should be wearable underneath smoke hood).

#### **Conclusions and Recommendations**

The evaluation found that the cabin crew communication systems should be improved to enable more effective communication especially during emergency situations. It is recommended that further research be conducted to investigate the feasibility of the following potential improvements:

- Requiring the handsets of interphone systems (if fitted) to be installed at all cabin crew i) stations and to provide two-way communication amongst cabin crew stations. This may already be installed in most aircraft.
- ii) Requiring the public address system (if fitted) to be intelligible in all areas of the cabin.
- iii) The use of radio headsets for all cabin crew.

<sup>&</sup>lt;sup>32</sup> Transportation Safety Board of Canada, Accident Investigation Report A05H0002: Airbus A340-313, F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, Canada. 2<sup>nd</sup> August 2005 <sup>33</sup> The Dutch Safety Board, Accident Investigation Report 2003071: MD-88, TC-ONP, Groningen Airport, Eelde,

Netherlands, 17th June 2003 <sup>34</sup> Australian Transport Safety Bureau, Accident Investigation Report 199904538: Boeing 747-438, VH-OJH,

Bangkok, Thailand, 23rd September 1999

<sup>&</sup>lt;sup>35</sup> Aviation Safety Council of Taiwan, Accident Investigation Report ASC-AAR-00-11-001: MD-90-30, B-17912, Hua-Lien, Taiwan, 24th August 1999 <sup>36</sup> Asmayawati S, Butcher N, Cherry R. (2009) *Cabin Crew Fire Training -Training Needs Analysis:* UK Civil

Aviation Authority.

### Cabin Safety Threat

#### 4. Inadequate Cabin Pressure Indication and Warning

BB06 / Flight Crew Unaware of Low Cabin Pressure Conditions

BB08 / Flight Crew Unaware of Pressurisation Mode Status (e.g. manual mode set when required to be automatic)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to this threat group are as follows:

*CS* 25.841(*b*) Pressurised cabins must have at least the following valves, controls, and indicators for controlling cabin pressure:

(4) An automatic or manual regulator for controlling the intake or exhaust airflow, or both, for maintaining the required internal pressures and airflow rates.

(5) Instruments at the pilot or flight engineer station to show the pressure differential, the cabin pressure altitude, and the rate of change of the cabin pressure altitude

(6) Warning indication at the pilot or flight engineer station to indicate when the safe or pre-set pressure differential and cabin pressure altitude limits are exceeded. Appropriate warning markings on the cabin pressure differential indicator meet the warning requirement for pressure differential limits and an aural or visual signal (in addition to cabin altitude indicating means) meets the warning requirement for cabin pressure altitude limits if it warns the flight crew when the cabin pressure altitude exceeds 3048 m (10 000 ft).

Warning, caution, and advisory lights installed in the cockpit are addressed by CS 25.1322 and AMC 25.1322 (not Cabin Safety requirements).

#### Accident Experience and Safety Recommendations

In the period reviewed, there is only one accident (Helios Airways B737, ADB Ref. 20050814A)<sup>37</sup> where the flight crew were unaware of low cabin pressure. In this accident the flight crew interpreted the cabin pressure horn as a Takeoff Configuration warning. The following findings were made by the Hellenic Air Accident Investigation and Aviation Safety Board (AAIASB):

- The initial actions by the flight crew to disconnect the autopilot, to retard and then again advance the throttles, indicated that it interpreted the warning horn as a Takeoff Configuration Warning.
- The incorrect interpretation of the reason for the warning horn indicated that the flight crew was not aware of the inadequate pressurization of the aircraft.
- The use of the same aural warning to signify two different situations (Takeoff Configuration and Cabin Altitude) was not consistent with good Human Factors principles.
- Over the past several years, numerous incidents had been reported involving confusion between the Takeoff Configuration Warning and Cabin Altitude Warning on the Boeing 737 and NASA's ASRS office had alerted the manufacturer and the aviation industry.

The investigation of this accident resulted in the following relevant safety recommendations:

2006 – 42 EASA/JAA require aircraft manufacturers to install in newly manufactured aircraft, and on a retrofit basis in older aircraft, in addition to the existing cabin altitude warning horn, a visual and/or an oral alert warning when the cabin altitude exceeds 10 000 ft.

2005 – 37 On 25 August 2005, the AAIASB recommended to the NTSB that the Boeing Company consider taking action to emphasize flight crew training and awareness in relation to (a) the importance of verifying the bleed and pack system configuration after takeoff and (b) the understanding and recognition of the differences between cabin altitude and takeoff configuration warnings.

On 25 August 2005, the NTSB responded that the Boeing Company was prepared to issue an October 2005 revision to 737- 300/400/500/600/700/800/900/BBJ Flight Crew Training Manuals (FCTM) to include a new section entitled Air Systems/Cabin Altitude Warning reminding flight crews on how to understand and recognize the differences between the two meanings of the warning horn and reminding them of the importance of verifying the bleed and pack system configuration after takeoff.

The accident report cited a series of previous pressurisation incidents investigated by the Irish AAIU and the Norwegian AIB:

- B737-548 EI-CDB (7 December 2000), B737-204 EI-CJE (28 September 2002), B737-204 EI-CJC (8 November 2004), B737-800 EI-CSC (7 October 2000). Following each of the incidents, the AAIU issued safety recommendations that dealt with pilot procedures, checklist requirements, training, equipment design, and CRM principles. The recommendations relevant to this study are as follows: "Installing, in addition to the existing Cabin Altitude Warning horn, a visual alert warning of excessive cabin altitude (SR23)"
- Boeing 737-700 Incident in Norway on 15 February 2001. One of the safety recommendations (no. 28/2002) called for the operator to evaluate, together with the Norwegian Civil Aviation Authority and Boeing, the dual use of the warning horn for Takeoff Configuration Warning and Cabin Altitude Warning, as well as the absence of a warning light for low cabin pressurization (over 10 000 ft) (as in use in MD-80 aircraft)

Boeing responded to the Irish AAIU recommendation on 20 June 2003: "The cabin altitude warning is an interrupted horn that sounds when the cabin altitude exceeds 10 000 feet. Boeing does not provide a "CABIN ALT" or "CABIN ALTITUDE" warning light associated with the cabin altitude warning horn on 737 airplanes. There are no provisions for such a light nor are there any plans to offer such a light."

The Hellenic AAIASB reviewed pressurisation incident reports from the NASA Aviation Safety Reporting System (ASRS) and the Pressurization Working Group (PWG) report. There were 10 reports in which the flight crews admitted to having, at least momentarily, misinterpreted a cabin altitude warning horn in flight to signify an improper aircraft configuration (i.e. takeoff configuration warning horn) rather than a pressurization problem.

Another threat discussed in this threat group is the flight crew being unaware of the cabin pressurisation status, which was identified from the same accident. The maintenance crew did not change the pressurisation mode selector back to AUTO. The best method to mitigate this is a clear procedure for the pressurisation check in the maintenance manual, and good design and compliance to flight procedures in checking and verifying the position of controls on the pressurisation panel. These subjects were recommended by the AAIASB and had a positive response from Boeing.

#### Research and Rulemaking Activities

The following studies were cited in the Helios Airways B737 accident report:

The NASA Aviation Safety Reporting System (ASRS) conducted a search of its database for incidents similar to the accident flight. The result of the search yielded 171 reports of air conditioning and pressurization problems that involved Boeing 737 aircraft in the past decade (1994-2004). Of the 171 reports, 58 were deemed critical. According to Boeing, the rate of reports per a million departures was 2.7. (The number of reports for other aircraft was 94 on the B727, 97 on the B757/767, and 205 on the DC9/MD80. According to Boeing, the rates of reports per a million departures for these aircraft types were 8.5, 4.9 and 6.3, respectively).

The aviation industry formed a Pressurization Working Group (PWG). Its December 2005 report (No. 525) showed that the ASRS database contained 158 reports describing pressurization problems experienced by crews of Boeing 737 aircraft from January 1994 to October 2005. Slightly more than half of these involved aircraft of the same type as the accident aircraft, i.e. the -300 series.

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

#### Discussion

#### 1) Attention Getting of Cabin Pressure Altitude Warning

Activation of a cabin altitude warning signal at 3048m (10,000ft) could potentially coincide with the flight crew suffering cognitive impairment due to early stage hypoxia. This is concluded from the Helios Airways Flight 522 Boeing 737 accident report<sup>1</sup> that states: - *"Smith (2005) performed a survey listing cognitive, psychomotor and behavioural symptoms of hypoxia with Australian Army helicopter aircrew who had operated at altitudes up to 10,000 ft. The most commonly reported symptoms were difficulty with calculations (45%), light-headedness (38%), delayed reaction time (38%), and mental confusion (36%)".* 

Therefore, given the potential for cognitive impairment of the flight crew, it is considered that the attention getting of the cabin altitude warning signal should be maximised. However, CS-25 currently allows the warning signal to be merely a flashing light, which may not be adequate. Therefore, as a minimum, it is proposed that consideration be given to the amendment of CS 25.841 (b)(6) so that it requires the warning for exceedence of the 3048m (10,000ft) cabin pressure altitude limit be an aural <u>and</u> visual signal rather than an aural <u>or</u> visual signal. Additionally CS 25.841 should include a reference to CS 25.1322 and thereby to AMC 25.1322, which define the requirements for warning, caution, and advisory signals in detail.

#### 2) Confusion between Warning Signals

The Helios Airways B737 accident<sup>1</sup> demonstrates the potential for flight crews to misinterpret warning signals. Additionally, the accident report<sup>1</sup> states "over the past several years, numerous incidents had been reported involving confusion between the Takeoff Configuration Warning and Cabin Altitude Warning on the Boeing 737 and NASA's ASRS office had alerted the manufacturer and the aviation industry".

It is therefore proposed that the cabin altitude warning, instead of being just a non-dedicated aural signal, should be a dedicated aural signal or voice signal to minimise any risk of confusion with other warnings. (Note: The addition of an extra dedicated aural signal may be problematic on some aircraft because AMC 25.1322 strongly recommends the number of aural signals should not exceed eight.)

#### 3) Incorrect Pressurisation Mode Selector setting

The flight crew of the Helios B737 failed to ensure the Pressurisation Mode Selector was set to AUTO instead of MANUAL. This is considered to be a checklist issue that does not require amendment of CS-25.

### Conclusions and Recommendations

The Helios Airways B737 accident has demonstrated the criticality of flight crew being adequately alerted to cabin altitude warnings. There are indications that the requirement for cabin altitude warnings should be improved from the current minimum standard (flashing light) to an aural signal and flashing light. It may be further beneficial to require a dedicated aural signal or voice signal to prevent confusion with other warnings. However, further research may be required to:

- (i) Ascertain the extent of this problem (i.e. investigate the prevalence of similar incidents in other types of aeroplanes), including a survey of current cabin altitude warning systems in in-service aeroplanes.
- (ii) Ascertain the implications of requiring a dedicated aural or voice signal for cabin altitude warnings, on various aspects (e.g. design/maintenance, human factors, operations/procedures, training, etc.).

<sup>&</sup>lt;sup>37</sup> Hellenic Republic Ministry of Transport & Communications, *Accident Investigation Report 11/ 2006, Helios Airways Flight HCY522, Boeing 737-31S, at Grammatiko, Hellas, August 14 2005* 

## Cabin Safety Threat:

### 5. Explosive Door Openings with Aircraft on Ground (BB01)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

There is no CS-25 requirement addressing 'Explosive Door Openings with Aircraft on Ground'. The requirements relating to fuselage doors in CS 25.783 do not address pressure relief systems.

#### Accident Experience and Safety Recommendations

The accident review found 2 accidents involving explosive door openings caused when a cabin door was opened whilst the cabin was partially pressurised on the ground. Extracts from the accident reports describing the events are as follows:

While the flight crew was preparing the aircraft for flight, the flight attendant opened the service door and was ejected onto the tarmac and seriously injured. At the time of the accident, the airplane was being cooled by an external diesel powered air conditioning cart that pressurizes the cabin when the airplane doors are closed. The external air conditioning cart was required because the auxiliary power unit was inoperative. The captain said that he briefed the flight attendant, before boarding the airplane and again in the cockpit, to keep one door open. The captain did not specify that the reason the flight attendant needed to keep a door open was because the air conditioning cart pressurized the cabin if all the doors were closed. (ADB Ref. 20050531A)<sup>38</sup>

At the captain's command to evacuate, the purser went to the 1 left door and tried to open it, using one hand. The door would not open. The purser then came out of the cockpit and tried to open the door using both hands. He [the FSD1] also heard someone from the back of the airplane say the doors are not opening. Also, the # 3 and 4 flight attendants stated their doors would not open. He was watching the purser out of the corner of his eye when all of a sudden there was an explosion. He was being pulled toward the 1 left door and hit the corner of the lavatory and the 1 left jumpseat. He fell to the floor and blacked out momentarily. When he awoke the 1 left door was open and the purser was on the ground about 50-70 feet from the airplane. Postmortem examination of the flight attendant who received fatal injuries during the emergency evacuation of the aircraft was performed by the Miami-Dade County Medical Examiner's Office. The cause of death was attributed to multiple blunt injuries. Closer inspection of the aft outflow valve found that an insulation blanket was obstructing the intake side of the valve, and the blanket was drawn through the intake screen in some areas. Marks indicated the insulation blanket at sometime had blocked the butterfly of the outflow valve. In addition, many of the insulation blankets in the compartment containing the aft outflow valve were displaced from their proper positions and were not secured in place. (ADB Ref. 20001120A)<sup>35</sup>

In a US NTSB presentation on the challenge of emergency and abnormal situations<sup>40</sup> and the NTSB Recommendation Letter A-02-20 through -23, other occurrences were cited:

- Tunis Air flight TARB631 on 20 October 2001 at Djerba Airport, Tunisia (Airbus A300-605R, TS-IPA). Door 2L exploded open during normal deplaning, the cabin crew who opened door was ejected and seriously injured whilst the cabin crew near the door was ejected and killed.
- Airbus production facility, Toulouse, France on 13 June 2002. A production pressurisation test was being carried out when a door exploded open, causing fatal injury to a mechanic who had performed the test many times before. A mechanic sustained a head injury when he opened a door on a pressurised ATR-72 from the outside (Aviation Safety Reporting

### System)

- A flight attendant received minor injuries when she opened a cabin door on a pressurised Canadair CL65 Bombardier and was ejected from the aeroplane

In the recommendation letter, the NTSB stated that "the type of overpressurisation event that occurred in these accidents could occur in any air carrier aeroplane equipped with doors of a similar design if it is not fully depressurised when the emergency exit doors are opened and if it is not equipped with systems on its emergency exit doors to relieve pressure. All transport-category aircraft have outflow valves that regulate pressure inside the cabin. If air is prevented from flowing through the outflow valves because of a command to close the valves or a blockage of the valves, this type of overpressurisation event could occur again." The Board notes that if the emergency exit doors on the aeroplanes had been equipped with pressure relief systems, such as vent doors or gates, the cabin crew or ground personnel would likely not have been able to open the doors until the pressure was relieved.

To address this matter, the US National Transportation Safety Board issued a safety recommendation letter on 2 August 2002 to the Federal Aviation Administration:

Require that all newly certificated transport-category airplanes have a system for each emergency exit door to relieve pressure so that they can only be opened on the ground after a safe differential pressure level is attained. (A-02-20) – Closed – Unacceptable Action

For those transport-category airplane emergency exit doors that can be opened on the ground when the airplane is overpressurized, require air carriers to provide specific warnings near the emergency exit doors (such as lights, placards, or other indications) that clearly identify the danger of opening the emergency exit doors when the airplane is overpressurized. (A-02-21) – Closed – Acceptable Action

Review all air carriers' flight and cabin crew training manuals and programs and require revisions, if necessary, to ensure that they contain information about the signs of an overpressurized airplane on the ground and the dangers of opening emergency exit doors while the airplane is overpressurized. (A-02-22) – Closed – Acceptable Action

Require that cabin crew training manuals and programs contain procedures to follow during an emergency evacuation when the airplane is overpressurized. (A-02-23) – Closed – Acceptable Alternate Action

#### **Research and Rulemaking Activities**

No current research on the subject has been identified.

On 14 January 2003, the FAA published a notice of proposed rulemaking (NPRM) 03-01, Design Standards for Fuselage Doors on Transport Category Airplanes. In the NPRM, the FAA requested comments on safety recommendation A-02-020; however, no comments were submitted to the FAA on the issue. On 4 April 2004, the FAA issued the final rule (Amendment 25-114) without incorporating the recommendation. On 25 April 2005, the FAA issued advisory circular (AC) 25.783-1A, Fuselage Doors and Hatches. The AC includes discussions on the ramifications of exits being opened when a pressure differential exists and directs applicants to address this issue as part of their design. The FAA stated that Amendment 25-114 addresses the primary safety issues of rapid evacuation and in-flight safety. It believes that additional requirements that would inhibit or delay opening the door as a function of the differential pressure, as recommended, would have a negative effect on at least one of those safety issues. Therefore, the FAA does not believe a new rule mandating the recommended design is appropriate. The NTSB notes the concerns raised by the FAA, but disagrees that these are a basis for not taking the recommended action.

#### **Conclusions and Recommendations**

Although the most current explosive door opening accident (Bombardier CL-600-2B19 at Chicago O'Hare Airport in 2005) could have been prevented by better procedures or communication, explosive door openings have resulted in serious and fatal injuries and there is one outstanding safety recommendation on this subject (A-02-20) that should be reviewed further. Therefore, it was concluded that further research will be required to investigate how explosive door opening occurrences can be prevented and to ensure that any solutions will not adversely affect rapid evacuation and in-flight safety.

<sup>&</sup>lt;sup>38</sup> National Transportation Safety Board, NTSB Identification DCA05MA071, Air Wisconsin Airlines Corporation, Bombardier CL-600-2B19, registration: N417AW, May 31, 2005, Chicago O'Hare, IL

<sup>&</sup>lt;sup>9</sup> National Transportation Safety Board, NTSB Identification MIA01FA029, American Airlines Airbus Industrie A300B4-605R, registration: N14056, November 20, 2000 in Miami, FL <sup>40</sup> Nora C. Marshall. (2009). The Challenge of Emergency and Abnormal Situations for Flight Attendants.

Washington, D.C.: National Transportation Safety Board.

### Cabin Safety Threat:

### 6. Impact Protection during Flight

GA01 / Occupants Not Seated or Not Belted during Encounter with Turbulence

GA05 / Occupants Not Seated or Not Belted during Sudden Extreme Flight Manoeuvre

GA13 / Lack of Protection from Turbulence and In-Flight Upset for Aircraft with VIP Configuration and Out-of-Seat Recreational Areas

TA01 / Loose Trolleys during Turbulence, In-Flight Upset or Normal Flight

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to occupant impact protection during flight are as follows:

*CS* 25.785(*h*) Each seat located in the passenger compartment and designated for use during take-off and landing by a cabin crewmember required by the Operating Rules must be –

(4) Located to minimise the probability that occupants would suffer injury by being struck by items dislodged from service areas, stowage compartments, or service equipment.

*CS* 25.785(*j*) If the seat backs do not provide a firm handhold, there must be a handgrip or rail along each aisle to enable persons to steady themselves while using the aisles in moderately rough air.

*CS* 25.789(a) Means must be provided to prevent each item of mass (that is part of the aeroplane type design) in a passenger or crew compartment or galley from becoming a hazard by shifting under the appropriate maximum load factors corresponding to the specified flight and ground load conditions, and to the emergency landing conditions of *CS* 25.561(b).

*CS* 25.791(*b*) Signs that notify when seat belts should be fastened and that are installed to comply with the Operating Rules must be installed so as to be operable from either pilot's seat and, when illuminated, must be legible under all probable conditions of cabin illumination to each person seated in the cabin.

CS 25.819(d) There must be a means, readily detectable by occupants of each lower deck service compartment that indicates when seat belts should be fastened.

CS 25.1423 Public address system

A public address system required by operational rules must –

(c) Be intelligible at all passenger seats, lavatories, and cabin crew member seats and work stations.

EU-OPS 1.731 Fasten seat belt and no smoking signs

An operator shall not operate an aeroplane in which all passenger seats are not visible from the flight deck, unless it is equipped with a means of indicating to all passengers and cabin crew when seat belts shall be fastened and when smoking is not allowed.

EU-OPS 1.695 Public address system

(a) An operator shall not operate an aeroplane with a maximum approved passenger seating configuration of more than 19 unless a public address system is installed.

#### Accident Experience and Safety Recommendations

The accident review found 83 accidents where turbulence has caused injuries to occupants. In the period analysed, turbulence caused 263 minor impact injuries, and 98 moderate to serious impact injuries, affecting 139 cabin crew and 222 passengers. Some of the extracts from the accident reports describing the events are as follows:

One flight attendant sustained serious injuries, and another flight attendant sustained minor injuries. The Captain informed the flight attendants to be seated; however, before he could return to his seat, he and another flight attendant were repeatedly thrown from the floor to the ceiling, by severe turbulence. The other flight attendant sustained a fractured ankle and a head injury. (ADB Ref. 20060916A)<sup>41</sup>

During the cruise, the Aircraft encountered clear turbulence at the sky of KEVOK point in front of Borneo Island at about 04:55 and the disturbance of the airframe was incurred, which resulted in the serious and slight injuries for 13 cabin crews and 69 passengers [of which 9 passengers sustained serious injuries] and the damage of a part of rear ceiling of the cabin of the Aircraft in the course of passengers who did not fasten seat belts hitting the ceiling. In the situation where many passengers were sleeping with seat belt unfastened in the early morning time, seat belt sign was turned on by the trembling of airframe and after the public announcement in Korean but before the announcement in English 69 passengers (all of them were Koreans) were seriously or slightly injured due to airframe disturbance and 13 cabin crews who were checking the passengers' seat belt fastening fell down on the floor of the cabin and were slightly injured. After passing the turbulence area, the captain checked the situation of the cabin to the purser and received the report saying that 4 Passengers were bleeding due to external wound from hitting to the ceiling of the cabin and many passengers had scratches, headaches and bruises. The types of injury of the injured passengers were concussion, cervical vertebral sprain, lumbar sprain, bruise, waist pain, nose bone fracture and scalp lacerated wound and the types of injury for the cabin crew were lumbar part sprain, cervical vertebral part sprain and left knee joint sprain. (ADB Ref. 20050714A)<sup>42</sup>

The flight attendant who was seriously injured was located in the aft galley preparing for landing when the airplane encountered the turbulence. The flight attendant stated that she heard the captain say "prepare for landing" and "all of [a] sudden I got lifted off the ground and slammed into the 4R door." This flight attendant suffered a fractured ankle. The flight attendant who sustained minor injures was located near the aft lavatories preparing for landing when the airplane encountered the turbulence. The flight attendant statedant stated that the airplane "hit some type of severe turbulence without warning" and that she was "thrown to the floor." This flight attendant suffered minor injuries to her shoulder, hip, foot, and lower back. She elected to complete the remainder of her scheduled flights. (ADB Ref. 20050605A)<sup>43</sup>

While standing in the galley, the airplane suddenly encountered "severe clear air turbulence," which threw her against the bulkhead. As she regained her balance, the airplane encountered more turbulence, which knocked her to the floor. (ADB Ref. 20030424A)<sup>44</sup>

In one severe clear air turbulence accident (not within the period analysed), one passenger

sustained fatal injuries, whilst 15 passengers and 3 cabin crew sustained serious injuries and 171 others sustained minor injuries.

Whilst normal turbulence can be detected, and hence in many cases injuries could have been avoided, clear air turbulence and sudden extreme flight manoeuvre occur without warning. Clear Air Turbulence was the cause of 13% of the 83 turbulence accidents identified in the accident review. There were 11 accidents in which sudden extreme flight manoeuvre has inflicted 36 minor injuries and 14 serious injuries to occupants. Some of the extracts from the accident reports describing the events are as follows:

The crew manipulated the aircraft to descend for an avoidance maneuver following the TCAS RA 'DESCEND' warning. The injury conditions of the four seriously injured passengers were seated respectively at 6A, 11D, 26C and 34A. 1. The passenger seated in 6A suffered from fracture of ribs and clavicle and left hemothorax and was sent to the National Taiwan University hospital after returned from South Korea. While the aircraft was moving violently, she encountered an impact with the ceiling and seat arm and caused a serious injury. 2. The passenger seated in 11D suffered from complicated fracture of left humerus with radial nerve injury, sprains of the right ankle region and fracture of a big toe and was sent to the Mackay Memorial Hospital after returned from South Korea. The male passenger seated in 11D, just walked out of the lavatory. He was bounced up and also encountered impact by the duty-free cart. 3. The passenger seated in 26C suffered from a head injury, intra-cranial hemorrhage (ICH) and subarachnoid hemorrhage (SAH) and was sent to the National Taiwan University hospital. after returned from South Korea. The female passenger seated in 26C with her seat belt unfastened was preparing to purchase duty-free goods. Due to the severe moving up and down of the aircraft, the passenger was bounced up several times and suffered from head injury, intra-cranial hemorrhage (ICH). In addition, she encountered an impact from a flying duty-free cart that bounced to ceiling. Her injuries resulted in coma. 4. The passenger seated in 34A suffered from fractures of left ribs and hemothorax and was sent to the Mackay Memorial Hospital after returned from South Korea. The male passenger seated in 34A did not fasten his seat belt because he just returned to his seat from the lavatory. The other 10 injured passengers and 6 cabin crews sustained minor injuries, such as contusion, sprain and abrasion. The rest of injured passengers sustained minor injury, their seat belts were not fastened. When the occurrence happened, some passengers were bounced up to the cabin ceiling and dropped to the seat back, handrail, or cabin equipment. It is concluded that most of the passenger did not have their seat belts fastened and lost their protection while the fasten seat belt sign was still on. (ADB Ref. 20061116B)<sup>45</sup>

He further stated that the captain applied "abrupt" braking to prevent the airplane from departing the taxiway, and all three flight attendants, who were standing at the time, were injured, one of whom received serious injuries. (ADB Ref. 20031016A)<sup>46</sup>

When the flight engineer closed the "number one bus-tie-breaker," the airplane experienced an uncommanded pitch-up, accompanied by numerous momentary instrument failures. Twelve occupants were injured. One passenger received serious injuries, while 10 passengers and 1 flight attendant sustained minor injuries. The National Transportation Safety Board determines the probable cause(s) of this accident as follows: Maintenance personnel's failure to reconnect the pitot connections to the elevator feel computer which resulted in an elevator control surface deflection which was outside of the normal autopilot elevator authority. The uncommanded autopilot input to the elevator control surface resulted from an undetermined electrical source. A factor in this accident was that the section of the 747 Maintenance Manual utilized by company maintenance personnel did not contain an "elevator feel light test." (ADB Ref. 20000227A)<sup>47</sup>

The accident review found 10 accidents where unsecured trolleys during turbulence or in-flight

upsets have or could have inflicted injuries to occupants. There were at least 1 minor injury and 4 serious injuries associated with this hazard. Some of the extracts from the accident reports describing the events are as follows:

During the TCAS avoidance maneuver, the 4L and 2L cabin crew were using the duty free cart on aisle. The duty free cart bounced up and dropped to seats of 28th row with 2 passengers sitting there. The 4L and 2L cabin crew helped the passenger underneath the cart and pushed the duty free cart back. The 4L cabin crew applied the First Aid Kit and took iodine to the passengers. (ADB Ref. 20061116B)<sup>45</sup>

One flight attendant, who was in the aft galley trying to stow away the beverage cart when the turbulence was encountered was injured by the cart. She reported that the cart rolled into her right side, resulting in a fractured femur. (ADB Ref. 20030406A)<sup>48</sup>

He said he saw one of attendants counting the duty free merchandise was thrown to the left of the airplane along with the duty free cart. The other flight attendant near to the duty free cart was also injured. The duty free cart ended up upside down, and all the merchandise was strewn over the floor. The seriously injured flight attendant was struck by the duty free cart. (ADB Ref. 20020322A)<sup>49</sup>

### Future Consideration

There appears to be a growing trend in the use of out-of-seat recreational areas, especially in very large transport aeroplanes. The following turbulence event occurred on a B747-300 with many injuries sustained by occupants who were in the standing area:

While overflying the equator over Atlantic international waters at flight level 340, the aircraft encountered sudden moderate-to-strong turbulence which caused serious injury to one passenger. She had a bruised incisive wound in the right temporal region and presented left hemiplegia. During the event, 11 other passengers and a flight attendant who was standing in the "grand class" area were injured or showed signs of anxiety. (ADB Ref. 20040226A)<sup>50</sup>

#### Research and Rulemaking Activities

Based on NTSB data, in the period 1997-1999, there were 42 turbulence-related accidents which had caused one passenger fatality, 32 serious injuries to cabin crew and 24 serious injuries to passengers<sup>51</sup>. An analysis of US (Part 121 and 135) aircraft accident and incident data in the period 1982-1991 indicates that turbulence accounted for nearly twice as many serious injuries in nonfatal accidents as those resulting from emergency evacuations<sup>52</sup>. The study suggested that turbulence-related accidents might be mitigated with steps such as increased enforcement of seat belt sign compliance, increased flight crew and flight attendant awareness of turbulence risk to flight attendants, improved cockpit/cabin communications and promotion of increased passenger awareness of the need to use seat belts at all times. The study recommended a joint government/industry effort to determine the most effective way of communicating this message to passengers.

The VLTA Conference<sup>53</sup> resulted in the following recommendations regarding turbulence:

- (1) That active protection systems be investigated
- (2) That the feasibility of early warning systems be investigated
- (3) That, if out-of-seat activities are encouraged through the provision of recreational/open spaces then sufficient means of providing protection in these places should be considered
- (4) That other means of avoiding possible injury to passenger and crew, such as trolley restraint devices in the passenger compartment, should be considered.

FAA's Aviation Weather Research Program aims to improve the timeliness of warnings of impending turbulence to passengers and cabin crew, as well as improving the accuracy of the analysis and forecasts of turbulence. ICAO has approved a system developed by the Turbulence Product Development Team which measures turbulence and downlinks the information in real time from

commercial air carriers<sup>54</sup>. The Integrated Turbulence Forecast Algorithm (ITFA) "produces easy to interpret web based displays of turbulence with different colours which represent different forecast intensities"<sup>55</sup>. It uses numerical weather prediction models and refines the assessments based on comparisons to current pilot reports of turbulence. The ITFA system became "operational" for qualified meteorologists and dispatchers in March 2003 and at that time was renamed the Graphical Turbulence Guidance (GTG) product<sup>56</sup>. GTG1 produces clear air turbulence forecasts for flight levels above 20,000 feet which was later expanded down to 10,000 feet as GTG2.

Researchers at the University of Georgia have developed a newer method which is based on a mathematical model (algorithm) derived from the Lighthill-Ford theory of spontaneous imbalance<sup>57</sup>.

Turbulence was addressed by JAA (CSSG DI #76) with focus on passenger use of restraint systems during flight. The subject was closed during CSSG 27.

In December 2000, U.S. government and industry representatives began planning for the certification of turbulence-detection systems for transport aircraft<sup>51</sup>.

It should be noted that the incidence of turbulence is influenced by geographical and topographical factors. This means that the risk of turbulence-related injury would vary in different regions. The United States is affected by the convergence of jet streams over North America, mountain wave activity over the Rocky Mountains, a high incidence of convective activity over the continent, and the influence of Caribbean Sea and the Gulf Stream in the US southern region and mid-Atlantic region<sup>51</sup>. High frequency of turbulence encounter is also found on the western rim of the Pacific Ocean. Compared to Western Europe, those areas have considerably higher frequency of turbulence encounters.

#### Discussion

The main aspects of these threats are as follows:

- Passengers not wearing seatbelts
- Cabin crew not having enough time to return to their seats
- No explicit requirement for '*Return to Seat*' signs in areas such as lavatories, special standing areas, etc
- Public address system (if fitted to comply with operational rules) are not required to be intelligible in areas other than passenger seats, lavatories, and cabin crew member seats and work stations
- Flight crew not communicating impeding turbulence adequately or in a timely manner to cabin crew
- Detection system for Clear Air Turbulence is still under development. Although not widely used, some predictive models are available (e.g. Graphical Turbulence Guidance/GTG)
- There is no securing system for trolleys when in use
- Protection at out-of-seat areas particularly in very large transport aeroplanes (lounge/bars, executive style offices, children play areas, beauty/fitness areas, duty free shops, or casinos).
- Remote areas where seat belt fastening may not be fully monitored by cabin crew
- Those who are on the stairs when a clear air turbulence or sudden extreme aircraft manoeuvre occurs will have a higher probability of sustaining injuries.

Whilst there are many operational measures that may considerably reduce the number of injuries, risks of injuries related to clear air turbulence and sudden extreme flight manoeuvre (which often causes the higher severity of injuries) cannot be addressed by operational measures only.

CS 25.785(j) refers to the use of seatbacks as a firm handhold in "moderately rough air". This means that no protection is provided in sudden encounters of clear air turbulence or in-flight upsets. Furthermore, it is considered questionable as to whether seatbacks as a "firm handhold" can be effective.

#### **Conclusions and Recommendations**

It is recommended that further research and testing be carried out in developing advanced technology for onboard turbulence detection, especially for clear air turbulence, that is affordable to the operators. Consideration should be given by EASA to investigate the feasibility of providing occupant protection in standing areas in the cabin during turbulence. Additionally, an investigation should be carried out on equipment restraint devices, especially for trolleys in use and an investigation on the effectiveness of seatbacks as firm handholds and whether there needs to be actual handholds on the seatbacks/sides.

There is no explicit requirement within CS-25 or operations requirements for lavatories or other areas of the cabin occupied by non-seated passengers to have 'Return to Seat' signs. This and the intelligibility of the public address system (if fitted) in those areas may be particularly relevant to very large transport aircraft. Amendment to CS-25 may be required to ensure that such signs are installed in those areas. It is recommended that this proposal be considered for evaluation via a Regulatory Impact Assessment.

nm South of Jeju Island, Korea, on November 16, 2006 <sup>46</sup> National Transportation Safety Board, NTSB Identification MIA04LA004, U.S. Airways, Inc. Airbus Industrie A-319-112, registration: N764US, October 16, 2003 in Tampa, FL

National Transportation Safety Board, NTSB Identification NYC00LA085, British Airways Boeing 747-236, registration: G-BDXL, February 27, 2000 in Providence, RI <sup>48</sup> National Transportation Safety Board, NTSB Identification FTW03LA121, Continental Airlines Boeing 737-924,

registration: N71411, April 06, 2003 in Palestine, TX <sup>49</sup> National Transportation Safety Board, NTSB Identification DCA02MA029, Northwest Airlines DC-10-30

Strategies Target Turbulence-related Injuries to Flight Attendants and Passengers, Flight Safety Foundation -Cabin Crew Safety Vol. 36 No. 1, January-February 2001

Coleman, Patricia J. "Turbulence-Related Injuries Pose Continued Risk to Passengers and Cabin Crew". Flight Safety Foundation Cabin Crew Safety Vol. 29, No. 3, May/June 1994. <sup>53</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16

<sup>&</sup>lt;sup>41</sup> National Transportation Safety Board, NTSB Identification NYC06LA223, Southwest Airlines Boeing 737-700, registration: N793SA, September 16, 2006 in Hastings, NE

Korea Ministry of Construction and Transportation Aviation and Railway Accident Investigation Board, Aircraft Accident Report Incurrence of Injured Persons due to Turbulence Korean Air Flight (KE) 630 B747-400, HL7472 In front of Borneo Island (Over the sky of KEVOK point) July 14, 2005, No.:ARAIB/AIR0504 <sup>43</sup> National Transportation Safety Board, NTSB Identification CHI05LA135, American Airlines, Inc. Boeing 757-

<sup>223,</sup> registration: N602AN, June 05, 2005 in New Chicago, IN

<sup>&</sup>lt;sup>14</sup> National Transportation Safety Board, NTSB Identification IAD03LA048, Atlantic Coast Airlines Dornier 328-300, registration: N427FJ, April 24, 2003 in Roanoke, VA

Aviation Safety Council Taiwan, Far Eastern Air Transport Flight EF306 Boeing 757-200 and Thai Airways Flight TG659 Boeing 777-300, A TCAS Event in Narrow Collision Avoidance at an Altitude of 34,000 ft and 99

N234NW, March 22, 2002 Over Track "Sierra"

<sup>&</sup>lt;sup>50</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, Technical Report A-011/2004, Accident to aircraft Boeing B747-300, registration TF-ATJ, operated by Iberia LAE, during flight over the Atlantic Ocean tropics on 26 February 2004

October 1998. <sup>54</sup> United States General Accounting Office (2003) Aviation Safety - Advancements Being Pursued to Improve

Airliner Cabin Occupant Safety and Health, GAO-04-33

<sup>&</sup>lt;sup>55</sup> Kulesa, G.J., Pace, D.J., Fellner, W.L., Sheets, J.E., Travers, V.S., and Kirchoffner, P.J., (2006) The FAA Aviation Weather Research Program's Contribution to Air Transportation Safety and Efficiency - Presented at the 12<sup>th</sup> Conference on Aviation Range and Aerospace Meteorology, January 2006 <sup>56</sup> Sharman, R., Comman, L., Williams, J., Koch, S. & Moninger, W. The FAA AWRP Turbulence PDT –

Presented at the 12<sup>th</sup> Conference on Aviation Range and Aerospace Meteorology, January 2006

Predicting Clear Air Turbulence. Air Safety Week Oct. 6, 2008. Retrieved from FindArticles.com. 15 Jul, 2009. http://findarticles.com/p/articles/mi\_m0UBT/is\_38\_22/ai\_n29484441/

## Cabin Safety Threat:

## 7. Windscreen Fragmentation due to Multiple Birdstrike (GA09)

Current Applicable CS-25 Requirements and Associated Regulatory Material
CS-25 Cabin Safety requirements related to this threat are as follows:
CS 25.775 Windshields and windows
(b) Windshield panes directly in front of the pilots in the normal conduct of their duties, and the supporting structures for these panes, must withstand, without penetration, the bird impact conditions specified in CS 25.631.

(c) Unless it can be shown by analysis or tests that the probability of occurrence of a critical windshield fragmentation condition is of a low order, the aeroplane must have a means to minimise the danger to the pilots from flying windshield fragments due to bird impact. This must be shown for each transparent pane in the cockpit that –

(1) Appears in the front view of the aeroplane;

(2) Is inclined  $15^{\circ}$  or more to the longitudinal axis of the aeroplane; and

(3) Has any part of the pane located where its fragmentation will constitute a hazard to the pilots.

The Advisory Circular addressing acceptable means of compliance with 25.775(d) relating to structural design of the windshields discusses the limitations of different materials in impact conditions.

CS 25.631 requires that "The aeroplane must be designed to assure capability of continued safe flight and landing of the aeroplane after impact with a 4 lb bird". It does not address multiple bird impacts.

#### Accident Experience and Safety Recommendations

The accident review found one accident where multiple birdstrikes on windshield occurred and caused injuries to the pilot. Extracts from the accident report describing the event are as follows:

The aircraft, which was on a downwind for a night visual approach, impacted a flock of Lesser Scaups (diving ducks). The nose structure of the aircraft and the windshield directly in front of the captain received multiple bird strikes. Some of the birds penetrated the aircraft's skin, but there was no direct penetration of the windshield. Although the windshield was not penetrated, hundreds of small pieces of glass were ejected from the most inner of the windshield's three panes, and approximately 70 of these pieces imbedded themselves in the face, forehead, and scalp of the captain. The first officer ultimately completed a successful landing, while using backup flight instruments. The investigation determined that the windshield certification process defined in Part 25 of the Federal Aviation Regulations and the Canadian Aviation Regulations does not take into account the effects of multiple bird strikes on the same windshield.

At the time of the impact, hundreds of pieces of glass of various sizes and shapes separated from the windshield's inner pane and travelled toward the aft wall of the flight deck. The captain, who at the time of the event was wearing special polycarbonate safety glasses, was hit in the upper torso, face, and scalp by numerous pieces of fractured glass. He sustained between 60 and 70 cuts to his face and scalp, and ultimately received approximately 20 stitches to the injuries that were severe enough to

warrant such treatment. In addition to the glass that penetrated his skin, numerous smaller pieces of glass became lodged between his eyeballs and his eyelids, but did not penetrate the membrane of either surface. Many of the cuts to his forehead and scalp bled heavily, and the dripping blood interfered with his ability to see.

A review of the Federal Aviation Administration and Transport Canada regulations that dictate the design, construction, and testing parameters for windshields in pressurized transport category airplanes (Part 25.775 for both), determined that the penetration limitation requirements defined there do not directly address multiple bird impacts of the same windshield. (ADB Ref. 20030108B)<sup>58</sup>

No recommendations on this particular issue were made in the accident report.

#### Research and Rulemaking Activities

No current research on the subject has been identified.

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

### **Conclusions and Recommendations**

Based on the review of the current applicable CS-25 requirements, accident experience, literature, and past/current rulemaking activities, it was concluded that further research is required to address windscreen fragmentation due to multiple birdstrike. In light of the recent accident to an A320 that ditched in the Hudson River, the relative likelihood of multiple birdstrike events may need to be investigated to ascertain whether extending the requirements to cover multiple birdstrike could be beneficial.

<sup>&</sup>lt;sup>58</sup> National Transportation Safety Board, *NTSB Identification SEA03FA024*. Scheduled 14 CFR (D.B.A. Horizon Airlines), Accident occurred Wednesday, January 08, 2003 in Medford, OR, USA, Aircraft: Bombardier DHC-8-401, registration: N409QX

## Cabin Safety Threat:

# 8. Emergency Equipment<sup>a</sup> Not Easily Retrievable or Not Conveniently Located near Cabin Crew (G01)

Current Applicable CS-25 Requirements and Associated Regulatory Material
Emergency equipment location and accessibility is addressed in CS-25 Amendment 6, as follows:
CS 25.1411(a) Accessibility Required safety equipment to be used by the crew in an emergency must be readily accessible.
CS 25.1411(b) Stowage provisions. Stowage provisions for required emergency equipment must be furnished and must- (1) Be arranged so that the equipment is directly accessible and its location is obvious;
CS 25.1411(d) Life rafts 2) Life rafts must be stowed near exits through which the rafts can be launched during an unplanned ditching.
CS 25.1411(e) Long-range signalling device. The stowage provisions for the long-range signalling device required by CS 25.1415 must be near an exit available during an unplanned ditching.
CS 25.1411(f) Life-preserver stowage provisions. The stowage provisions for life preservers described in CS 25.1415 must accommodate one life preserver for each occupant for which certification for ditching is requested. Each life preserver must be within easy reach of each seated occupant.
CS 25.1415(c) Approved survival equipment must be attached to, or stored adjacent to, each liferaft.
CS 25.1415(d) There must be an approved survival type emergency locator transmitter for use in one life raft.
AMC 25.851(a) Fire Extinguishers 1 Each extinguisher should be readily accessible and mounted so as to facilitate quick removal from its mounting bracket
Accident Experience and Safety Recommendations
The accident review found five accidents where the emergency equipment was not easily retrievable or not conveniently located near cabin crew. None of the events presented high risk to the safety of the occupants or contributed directly to the occupants' injuries or fatalities. Extracts from the reports of some of those accidents describing the events are as follows:
During emergency procedures training, cabin crews are taught to use a megaphone when wearing a smoke hood so as to make themselves heard/understood.

Commands given with the assistance of a megaphone were not difficult to hear. In

<sup>&</sup>lt;sup>a</sup> "Emergency equipment" addressed in this group includes fire extinguishers, megaphones, PBE, ELTs, flashlights, crash axes, and protective gloves. PA/Interphone location/accessibility is also addressed in this group.

this occurrence, the L3 cabin attendant did not have ready access to either megaphone on the aircraft. Regulations that speak to accessibility of emergency equipment state that "The commander shall ensure that relevant emergency equipment remains easily accessible for immediate use." Relevant emergency equipment is not defined in the regulations. (ADB Ref. 20050802A<sup>59</sup>)

The flight attendant handbook states that during an emergency evacuation, the front section flight attendant shall be by the aisle of L1 and R1 emergency exits and that her normal seat must be near the L1 exit aisle. However, the portable loudspeaker is located in the main cabin bin, without easy access to the flight attendant in case of emergency. This hindered communication between the front and the rear sections of the main cabin. ... This prevented the evacuation message from reaching the rear section of the main cabin....They concluded that the PA was off because there was no power available and the evacuation path was packed with passengers. They did not have time to reach the portable loudspeaker located in the bin above the seats of the first row. (ADB Ref. 19990824A<sup>60</sup>)

Immediately after the aircraft came to a halt, the flight attendants began to look for torches to assist them in the evacuation. The task of locating torches was complicated by the aircraft being inverted and the fact that the aircraft ceiling (now floor) was cluttered with debris. (ADB Ref. 19990822A<sup>61</sup>)

The UK AAIB issued a recommendation regarding emergency equipment location following the Manchester B737 accident on 22 August 1985 (ADB Ref. 19850822A<sup>62</sup> - not part of the accident review), as follows:

4.5 Emergency equipment for use by cabin crew during an emergency evacuation should be stowed at the cabin crew stations.

#### Research and Rulemaking Activities

A study commissioned by the UK Civil Aviation Authority on cabin crew in-flight fire training needs<sup>63</sup> found that cabin crew had experienced difficulties in accessing and retrieving firefighting equipment during in-flight fire emergencies.

A study on ditching and water survival training programs<sup>64</sup> questioned how effectively cabin crew could move stowed rafts to exits or slide/rafts from unusable exits to accessible door-ways, even with the help of able-bodied passengers.

One of the recommendations made at the Very Large Transport Aeroplane Conference in the Netherlands<sup>65</sup> recommended that the amount and location of fire emergency and survival equipment for use by the crew be studied during VLTA design, development, and certification.

SAE Standard ARP583 (Flight Attendant Stations) provides guidance for the design and location of flight attendant stations, including emergency equipment installations at or near such stations, so as to enable the flight attendant to function effectively in emergency situations, including emergency evacuations. However, this document is not referred to by CS-25 Requirements or Acceptable Means of Compliance.

The review carried out in this study did not identify any recent EASA or FAA rulemaking activities pertinent to this cabin safety threat.

#### Discussion

The accident evidence and research studies demonstrate that there can be situations where emergency equipment that is accessible in normal circumstances, becomes inaccessible in an emergency situation, because it is not actually situated near enough to where it will be used.

In a survivable post crash or ditching situation, cabin crew are most likely to be located, at least initially, at their crew stations. The aisles are likely to be filled with passengers. It would therefore be impossible for the cabin crew to retrieve emergency equipment from any location other than beside their stations. It is therefore likely that for some items of emergency equipment, stowage in the aisle is unsuitable.

It is therefore evident that the term 'readily accessible' may be open to interpretation, and it may be necessary to provide guidance material to CS 25.1411 to ensure that emergency equipment is readily accessible at the location it is intended to be used, given the circumstances likely to be present in an emergency. For example:

- Fire extinguishers, torches, and megaphones should be located at the cabin crew stations.
- Portable life rafts must be located near to exits and should not be located in the aisle.

#### Conclusions and Recommendations

Based on the review of the current applicable CS-25 requirements, accident experience, and literature, it was concluded that amendments to CS-25 are not considered necessary to mitigate the threat associated with accessibility of emergency equipment. However, it is recommended that EASA give consideration to referring to existing industry standards in the AMC in addition to providing guidelines (e.g. guidance material to CS 25.1411) as to what constitutes "readily accessible", "near to" and "directly accessible and its location is obvious" in the context of the circumstances likely to be present in emergency situations.

<sup>&</sup>lt;sup>59</sup> Transportation Safety Board of Canada, Aviation Investigation Report, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005, Report

Number A05H0002 <sup>60</sup> Aviation Safety Council Taiwan, Accident Investigation Report ASC-AAR-00-11-001, UIA 873, B-17912, MD-90-30 Cabin explosion and fire during landing roll. Hua-Lien. Taiwan. August 24<sup>th</sup>. 1999

<sup>&</sup>lt;sup>61</sup> Accident Investigation Division, Civil Aviation Department Hong Kong, Aircraft Accident Report 1/2004, Report on the accident to Boeing MD11 B-150 at Hong Kong International Airport on 22 August 1999

<sup>&</sup>lt;sup>2</sup> UK Air Accidents Investigation Branch, Aircraft Incident Report No: 8/88, Report on the accident to Boeing 737-236, G-BGJL at Manchester International Airport on 22 August 1985 <sup>63</sup> Asmayawati, S., Butcher, N, & Cherry, R. (2009) CAA Paper 2009/01 Cabin Crew Fire Training – Training

Needs Analysis. Gatwick: UK Civil Aviation Authority

<sup>&</sup>lt;sup>64</sup> Cosper, D.K. & McLean, G.A. (1998) DOT/FAA/AM-98/19, Analysis of Ditching and Water Survival Training Programs of Major Airframe Manufacturers and Airline. Washington, D.C.: Office of Aviation Medicine <sup>65</sup> Proceedings for the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16

October 1998

### Cabin Safety Threat:

## 9. Inadequate Performance or Reliability of Emergency Equipment (IB07)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

There are no CS-25 requirements that specify the performance standards of emergency equipment. CS-ETSO addresses the standards of some emergency equipment.

#### Accident Experience and Safety Recommendations

Failures of emergency equipment, such as the ELT and megaphone, were identified in four accidents. The failure of the megaphone in accident ADB Ref. 20030524A was not considered a high risk and did not contribute to occupants' injuries or fatalities. The failure of the ELT in accident ADB Ref. 20050802A was not considered a high risk; however, in circumstances such as those present in accidents ADB Ref. 19991112A and 20030622A the delay of the arrival of fire/rescue services could have contributed to occupant fatalities. The extracts from the accident reports are as follows:

The aircraft is equipped with three emergency locator transmitters (ELTs); one of the ELTs is equipped with an automatic g switch, which is unidirectional along the longitudinal axis. No signals were reported to have been received from any of the transmitters. (ADB Ref. 20050802A)<sup>66</sup>

The aeroplane was equipped with a Socata ELT 96 406-megahertz emergency beacon. The beacon did not trigger during the accident. The findings were that the beacon, when subjected to a high acceleration, transmitted the correct distress signal, but that it did not function for the acceleration values stated in the specifications. The error was significant; it could not be established which of the circuit boards was faulty (sensor or G-switch). (ADB Ref. 20030622A)<sup>67</sup>

She [the "B" flight attendant] stated the "A" flight attendant was making an announcement, but she could not hear it. She stated she moved forward and determined that the megaphone was not working properly; it was fading in and out and could barely be heard mid-cabin. She stated she returned to the aft cabin, got the aft megaphone, and gave it to the "A" flight attendant about mid-cabin. She stated the "A" flight attendant then repeated the "no smoke, no fire" announcement again to the passengers. (ADB Ref. 20030524A)<sup>68</sup>

At 10h 45, KFOR was informed of the loss of radio/radar contact. Land patrols were sent out immediately to obtain information from the population. At 13h 30, SAR operations were started with four helicopters. From 15h 45 onwards, the search continued in the dark, with four other helicopters equipped with infrared cameras and night vision apparatus. At 20h 41, a helicopter discovered the wreckage. A medical team and troops were deployed to the spot. Note: The emergency locator transmitter from F-OHFV was never heard. (ADB Ref. 19991112A<sup>69</sup> – non-survivable accident)

One safety recommendation regarding ELT reliability was made by the French BEA, following the investigation of the accident ADB Ref. 19991112A<sup>69</sup>, as follows:

The emergency locator transmitter installed on board did not work after the accident. This delayed discovery of the wreckage and, incidentally, obliged the search and rescue helicopters to undertake night searches in conditions which were particularly dangerous for the crews. It is not the first time that failure of this type of emergency equipment to operate has been noted following an aircraft accident. These failures and the delays they generate could cause the possible death of survivors or prolong their suffering. Consequently, the BEA recommends that:

- the ICAO take the initiative in the near future to re-examine the standards applicable to emergency locator transmitters so as to ensure that they correspond to the objective of operating correctly after an accident in order that the aircraft's location be established rapidly and

- in parallel, the study of supplementary or replacement systems which permit rapid and precise identification of the location of an accident aircraft be considered as a priority.

#### Research and Rulemaking Activities

A research project carried out by the Civil Aeromedical Institute<sup>70</sup> concluded that it is critical that all water-related emergency equipment be made of waterproof materials. The study found that in an accident at LaGuardia International Airport on September 20, 1989, a megaphone, which was the only effective mode of communication amongst the crew and passengers, stopped working when it became wet. However, the accident review carried out in this study was for the period (1998-2007) and did not identify this threat.

There is an SAE Standard AS4950B which addresses the design and performance criteria for transport aircraft portable megaphones. This document provides design criteria and performance tests for portable, hand-held, battery-powered, electronic megaphones used by aircraft crew members to provide information and guidance in the event of an aircraft emergency or other non-routine situation. However, this document is not referred to by CS-25 Requirements or Acceptable Means of Compliance.

The review carried out in this study did not identify any recent EASA or FAA rulemaking activities pertinent to this cabin safety threat.

#### Conclusions and Recommendations

Based on the review of the accident experience and literature, it was concluded that amendments to CS-25 are not considered necessary to mitigate the threat associated with inadequate performance or reliability of emergency equipment. However, it is recommended that EASA review the relevant standards specified in CS-ETSO or any other standards recognised by EASA to ensure that the performance of emergency equipment is adequately addressed.

<sup>&</sup>lt;sup>66</sup> Transportation Safety Board of Canada, Aviation Investigation Report, Runway Overran and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005, Report Number A05H0002

<sup>&</sup>lt;sup>67</sup> Bureau d'Enquetes et d'Analyses pour la Securite de l'Aviation Civile, *Accident on 22 June 2003* 

at Guipavas (21) to the Bombardier Canadair CL-600 2B 19 registered F-GRJS operated by Brit Air, Report Translation f-js030622a

 <sup>&</sup>lt;sup>68</sup> National Transportation Safety Board, Aircraft Accident Brief FTW03MA160, Southwest Airlines Flight 2066, Boeing 737-300 N343SW, Amarillo, Texas, May 24, 2003
 <sup>69</sup> Bureau d'Enquetes et d'Analyses pour la Securite de l'Aviation Civile, Report Translation on the accident on

<sup>&</sup>lt;sup>69</sup> Bureau d'Enquetes et d'Analyses pour la Securite de l'Aviation Civile, *Report Translation on the accident on* 12 November 1999, North of Pristina (Kosovo) to the ATR 42-300 registered F-OHFV operated by SI FLY, Report No. F-FV991112A

<sup>&</sup>lt;sup>70</sup> Cosper, D.K. & McLean, G.A. (1998) *DOT/FAA/AM-98/19, Analysis of Ditching and Water Survival Training Programs of Major Airframe Manufacturers and Airline*. Washington, D.C.: Office of Aviation Medicine

### Cabin Safety Threat:

## 10. General Occupant Safety

GA02 / Slip, Trips and Falls In and From Aircraft Cabin during Normal Operation

Y25 / Injuries Related to Deplaning or Evacuating Using Airstairs

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 requirements related to this threat group are as follows:

CS 25.793 The floor surface of all areas, which are likely to become wet in service, must have slip resistant properties.

25.810(e) If an integral stair is installed in a passenger entry door that is qualified as a passenger emergency exit, the stair must be designed so that, under the following conditions, the effectiveness of passenger emergency egress will not be impaired:

(1) The door, integral stair, and operating mechanism have been subjected to the inertia forces specified in CS 25.561(b) (3), acting separately relative to the surrounding structure.

(2) The aeroplane is in the normal ground attitude and in each of the attitudes corresponding to collapse of one or more legs of the landing gear.

#### Accident Experience and Safety Recommendations

The accident review found 2 accidents related to slips/falls from the aircraft. Extracts from the accident reports describing the events are as follows:

During pushback, the flight attendant stated that she was contacted by the lead flight attendant who asked if the crew rest area was secure. The attendant answered yes and looked to check again and found the door ajar. Fearing a passenger may have gone in she went over and climbed the stairs and checked the rest area. On her way down she believes she misplaced a foot on the narrow stairs and fell down breaking her arm in three places. Probable cause: The flight attendant's inadvertent misstep on a ladder and falling during pushback resulting in serious injuries. (ADB Ref. 20070712A<sup>71</sup>)

[A] mechanic sustained fatal injuries [after] he fell onto the ramp from the main cabin entrance door while attempting to close the door during a thunderstorm. The witness added that "suddenly his hand slipped from the door handle, his feet slipped from under him, and he fell out the doorway" onto the ramp. Following the accident, the airline developed and implemented numerous safety enhancements, including revised procedures and training regarding portable airstairs and jet-bridge operations. The National Transportation Safety Board determines the probable cause(s) of this accident as follows: Ground service personnel's removal of the portable stairway prior to the main cabin door being secured. Factors were the high winds and heavy rain. (ADB Ref. 20070710A<sup>72</sup>)

According to an article published by the Flight Safety Foundation in 2000<sup>73</sup>, other slip, trip, and fall accidents are as follows:

- 1. Lack of supervision of boarding/deplaning passengers
  - a. MIA97WA226, 2 August 1997 near Lima, Peru, Boeing 757-200 Continental Airlines

#### - 1 fatality

- b. FTW95LA103, 27 January 27, 1995 at Dallas, Texas, U.S., Boeing 737-2H4 Southwest Airlines – 1 serious injury
- c. TSB Occurrence no. A91W0142, 24 July 1991, at Yellowknife, Northwest Territories, Canada, DHC-6-300 Ptarmigan Airways 1 minor injury

### 2. Stairs not against doorway

- a. BFO87FA053, 11 August 1987 at Washington, D.C., U.S., Boeing 747-200B All Nippon Airways 1 fatality
- b. FTW97LA177, 4 May 1997 at Denver, Colorado, U.S., Boeing 737-201 Frontier Airlines – 1 serious injury
- c. TSB Occurrence no. A99F0073, 1 October 1999 on an Airbus A310-300, Royal Aviation 1 serious injury
- d. TSB Occurrence no. A99A0046, 31 March 1999 on a Boeing 767-200, Air Canada 1 serious injury
- 3. Elderly passengers
  - a. MIA95IA134, 19 May 1995 at Brooksville, Florida, U.S., Boeing 727-227 Continental Airlines 1 serious injury

### 4. Aircraft design

- LAX89LA328, 26 July 1989 at Bullhead City, Arizona, U.S., British Aerospace 3201 American International – 1 serious injury, passenger tripped against the wing spar hump in aisle
- b. FTW88LA050, 10 January 1988 at Dallas/Fort Worth International Airport, Texas, U.S., McDonnell Douglas DC-6 American Airlines – 1 serious injury, passenger caught between door and bulkhead

#### 5. Other

- a. ATL97LA075, 26 May 1997 over the Atlantic Ocean, Lockheed L-1011-385-3 Delta Air Lines - 1 serious injury, cabin crew stepped on galley item
- b. TSB Occurrence no. A93A0123, 14 June 1993, Boeing 757 American Trans Air 1 serious injury, cabin crew fell down the aircraft stairs chasing a deportee

No recommendations on this particular issue were made.

The accident review found 4 accidents where occupants had been injured when they fell whilst on the integrated airstairs. Extracts from the accident reports describing the events are as follows:

The passenger fell while exiting the aircraft using the door-stair during normal deplaning. The passenger reportedly fractured his cheek bone, sinus cavity, eye cavity, and shoulder. (ADB Ref. 20051026A)<sup>74</sup>

According to the passenger, she raised her left foot to reach the first step on the airplane, and then retracted her foot to place it on the ground. In the process, she lost her balance, fell, and fractured her left wrist. (ADB Ref.20030902B)<sup>75</sup>

The director of safety further stated that as the 53rd passenger in the sequence of 58 passengers exited the airplane, she grabbed the handrail at the top of the stairs, and the handrail collapsed. He said the passenger fell from the top of the stairs to the ground, and sustained serious injuries.(ADB Ref. 20030208A)<sup>76</sup>

The three passenger injuries were sustained from falling off the steps of the rear main passenger loading door during deplanement. He saw a girl and an older woman trip and fall onto the tarmac, suffering minor scrapes. He saw the pilot exit out the left fuselage emergency exit. (ADB Ref. 19981025A)<sup>77</sup>

No recommendations on this particular issue were made.

Other accidents involving integral airstairs cited in an article published by the Flight Safety Foundation in 2000<sup>73</sup> are:

1. NTSB Identification MIA87LA063. This accident occurred on December 30, 1986 on a Fokker F28 Mark 4000 operated by Piedmont Aviation and resulted in one serious injury and 78 occupants uninjured. (Airstair handrail collapsed)

During passenger boarding at Tallahassee it was discovered that the left handrail on the airstair was collapsed. The failure was at the soldered joint at the handrail locking mechanism. The station manager used metal glue for a temporary repair of the joint. The flight crew was made aware of the discrepancy. The aircraft then departed for West Palm Beach via Orlando. The airstair was not used at Orlando. A disabled passenger was injured when the handrail collapsed when boarding the aircraft unassisted at West Palm Beach. The passenger stated that he did not need assistance in boarding, just a little extra time. When the handrail collapsed the passenger lost his balance and fell to the ground receiving serious injuries.

 NTSB Identification CHI93LA327. This accident occurred on May 7, 1993 at Green Bay, Wisconsin, U.S. on a British Aerospace ATP operated by Air Wisconsin and resulted in one serious injury and 33 occupants uninjured:

The 73 year-old passenger reported she had made the first step, but her foot caught on the second step before she had grasped the hand rail. She said she then lost her balance and fell.

#### Research and Rulemaking Activities

In a 1992 study based on compensation claims of nearly 2,500 U.S. pilots and flight attendants in 1988, it was found that falls involving walkways, stairs and vehicles were the most common "injury and illness cases by event or exposure" for pilots and the third most common for flight attendants<sup>78</sup>.

A Flight Safety Foundation article<sup>73</sup> stated "that accident/incident reports from several sources indicate that crewmembers and passengers have been involved in falls in, on or from aircraft during normal operations because of controllable factors such as objects in aisles, wet surfaces, unserviceable equipment and noncompliance with standard operating procedures. Moreover, because transport aircraft typically have door sills higher than four feet (1.2 meters) above the ground, open doors also can present hazards."

A Flight Safety Foundation publication in 1999<sup>79</sup> found that training generally prepares cabin crew members to perform their duties safely in aircraft galleys, however it made the following safety observations:

- Assist handles should be installed and used to help maintain balance while working in galleys;
- Falls in and near galleys can be caused by floor surfaces contaminated by spilled liquids and because of the need to use excessive bodily force to release cart brakes.

Certain aircraft cabin features, such as the spar across the aisle in the Jetstream 31/32 has been cited as a contributing cause in an accident involving a passenger being seriously injured<sup>80</sup> ("*darkness and the fuselage floor exit aisle was designed with a raised area which partially obstructed its use*").

The report for the VERRES work package<sup>81</sup> noted that there are no regulations in which the dimensions of any internal stairways or the number of stairs for use by passengers are specified. There is a concern that internal stairways used in emergencies, by a large number of passengers during various circumstances, may lead to serious injuries and possible fatalities. Therefore, if such regulations were to be adopted, they should take into account safety during normal and emergency

situations as well as evacuation considerations.

It is understood that the Society of Automotive Engineers have been developing an Aerospace Information Report (AIR) addressing 'Issues in Stairway Design Aboard Transport Category Airplanes' (AIR5670). This AIR contains information that can be used by the air transportation industry to evaluate the design of airplane interior stairways with respect to the safety of passengers and crew in normal operating conditions and emergency evacuations.

Another SAE publication relevant to this issue is ARP836 which addresses 'Design and Safety Criteria for Passenger Boarding Stairways'. These SAE publications are industry standards and are not mandatory.

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

#### **Conclusions and Recommendations**

Whilst many of the slip, trip, and fall accidents inside or from the cabin involved non-compliance with standard operating procedures or complacency, there may be aircraft design features that can reduce its risk. This may be particularly relevant to features like staircases within very large twin deck aircraft such as the A380. Additionally, there are no regulations governing the height, angle or slip resistance of the steps, or the provision of handrails for integrated airstairs. Industry standards (SAE publications) on these subjects are available. It is recommended that further deliberation be given by EASA to investigate the feasibility of the incorporation of (or referral to) such standards into airworthiness requirements.

<sup>&</sup>lt;sup>71</sup> National Transportation Safety Board, NTSB Identification MIA07CA119, Scheduled 14 CFR Part 121: Air Carrier Delta Air Lines, Inc., Accident occurred Thursday, July 12, 2007 in Atlanta, GA, Aircraft: Boeing 777-232,

registration: N865DA <sup>72</sup> National Transportation Safety Board, NTSB Identification: DFW07LA155, Nonscheduled 14 CFR Part 121: Air Carrier operation of Sky King, Inc. (D.B.A. operation of Sky King, Inc.), Accident occurred Tuesday, July 10, 2007 in Tunica, MS, Aircraft: Boeing 737-232, registration: N332DL

Working in, Around Aircraft Cabins Requires Awareness of Fall Prevention, Flight Safety Foundation - Cabin Crew Safety, Vol. 35 No. 1, January-February 2000.

<sup>&</sup>lt;sup>4</sup> National Transportation Safety Board, NTSB Identification CHI06LA016, Comair Airlines Inc. CL-600-2C10, *registration: N391CA, October 26, 2005, Covington, KY*<sup>75</sup> National Transportation Safety Board, *NTSB Identification NYC03FA186, American Airlines Inc, McDonnell* 

Douglas DC-9-82, registration: N454AA, September 02, 2003 in Jamaica, NY <sup>76</sup> National Transportation Safety Board, NTSB *Identification MIA03LA055, American Eagle Executive Airlines* 

Inc. ATR71-212, registration: N448AM, February 08, 2003, San Juan

<sup>&</sup>lt;sup>77</sup> National Transportation Safety Board, NTSB Identification MIA99FA012, Executive Airlines ATR-42-300, registration: N143DD, October 25, 1998, San Juan

Mohler, Stanley R. Airline Crew Members Suffer High Rate of Occupational Injuries, Human Factors & Aviation Medicine, Volume 40 (May – June 1993):3.

Vigilance in Aircraft Galley and Service Procedures Preservers Margin of Safety, Flight Safety Foundation -Cabin Crew Safety, Vol. 34 No. 1, January-February 1999

 $<sup>^{</sup>m J}$  National Transportation Safety Board, NTSB Identification: LAX89LA328, Accident occurred Wednesday, July 26, 1989 in Bullhead City, AZ. Aircraft: British Aerospace 3201, registration: N332QC <sup>81</sup> Wilson, R., & Muir, H. (2003). VERRES VLTA Emergency Requirements Research Evacuation Study, Work

Package 1, Task 1.1. report

## Cabin Safety Threat:

## 11. Issues Associated with Seat Pitch

SA03 / Health and Evacuation Problems Associated with Seat Pitch (e.g. DVT)

CA03 / Difficulty in Retrieving Life Preservers related to Limited Seat Pitch

### Current Applicable CS-25 Requirements and Associated Regulatory Material

There is no CS-25 requirement addressing minimum seat pitch relating to possible health problems.

On 16<sup>th</sup> March 1989, the UK CAA issued Airworthiness Notice No. 64 that regulates the minimum space for seated passengers, applicable to all UK registered aeroplanes over 5700 kg MTWA certificated in the Transport Category (Passenger) and configured to carry 20 or more passengers. There were 3 dimensions related to seat spacing regulated in this Airworthiness Notice. These dimensions are defined taking into account head, trunk and leg strike areas of the seat in front, the ability to occupy the seat and, if necessary, quickly vacate the seat and enter the aisle in an emergency.

Stowage of life preservers is addressed in CS 25.1411(f):

Life-preserver stowage provisions. The stowage provisions for life preservers described in CS 25.1415 must accommodate one life preserver for each occupant for which certification for ditching is requested. Each life preserver must be within easy reach of each seated occupant.

#### Accident Experience and Safety Recommendations

The accident review carried out in this study did not identify events associated with this cabin safety threat.

#### **Research and Rulemaking Activities**

#### 1) Health Problems Associated with Seat Pitch

A study into the occurrence of "Flight Related Deep Vein Thrombosis"<sup>82</sup> suggested that it occurred to first class passengers as well as economy class passengers. The Medical Guidelines for Airline Travel, 2nd Ed.<sup>83</sup> stated that there have been no epidemiological studies published which show a statistically significant increase in cases of Deep Vein Thrombosis (DVT) when travelling in the absence of pre-existing risk factors. In the absence of any good published information, the evidence linking DVT with flying is circumstantial. Whether DVT occurs in airline travel simply because of prolonged immobility of an individual that may have predisposing risk factors is not known. In the absence of conclusive studies showing a causal relationship between DVT and flying, there is currently no substantive scientific evidence for providing recommendations, for the prevention of DVT, related specifically to aircraft travel<sup>83</sup>. The International Travel and Health publication issued by the World Health Organization in 2009<sup>84</sup> states that in most cases of DVT, the clots are small and do not cause any symptoms. The body is able to gradually break down the clots and there are no long-term effects. The publication recommended moving around the cabin once every 2-3 hours, exercising the calf muscles, and wearing compression stockings to reduce the risk of developing DVT.

A JAA/UK CAA-funded research project entitled "Anthropometric Study to Update Minimum Aircraft Seating Standards"<sup>85</sup> concluded that the contribution of seat design and spacing to the development of thromboembolic disease is not known. However, the study suggested that aircraft seat redesign could theoretically reduce the risk, and research should incorporate the testing of venous physiology in response to altered seat design.

#### 2) Retrieval of Life Preservers (under-seat mounted)

A series of human subject tests were conducted by the Biodynamics Research Team at the FAA's Civil Aerospace Medical Institute (CAMI) to investigate human factors associated with the "easy reach" requirement in FAA regulations for under-seat mounted life preservers<sup>86</sup>. The tests were designed to observe and measure the effects of human physical attributes and life preserver installation features relevant to the retrieval of life preservers. A mock-up of a 30-inch pitch, economy class transport passenger seat installation was used to evaluate 4 configurations of life preserver installations. The study concluded the following:

The FAA regulation addressing life preserver installations specifies: "Each life preserver must be within easy reach of each seated occupant" (2). There are no published FAA guidance or policy documents to define the term "easy reach" in this regulation. Nor is there any implication regarding the range of occupants (e.g. body size) that should be able to reach the life preserver easily. Thus, the pass/fail assessment of life preserver installation, based on the judgement of the approving official, is subjective and potentially inconsistent.

The 30-inch seat pitch used in this study should be considered as a conservative factor. Wider pitch installations would likely present less difficulty in retrieving the life preserver, especially for larger occupants.

#### 3) Evacuation Issues Related to Seat Pitch

There have been limited studies that focused on passenger seat spacing in relation to the dynamics of an emergency evacuation. In a safety study conducted by the US National Transportation Safety Board<sup>87</sup>, the Safety Board asked passengers and flight attendants involved in 30 evacuation-related accidents to indicate from a list what hindered the evacuation. From the 2 accidents with the most severe crash forces, 16 passengers mentioned the seatback in front of them as an impediment. From the other 28 accidents, eleven passengers indicated that the seatback in front of them slowed their movement. However it is not known whether the impediment was caused by distortion of the seat.

An extensive media exposure in 2001 raised the concern that a greater seat pitch might adversely affect the overall emergency evacuation because passengers left their seats too quickly causing "bottlenecks" and a crush at the exits. Although this concern was inferred from a preliminary evacuation trial which was not particularly designed to address the subject, further study would be required in order to identify the actual effect of seat pitch variations on the overall emergency evacuation process.

The review carried out in this study did not identify any current/past US FAA rulemaking activities pertinent to this cabin safety threat. In 2003, JAA initiated a study on this issue (Cabin Safety Study Group #39 – Minimum distance between passenger seats). The proposal was to introduce a JAR 26 requirement (in association with JAR 25 change) to control the distance between passenger seats (based upon UK CAA Airworthiness Notice No 64).

## 4) Future Developments

Future developments that may need to be considered in assessing the need for setting minimum seat pitch are:

#### - Out-of-seat recreational areas

Passengers will be more encouraged to leave their seats and move around the cabin as recommended by the World Health Organization with the increasing popularity of out-of-seat recreational areas primarily set up in Very Large Transport Aeroplanes. This may reduce the risk of DVT due to reduced mobility especially in passengers with pre-existing risk factors. However, out-of-seat recreation areas also increase the risk of getting injured in a turbulence or in-flight upset event.

#### Increasing human size and aging passengers

A UK CAA/JAA funded study<sup>85</sup> concluded that the minimum dimensions specified in Airworthiness Notice No. 64 needed to be increased. This research suggested that Dimension A, i.e. the minimum distance between the back support cushion of a seat and the back of the seat or other fixed structure in front, needed to be increased from 26" (AN No. 64 minimum dimension) to 28.2" to accommodate the 95th percentile body dimensions appropriate to the European population. In practice, this equates to increasing the 28" seat pitch to more than 30" (assuming a typical 2" seatback thickness). This research also suggested that as far as safety is concerned this dimension should be increased to accommodate up to the 99th percentile. On the subject of passenger dimensions, an article in Air Safety Week<sup>88</sup> further stated that: "Two other factors bear on the issue. People are growing taller, and they are growing fatter. Over 14 years, 1981-1995, mean height among UK men increased 17 mm (0.6 inches) and among UK women increased 12 mm (0.4 inches). On the weight issue, good data are hard to come by, but there is enough information for the study authors to safely say, 'People in Western populations are becoming broader'."

The increasing height and weight of the world's population is typically correlated with health, longevity, and nutritional quality. Since quality of life is ever improving, it is very likely that the anthropometry measurements for seats and the distance between seats, as well as the ease of life preserver retrieval will need to be adjusted to accommodate this.

Additionally, the study also stated that more people of advanced years will be flying ("... by 2030 older people will outnumber younger adults by a fifth and this is likely to be represented within the flying population..."), and they will encounter greater difficulty in getting in and out of seats at lower seat pitches. This may also have an implication on evacuation.

#### 5) Cost Impact

Regulating minimum seat spacing is likely to economically impact those Operators with reduced seat pitch and a segment of the flying population. Operators with a high load factor (typically charter and low-cost airlines) may need to increase fares. Since the majority of charter and low-cost airline passengers are holiday makers, this segment would most likely be the most affected (in terms of having to pay higher fares). If the requirement is retrofit, there will be costs incurred by Operators in rearranging seating configurations. These will include seat removal, ground-time costs and some increase in seat mile costs with the potential for fare increases. By way of example of the potential economic impact, a single row of six seats in an aircraft, with four of them filled on an average flight, can generate up to \$8 million in ticket revenue over a 20-year period<sup>88</sup>. The British Air Transport Association estimates that adding two inches to existing seat pitch would put fare prices up by about 10%<sup>89</sup>.

#### **Conclusions and Recommendations**

In the absence of conclusive studies showing a causal relationship between DVT and flying, there is currently no substantive scientific evidence to form the basis of recommending a requirement for (minimum) seat pitch for the prevention of DVT.

Increasing seat pitch may improve passengers' evacuation capability, although the studies that have been carried out to date are not conclusive in this respect. However, it is feasible that any improvements in passenger egress may only be achieved if seat pitch increases are carried out in conjunction with other changes to the cabin interior configuration that will prevent congestion in other areas of the egress path. It is recommended that consideration be given to carrying out research to investigate the effects of various seat spacing dimensions on evacuation, not just on the passengers' ease of egress but also on the overall dynamics of the emergency evacuation. The investigation should take into account the projected increasing proportion of elderly people in the flying population and people from the higher body dimension percentile group.

The economic impacts of a minimum seat-pitch rule with varying seat pitch dimensions will need to be established if such a rule is to be implemented. The study should include but not be limited to, the number and size of operators adversely affected, and the effects on first cost, operating cost, and passenger fares.

In summary it is considered that further research is required to support any future regulatory activity. A preliminary Regulatory Impact Assessment<sup>90</sup> carried out for EASA in 2006 concluded that:

"The subjects which should be considered for further research and analysis are:

To determine the effects of increased seat pitch on:

- *i)* Emergency evacuation capability
- ii) The incidence of Deep Vein Thrombosis
- iii) Seat mile costs"

It is recommended that consideration be given by EASA to provide guidelines for the installation of under-seat mounted life preservers. Anthropometrics measurements and their likely future increases may need to be taken into consideration. Seat pitch may not be the only factor; other factors such as the position of the stowage and the stowage mechanism also influence ease of retrieval. It is recommended that the guidelines should consider these factors in defining the term "*easy reach of each seated occupant*" used in CS 25.1411(f)).

<sup>&</sup>lt;sup>82</sup> Yeung, Lingam (2002) *Flight Related Deep Vein Thrombosis*. United Kingdom: Scottish Medical Journal SMJ 2002: 47(6) 123-126

<sup>&</sup>lt;sup>83</sup> Aerospace Medical Association, Medical Guidelines Task Force (2003) Medical Guidelines for Airline Travel, 2<sup>nd</sup> Edition. United States: Aviation, Space, and Environmental Medicine Vol 74 No 5 Section II, Supplement May 2003

<sup>2003</sup> <sup>84</sup> World Health Organization (2009) International Travel and Health, 2009 Edition, retrieved July 2009 from http://www.who.int/ith/en/

<sup>&</sup>lt;sup>85</sup> Quigley, C., Southall, D., Freer, M., Moody, A., & Porter, M. (2001) *Anthropometric Study to Update Minimum Aircraft Seating Standards, EC1270, Prepared for Joint Aviation Authorities*. Loughborough: Author

<sup>&</sup>lt;sup>86</sup> Gowdy, V. & DeWeese, R. (2003) *DOT/FAA/AM-03/9, Human Factors Associated With the Certification of Airplane Passenger Seats: Life Preserver Retrieval.* United States: Federal Aviation Administration, Civil Aerospace Medical Institute

<sup>&</sup>lt;sup>87</sup> National Transportation Safety Board (2000) *Safety Study – Emergency Evacuation of Commercial Airplanes, NTSB/SS-00/01*. Washington, D.C.: NTSB

<sup>&</sup>lt;sup>88</sup> Cramped Seating Can 'Trap' and 'Trip' Passengers during Emergency Evacuation, Air Safety Week November

<sup>5, 2001.</sup> Retrieved December 2008 from http://findarticles.com/p/articles/mi\_m0UBT/is\_42\_15/ai\_79746357/ <sup>89</sup> House of Lords Select Committee Fifth Report, 15 November 2000, retrieved from

http://www.publications.parliament.uk/pa/ld199900/ldselect/ldsctech/121/12101.htm <sup>90</sup> European Aviation Sofety Aconsy (2006) Decliminant DIA CO. 25 646. http://

<sup>&</sup>lt;sup>90</sup> European Aviation Safety Agency, (2006), Preliminary RIA CS--25.046 – Minimum Distance between Passenger Seats, Germany Author

### Cabin Safety Threat:

### 12. Cabin Air Quality and Other Health Issues

H01 / Contamination of Cabin Air from APU/Engines

H03 / Occupants' Health Problems Associated with Cabin Environment

H04 / Contamination of Cabin Air from Dangerous Goods in Cargo and Cabin



(2) The air inlets and passages for air to flow between flight-crew and passenger

compartments are arrange to provide compartment temperatures within 2.8  $^{\circ}$ C (5 $^{\circ}$ F) of each other and adequate ventilation to occupants in both compartments.

(3) The temperature and ventilation controls are accessible to the flight crew.

CS 25.832 Cabin ozone concentration

(a) The aeroplane cabin ozone concentration during flight must be shown not to exceed –

(1) 0.25 parts per million by volume, sea level equivalent, at any time above flight level 320; and

(2) 0.1 parts per million by volume, sea level equivalent, time-weighted average during any 3-hour interval above flight level 270.

(c) Compliance with this paragraph must be shown by analysis or tests based on aeroplane operational procedures and performance limitations, that demonstrated that either –

(1) The aeroplane cannot be operated at an altitude which would result in cabin ozone concentrations exceeding the limits prescribed by sub-paragraph (a) of this paragraph; or

(2) The aeroplane ventilation system, including any ozone control equipment, will maintain cabin ozone concentrations at or below the limits prescribed by sub-paragraph (a) of this paragraph.

FAR 25.831(a) Amdt. 25-89 (eff. June 1996) is different to CS 25.831(a), in that it specifies ventilation rate for occupants (not just crew compartments) and addresses passenger comfort:

(a) Under normal operating conditions and in the event of any probable failure conditions of any system which would adversely affect the ventilating air, the ventilation system must be designed to provide a sufficient amount of uncontaminated air to enable the crewmembers to perform their duties without undue discomfort or fatigue and **to provide reasonable passenger comfort**. For normal operating conditions, the ventilation system must be designed to provide **each occupant** with an airflow containing at least 0.55 pounds of fresh air per minute.

According to the House of Lords' Select Committee on Science and Technology Fifth Report<sup>91</sup>, JAA did not carry out a harmonisation on this requirement because of industry concerns about the ability of new aircraft to meet the new regulation in some cases.

There are also several relevant FAA Advisory Circulars as follows:

- AC 121-35 Management of Passengers during Ground Operations without Cabin Ventilation
- AC 120-38 Transport Category Airplanes Cabin Ozone Concentrations
- AC 20-32B Carbon Monoxide (CO) Contamination in Aircraft Detection and Prevention
- AC 25-20 Pressurization, Ventilation and Oxygen Systems Assessment for Subsonic Flight including High Altitude Operation

#### Accident Experience and Safety Recommendations

The accident review found 5 occurrences featuring contamination of cabin air. It should be noted that this number does not represent the frequency of cabin air contamination by APU/Engines; these occurrences were in the Accident Database because there was an emergency evacuation. Two passengers sustained serious injuries, and one cabin crew and five passengers sustained minor injuries during the emergency evacuation in two of the accidents. Extracts from the accident reports describing the events are as follows:
While the copilot was obtaining clearance to continue taxiing, the commander was monitoring the internal communication between the two flight attendants. As he did so, he heard the flight attendant in the rear section of the cabin report to his colleague that that there was a lot of smoke in the cabin. The commander now asked the responsible flight attendant in the front section of the cabin whether smoke was visible. The flight attendant confirmed that there was now smoke in the cabin too. There was not much, but one could smell it. Causes: The serious incident is very probably attributable to the fact that smoke from the auxiliary power unit (APU) entered the aircraft via the air conditioning system. (ADB Ref. 20060319A)<sup>92</sup>

The pressure relief valve then opened and gearbox oil got to the outside of the propeller. The oil flowed into the spinner and from there was flung into the environment. Some of the oil was sucked back in through the engine air inlet and in this way passed through the compressor into the bleed air, and from there through the air-conditioning pack into the cabin in the form of odour, mist and smoke.[Findings:] A defective seal on the adjusting piston allowed gearbox oil to penetrate the propeller housing and finally make its way to the exterior. This oil was sucked back in through the engine air inlet and in this way passed into the bleed air and through the air-conditioning pack into the cabin, where it was perceived as smoke. This smoke triggered the lavatory smoke warning for seven seconds. (ADB Ref. 20051117A)<sup>93</sup>

At 0702:28, the captain informed the in-charge flight attendant on the interphone that the pilots were aware of the fire and were working on the problem. At that time, the flight attendant informed the captain that smoke had begun to infiltrate the aft cabin. Both air conditioning packs were off for the start, but the auxiliary power unit (APU) was operating. Under those conditions, it is possible for smoke to enter the aft portion of the cabin via the APU intake, through the air conditioning system, and eventually through the aft cabin floor vents. Passengers seated in the rear of the aircraft became anxious to evacuate because of the visible flame and irritation caused by the smoke in the cabin. (ADB Ref. 20051030B)<sup>94</sup>

*Examination of the airplane revealed the smoke was caused when the APU ingested hydraulic fluid that leaked from the pump after APU start-up.* (ADB Ref. 20030416A)<sup>95</sup> – 1 passenger sustained serious injuries during evacuation

According to a representative of American Airlines, the airplane landed uneventfully and taxied toward the parking area. While waiting on the ramp, the flight crew started the airplane's auxiliary power unit (APU) and about 30 seconds later, the cabin began to fill with smoke. (ADB Ref. 20021109A)<sup>96</sup> – 1 passenger sustained serious injuries, 1 cabin crew and 5 passengers sustained minor injuries during evacuation

A review of UK Mandatory Occurrence Reports data in the period 2002-2006 inclusive found that there were 396 occurrences involving contamination of cabin air (by oil, de-icing fluid, external contaminates, cleaning agent, passenger cosmetics, etc), and smoke/fumes in cabin due to failure of the aircraft air conditioning/pressurisation system (including failure of recirculating fan/cooling fan, failure of ACM, contaminated filters, excessive amount of dust, etc.). This is in line with the findings of the UK AAIB. As part of their investigation on an incident<sup>97</sup>, the UK AAIB reviewed the CAA database and found that in the 3-year period to 1 August 2006 there had been 153 cases of fumes, abnormal odour or smoke or haze in the flight deck and/or cabin of UK registered public transport aircraft of various types. The report states;

Details on a number of the cases were limited but the available information suggested that around 11 9 of the cases had probably resulted from conditioned air contamination. This had commonly been caused by oil release from an engine, APU or air conditioning unit or ingestion of de-icing or compressor wash fluid by an engine or APU, with consequent smoke and/or oil mist in the conditioned air supply to the fuselage. It appeared that in many of the cases the crew members had

found it difficult or impossible to establish the source of the contamination. Adverse physiological effects on one or both pilots, in some cases severe, were reported in 40 of the cases. A diversion was made in 31 cases.

Contaminated cabin air could pose a greater danger when it affects the flight crew (in the incident on 12 November 1999, the captain and co-pilot of a BAe 146-200 were incapacitated temporarily by nausea and dizziness during descent):

The captain felt markedly dizzy and groggy for a couple of minutes. He had difficulty with physiological motor response, simultaneity and in focusing. Finally, he handed over the controls to the co-pilot... In his groggy state, the captain even had difficulty in grasping the purser's finger as acknowledgement of her clear [cabin-ready] signal.

The incident report stated that there was no fault or abnormality that could cause the cabin air contamination other than the oil leak found by the operator. Another cabin air contamination incident occurred to the same aircraft type in November 2000 and was investigated by the UK AAIB. A recommendation to UK CAA and US FAA was issued regarding developing maintenance standards and modification standards to prevent the accumulation of oil by-products in air-conditioning systems and specifically to prevent the contamination of cabin air in the BAe 146 and the Boeing 757.

Health problems are not usually recorded in accident/incident databases.

#### Research and Rulemaking Activities

The following are health problems associated with air travel identified from the UK Department for Transport's studies<sup>98,99,</sup> and the House of Lords' Fifth Report<sup>91</sup>:

- (1) Poor cabin air quality and cabin air contamination
- CS 25.831(a) only specifies cabin air supply requirements for flight crew and not for passengers (see requirements above). One of the recommendations from the House of Lords Fifth Report<sup>91</sup> was for the Government, CAA and JAA to find a practicable way forward on this matter as soon as possible.
- As discussed above, cabin air contamination occurs quite frequently and could cause injuries due to ensuing precautionary emergency evacuations or endangering the safety of the flight if the flight crew are affected. Additionally, with regard to breathing harmful substances, a report by the U.S. National Research Council<sup>100</sup> ranked cabin air contamination from the compounds released upon heat degradation of hydraulic fluids and engine oil fumes as a moderate concern due to their high potential severity of health effects but low likelihood of exposure at high concentration. Nevertheless, they recommended that the FAA assess whether air-cleaning equipment is necessary and whether such equipment would be feasible for preventing air-quality incidents by removing particles and vapours from air supplied by the Environmental Control System (ECS). Many research studies recommended further monitoring of cabin air quality to investigate the prevalence/frequency, composition and triggers for 'fume events' <sup>100,101,102</sup>. At the time this evaluation was conducted, EASA has commenced a rulemaking task (Task No. 25.035) which addresses contaminated cabin air (from aircraft systems such as engines and APU).

A UK CAA research has resulted in the CAA requiring operators and manufacturers of particular aircraft types to make a number of changes including modifications to minimise oil leaks into the bleed air<sup>103</sup>.

- The House of Lords Fifth Report<sup>91</sup> found that pesticide contamination, volatile organic compounds, and carbon monoxide levels in cabin air are not significant health issues. This is in line with the findings in the BRE Environment study<sup>102</sup>, Maximum cabin ozone concentration as specified in 25.832 and maximum carbon dioxide concentration in 25.831(b)(2) are considered adequate. There is no evidence of other contaminants that may pose significant health hazards.

- (2) Poor cabin environment
- There are no airworthiness requirements for cabin temperature. FAR 25.831(g) addresses time-temperature relationship for temperatures above 35°C, which is not addressed in CS-25. In terms of normal operating cabin temperature, a report by BRE Environment<sup>102</sup> found that only at about 24°C can both passenger and crew achieve the ideal temperature but there are other factors. BRE stated that the aim should be a range of temperatures to which people can easily adapt to achieve comfort rather than the exact temperature. The American Society of Refrigerating, Heating and Air-Conditioning Engineers (ASHRAE) has suggested that further work should be done to establish guidelines for cabin thermal conditions<sup>104</sup>.
- The low humidity of cabin air poses several potential health issues, and is a significant factor in general malaise of passengers and crew<sup>105</sup>. Cabin relative humidity limits are not regulated by airworthiness requirements; however, the House of Lords' Fifth Report concluded that low cabin humidity as found in service is not harmful and any discomforts can be addressed individually. This is in line with the findings in the BRE Environment study<sup>102</sup>.
- There are no airworthiness requirements for the rates of pressurisation change. The rates were set at the design stage to minimise any passenger or crew discomfort within the requirements for safe aircraft operation<sup>91</sup>. Pressurisation changes may cause serious health concerns on vulnerable individuals (people with certain pre-existing medical conditions).
- There is no requirement for minimum noise inside the cabin. Whilst in shorter flights, noise may not be a significant issue, its adverse effects on the health of passenger and crew members on long haul flights may need to be addressed. New design aeroplanes have now taken noise into consideration, predominantly for passenger comfort.
- (3) Contamination of cabin air from dangerous goods

Although carriage of dangerous goods is highly regulated by operations requirements, there have been incidents caused by items which are allowed on board but then developed faults during flight. The International Civil Aviation Organization has developed guidelines for cabin crew in responding to suspected in-flight dangerous goods incidents<sup>106</sup>.

(4) Cosmic radiation exposure (especially for crew)

High levels of radiation have been linked to an increased risk of cancer and potential harm to foetuses<sup>107</sup>. FAA issued Advisory Circular No. 120-61A (In-flight Radiation Exposure) dated 07/06/2006 which contains information intended to augment existing programs an air carrier may be using to inform crewmembers about radiation exposure. FAA provides an online tool to calculate exposure that can be used by crewmembers. In May 1996, the European Union issued a directive for workers, including air carrier crew members (cabin and flight crews) and the general public, on basic safety and health protections against dangers arising from ionizing radiation. There is no airworthiness requirement related to cosmic radiation exposure and it is not considered an airworthiness subject.

(5) Spread of infectious disease in aircraft cabin

Air travel is highly associated with confined space, limited ventilation, prolonged exposure times and recirculating air. These are demonstrated risk factors for the transmission of upper respiratory tract infections in other settings<sup>108</sup>. A study carried out by the ATSB<sup>109</sup> found that the risk of airborne infections in the aircraft cabin is low. Nevertheless, the House of Lords Fifth Report<sup>91</sup> recommended the use of High Efficiency Particulate Air (HEPA) filtration to minimise the risk of cross-infection to be made mandatory in re-circulatory systems.

(6) In-flight Medical Emergencies

In-flight medical emergencies are particularly critical on long haul flights. Requirements for first aid kits are given in EU-OPS 1.745. Requirements for emergency medical kits for aeroplanes with a passenger seating configuration of more than 30 and a planned route of more than 60 minutes flying time are given in EU-OPS 1.755. The required contents of the kits are listed in TGL-44 part AMC

OPS 1.745 for first-aid kits and AMC OPS 1.755 for emergency medical kits.

(7) Deep Vein Thrombosis (DVT)

DVT is addressed in Group 29 (Seat Pitch Related Issues).

(8) Jet lag and stress

The subject of jet lag and stress is considered outside the scope of this study.

EASA will be reviewing existing CS-25/FAR 25 and AMC/AC to consider changes that will provide crew and passengers with safe aircraft cabin and flight deck environments (Task 25-035).

As a result of continued concerns about aircraft cabin air quality and health issues raised by cabin crew and passengers, Congress directed the FAA in the Wendell H. Ford Aviation Investment and Reform Act of the 21st Century, enacted in 2000, to request the National Research Council (NRC) to perform another independent study to examine cabin air quality. The NRC convened a Committee on Air Quality in Passenger Cabins of Commercial Aircraft chaired by Morton Lippmann, PhD. of the New York University School of Medicine. The committee reported its findings to the FAA in 2002.<sup>110</sup> The summary of recommendations is as follows<sup>111</sup>:

- Use "quantitative evidence and rationales" to support its existing and proposed regulations related to air quality and change the ventilation standard
- Mandate the use of ozone converters or prohibit flights above 25,000 feet
- Investigate the need for particulate filters and gaseous filtration systems on all aircraft
- Require a CO (carbon monoxide) monitor in the air supply ducts to passenger cabins
- An FAA surveillance program for air quality and health that would provide the data to analyze the relationship between cabin air quality and health effects or complaints
- A range of potential research efforts that would be defined, in part, by the data gathered through surveillance
- Congressional designation of a lead agency and funding for a research program with an independent advisory committee

#### **Conclusions and Recommendations**

The airworthiness requirements should address the design of the cabin air supply system such that it is not prone to contamination from other aircraft systems such as engines and APUs. At the time this evaluation was conducted, EASA has commenced a rulemaking task addressing this subject (Task 25.035).

It is recommended that consideration be given by EASA to providing guidelines for cabin environment and cabin air quality in addition to the current provisions on ventilation rates, carbon dioxide, carbon monoxide, and ozone concentration.

For in-service commercial transport aeroplanes, it is recommended that consideration be given by EASA to assess the need for using cabin air-cleaning equipment (e.g. filters) and the feasibility of such equipment. Liaison with the FAA is strongly recommended.

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at Zurich Airport Bundeshaus
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<sup>&</sup>lt;sup>91</sup> House of Lords (2000) *Science And Technology – Fifth Report,* retrieved from http://www.parliament.thestationery-office.co.uk/pa/ld199900/ldselect/ldsctech/121/12101.htm

<sup>&</sup>lt;sup>92</sup> Aircraft Accident Investigation Bureau AAIB Swiss Confederation, *Final Report No. 1935 by the Aircraft Accident Investigation Bureau concerning the serious incident to the aircraft AVRO 146-RJ100, HB-IXS operated by Swiss European Air Lines under flight number LX 639 on 19 March 2006* 

<sup>93</sup> Aircraft Accident Investigation Bureau AAIB Swiss Confederation, Investigation Report No. u1956 by the Aircraft Accident Investigation Bureau concerning the serious incident to the SAAB 2000 Aircraft, HB-IZZ operated by Darwin Airline under flight number DWT 018 on 17 November 2005 at Lugano Airport, municipality of Agno/TI

Transportation Safety Board of Canada. Aviation Investigation Report A05W0222 . Engine Torching Alaska Airlines Inc. Boeing 737-900 N317AS Calgary International Airport, Alberta 30 October 2005 <sup>95</sup> National Transportation Safety Board, NTSB Identification: FTW03LA132, American Airlines McDonnell

Douglas DC-9-82 (MD-82) registration: N452AA, April 16, 2003, DFW Airport, TX

<sup>96</sup> National Transportation Safety Board, NTSB Identification: NYC03LA016, American Airlines McDonnell Douglas DC-9-82 (MD-82) registration: N452AA, November 09, 2002, Flushing, NY

UK Air Accidents Investigation Branch. AAIB Bulletin No: 4/2007. Ref: EW/C2005/08/10. Bombardier DHC-8-400, G-JECE, 4 August 2005, Near Leeds, West Yorkshire

98 UK Department for Transport, Study of possible effects on health of aircraft cabin environments – Stage 1

(2004) <sup>99</sup> UK Department for Transport, *Study of possible effects on health of aircraft cabin environments – Stage 2* 

(2005) <sup>100</sup> Committee on Air Quality in Passenger Cabins of Commercial Aircraft (2002) *The Airliner Cabin Environment* and the Health of Passenger and Crew. Washington, D.C.: US National Research Council <sup>101</sup> Muir, H., Walton, C., & McKeown, R. (2008) *Cabin Air Sampling Study – Functionality Test, Report prepared* 

for the Department for Transport. Cranfield: Cranfield University <sup>102</sup> BRE Environment (2003) Extending Cabin Air measurements to include older aircraft types utilised in high

volume short haul operation. Watford: BRE Environment

UK Civil Aviation Authority (2004) CAA Paper 2004/04 Cabin Air Quality. Gatwick: UK CAA

<sup>104</sup> Air Quality on Passenger Planes, ASHRAE Journal, September 1999

<sup>105</sup> Muir, H. & Moyle, J.T.B. (2005) *Disruptive Behaviour ("Air Rage"): Possible Aetiology* 

<sup>106</sup> International Civil Aviation Organization, Doc 9481 AN/928, Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods, 2005-2006 Edition (November 2004)

United States General Accounting Office (2003) Aviation Safety - Advancements Being Pursued to Improve Airliner Cabin Occupant Safety and Health, GAO-04-33

<sup>108</sup> Leder, K., & Newman, D. (2005). *Review: Respiratory infections during air travel. Internal Medicine Journal, 35, 50-55.* <sup>109</sup> Australian Transport Safety Bureau (2007) *Aviation Research and Analysis Report AR-2007-050 Final,* <sup>109</sup> Australian Transport Safety Bureau (2007) *Aviation Research and Analysis Report AR-2007-050 Final,* 

<sup>110</sup> Proposed Implementation of Cabin Air Quality Recommendations, retrieved from

http://www.faa.gov/safety/programs\_initiatives/aircraft\_aviation/cabin\_safety/rec impl/

The Airliner Cabin Environment Report Response Team (2002) Report to the Administrator on the National Research Council Report, "The Airliner Cabin Environment and the Health of Passengers and Crew"

## Cabin Safety Threat:

## 13. Future Considerations for Crashworthiness Standards

J06 / Inadequate Crashworthiness Standards for Aeroplanes with Complex Structures (e.g. Double-Deck)

J07 / Inappropriate Crashworthiness Standards for Aeroplanes with Advanced Materials (e.g. All-Composite Structure)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to these threats are as follows:

CS 25.561 General

(a) The aeroplane, although it may be damaged in emergency landing conditions on land or water, must be designed as prescribed in this paragraph to protect each occupant under those conditions.

(b) The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing when –

(1) Proper use is made of seats, belts, and all other safety design provisions;

(2) The wheels are retracted (where applicable); and

(3) The occupant experiences the following ultimate inertia forces acting separately relative to the surrounding structure:

(i) Upward, 3.0g
(ii) Forward, 9.0g
(iii) Sideward, 3.0g on the airframe and 4.0g on the seats and their attachments
(iv) Downward, 6.0g
(v) Rearward, 1.5g (See AMC 25.561 (b) (3).)

There is no further explanation on what constitutes a "minor crash landing".

#### Accident Experience and Safety Recommendations

The accident review carried out in this study did not identify occurrences associated with these cabin safety threats [Inadequate Crashworthiness Standards for Aeroplanes with Complex Structures (e.g. Double-Deck) and/or Advanced Material.]

#### Research and Rulemaking Activities

The VLTA Conference<sup>112</sup> issued a recommendation on the crashworthiness of very large transport aeroplanes:

Definition needed of a minor and/or survivable crash condition. These conditions could be different for different types (size?) of aeroplanes. For all occupants the survivability should have a minimum level, although the intrinsic level could be different for individual occupants. ...

The rationale of this recommendation is that no further details are available for "minor crash conditions" and different interpretations may have been used in the past. Additionally, due to issues such as double decks, lower floor occupancy and larger (more flexible) structures, the crash

conditions might have more influence on the structural design of the aeroplane.

Special Conditions have been used for crashworthiness of the A380-800<sup>113</sup>. In this Special Conditions document, it states:

... neither 14 CFR 25.561 nor any other part 25 requirements address the structural capability of the airframe as a whole in a crash landing. Service experience indicates that - even without specific regulatory requirements - the airframes of conventional transport category airplanes show reasonable structural capability in crash landings. Therefore, in the past we have not considered it necessary to specify design load conditions addressing the structural capability of the airplane as a whole in a crash landing.

The Special Conditions state that the effects of the A380 design on occupant loads are not expected to be significant since it has a large volume that absorbs energy. In order to confirm that this assumption is correct, these special conditions require an assessment of the effect of the design on the occupant loads. An analytical tool (Dynamic Response Index/DRI) is used to make the assessment. The Special Conditions require a vertical crash impact test where it should be shown that:

- Structural deformation will not result in infringement of the occupants' normal living space.
- The occupants will be protected from the release of seats, overhead bins, and other items of mass due to structural deformation of the supporting structure. That is, the supporting structure must be able to support the loads imposed by these items of mass, assuming that they remain attached during the impact event, and the floor structure must deform in a way that would allow them to remain attached.
- The Dynamic Response Index experienced by the occupants will not be more severe than that experienced on conventional large transport airplanes.
- Cargo loading of the fuselage for this evaluation accounts for variations that could have a deleterious effect on structural performance

The FAA has also applied Special Conditions to the Boeing 787-8<sup>114</sup> due to its use of carbon fibre reinforced plastic in the construction of the fuselage. Such structures may behave differently from metallic structure because of the differences in material ductility, stiffness, failure modes, and energy absorption characteristics. The Special Conditions require Boeing to carry out a vertical crash impact test with velocities up to 30ft/sec. The Special Conditions document states that:

If the 787 impact characteristics differ significantly from those of a previously certificated wide body transport, this will result in a need to meet load factors higher than those defined in 14 CFR 25.561. The higher load factors will be necessary in order to maintain the same level of safety for the occupants, in terms of retention of items of mass. In the case of acceleration and loads experienced by the occupants, means would have to be incorporated to reduce load levels experienced by those occupants to the injury criteria levels of Sec. 25.562, or load levels of a previously certificated comparable airplanes, in order to maintain the same level of safety for the occupants.

#### Conclusions and Recommendations

Materials used in the construction of aeroplanes are likely to continually change and current airworthiness requirements do not appear to cater for this. The definition of "minor crash landing" still needs to be developed to ensure the same level of safety for all aeroplanes of different sizes, configuration and materials.

Therefore, it is recommended that consideration be given by EASA to carry out further research into the appropriateness of current crashworthiness standards.

<sup>112</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16

October 1998 <sup>113</sup> Federal Aviation Administration, Special Conditions No. 25-321-SC, Special Conditions: Airbus Model A380-<sup>800</sup> Airplane, Crashworthiness<sup>114</sup> Federal Aviation Administration, Special Conditions No. 25-362-SC, Special Conditions: Boeing Model 787-8

Airplane; Crashworthiness

## Cabin Safety Threat:

## 14. Cabin Crashworthiness

J02 / Detached Cabin/Cockpit Fittings/Equipment during Impact Sequence (hitting occupants)

V06 / Disrupted Cabin (Detached Panels, Stowage etc) Obstructing Evacuation Route

TB01 / Items Falling Out from Overhead Bin during Impact Sequence (hitting occupants)

TB02 / Overhead Bin Detached during Impact Sequence (hitting occupants)

V03 / Cabin Baggage Dislodged from Stowage Positions Obstructing Evacuation Route

TA02 / Items Falling Out of Overhead Bin during Turbulence, Hard Landing, or In-Flight Upset

TA03 / Items Falling Out of Overhead Bin when Opening the Bin

R18 / Overhead Bin Failure due to Stowage of Cabin Baggage Exceeding the Design Limitation of the Stowage Compartment

R17 / Insufficient Protection (of Other Occupants) from Failed Stretchers during Impact Sequence

GB15 / Insufficient Protection from Damaged Large Glass Structure Installed in Passenger Cabins

Y29 / The Nature of Damaged Carbon Fibre Material Increases the Risks of Injuries during Evacuation

## Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to this threat group are as follows:

CS 25.365 For aeroplanes with one or more pressurised compartments the following apply:

(g) Bulkheads, floors, and partitions in pressurised compartments for occupants must be designed to withstand conditions specified in subparagraph (e) of this paragraph. In addition, reasonable design precautions must be taken to minimise the probability of parts becoming detached and injuring occupants while in their seats.

*CS* 25.561(*c*) For equipment, cargo in the passenger compartments and any other large masses, the following apply:

(1) These items must be positioned so that if they break loose they will be unlikely to: (i) Cause direct injury to occupants; (ii) Penetrate fuel tanks or lines or cause fire or explosion hazard by damage to adjacent systems; or (iii) Nullify any of the escape facilities provided for use after an emergency landing.

(2) When such positioning is not practical (e.g. fuselage mounted engines or auxiliary power units) each such item of mass must be restrained under all loads up to those specified in subparagraph (b)(3) of this paragraph. The local attachments for these items should be designed to withstand 1.33 times the specified loads if these items are subject to severe wear and tear through frequent removal (e.g. quick change interior items).

(d) Seats and items of mass (and their supporting structure) must not deform under any loads up to those specified in sub-paragraph (b)(3) of this paragraph in any manner that would impede subsequent rapid evacuation of occupants. (See AMC 25.561(d).)

*CS* 25.785(e) Each berth must be designed so that the forward part has a padded end board, canvas diaphragm, or equivalent means, that can withstand the static load reaction of the occupant when subjected to the forward inertia force specified in *CS* 25.561. Berths must be free from corners and protuberances likely to cause injury to a person occupying the berth during emergency conditions.

*CS* 25.787(a) Each compartment for the stowage of cargo, baggage, carry-on articles and equipment (such as life rafts) and any other stowage compartment must be designed for its placarded maximum weight of contents and for the critical load distribution at the appropriate maximum load factors corresponding to the specified flight and ground load conditions and, where the breaking loose of the contents of such compartments could–

(1) Cause direct injury to occupants;

(3) Nullify any of the escape facilities provided for use after an emergency landing, to the emergency landing conditions of CS 25.561 (b) (3).

(b) There must be a means to prevent the contents in the compartments from becoming a hazard by shifting, under the loads specified in subparagraph (a) of this paragraph. (See AMC 25.787 (b).)

CS 25.789

(a) Means must be provided to prevent each item of mass (that is part of the aeroplane type design) in a passenger or crew compartment or galley from becoming a hazard by shifting under the appropriate maximum load factors corresponding to the specified flight and ground load conditions, and to the emergency landing conditions of CS 25.561(b).

(b) Each interphone restraint system must be designed so that when subjected to the load factors specified in CS 25.561 (b)(3), the interphone will remain in its stowed position.

*CS* 25.1421 If a megaphone is installed, a restraining means must be provided that is capable of restraining the megaphone when it is subjected to the ultimate inertia forces specified in CS 25.561 (b)(3).

FAR 25.787(b) Amendment 25-51 (effective date 3/6/80) has an additional sentence that requires the design of stowage compartments to take into consideration the wear and deterioration expected in service. This is incorporated in AMC 25.787(b) as follows:

AMC 25.787(b) Stowage Compartments

For stowage compartments in the passenger and crew compartments it must be shown by analysis and/or tests that under the load conditions as specified in CS 25.561(b)(3), the retention items such as doors, swivels, latches etc., are still performing their retention function. In the analysis and/or tests the expected wear and deterioration should be taken into account.

## Accident Experience and Safety Recommendations

The following table summarises the findings of the accident review related to this threat group:

THREAT	RELEVANT ACCIDENTS (ADB Ref)	ASSOCIATED INJURIES (WHEN APPLICABLE)
Detached cabin/cockpit fittings/equipment during impact sequence (hitting occupants and/or obstructing evacuation route) The fittings/equipment included: - Panel in cockpit - Emergency exit light - Exit sign battery pack	20051208A 20050802A 20041128A 20020415A 20020114B 20010317A 20001031B 19990923A 19990914A	In accident 19990923A, 3 passengers reported injuries from being struck by Passenger Service Units (PSUs). In accident 19990822A, "many persons sustained lower limb injuries during the evacuation" due to presence of debris and passenger belongings.
<ul> <li>Ventilation grill</li> <li>Curtain rod</li> <li>Passenger Service Units</li> <li>Ceiling panels</li> <li>Oxygen masks</li> <li>Television monitor</li> <li>Air conditioning duct (from ceiling)</li> <li>Handset for PA/interphone system</li> <li>Trolley</li> <li>Passenger seat assembly trim panels</li> <li>Overhead electrical wiring bundles</li> <li>Ceiling liferaft stowage compartment door</li> </ul>	19990822A 19990601A 19980209A	
Items falling out from overhead bin or other stowage during impact sequence, turbulence, hard landing, or in-flight upset (hitting occupants and/or obstructing evacuation route) Such items included: - Luggage - Life jackets - Emergency escape reel in cockpit	20050802A 20041128A 20010419B 19990923A 19990914A 19990822A 19990601A	In accident 19990601A, 1 passenger possibly sustained serious injuries as a result of being struck by luggage. In accident 19990822A, "many persons sustained lower limb injuries during the evacuation" due to presence of debris and passenger belongings.
<ul> <li>Overhead bin detached during impact sequence (hitting occupants)</li> <li>The causes mentioned were: <ul> <li>Overstressed tie rod ends of the overhead bins (mounting rod failure)</li> <li>Locker bracket insert detachments</li> </ul> </li> </ul>	20030117A 20001031B 19990914A 19990601A	3 passengers sustained serious injuries in accident 19990601A.

The safety recommendations relevant to the above threats are as follows:

*REC 29/04. It is recommended that the aircraft manufacturer take measures aimed at ensuring adequate crashworthiness of the B757 passenger service units and exit sign batteries.* (ADB Ref. 19990914A)<sup>115</sup>

REC 23/05. It is recommended to KLM that the ceiling panels of the forward and rear cabin attendant compartments of similar aircraft of their fleet are inspected to ensure that the S-hook of the lanyards is located at the appropriate position in the middle of the lanyard assembly. (ADB Ref. 20041128A)<sup>116</sup>

Directorate General of Air Communications [to] 1. Ensure that the trolley stowage in the cabin [is] strong enough so that the trolley would not [loosen] easily. (ADB Ref. 20020114B)<sup>117</sup>

Based on the circumstances of the evacuation in this accident, the Safety Board recommended that the FAA identify all airplanes operated under Title 14 Code of Federal Regulations Part 121 with liferaft ceiling stowage compartments or compartments that formerly stored liferafts that open downward and issue an airworthiness directive to limit the distance that those compartments can open. (Recommendation A-99-10) (ADB Ref. 19980209A)<sup>118</sup>

The FAA responded favourably to Recommendation A-99-10 by requesting that its aircraft certification office identify airplanes affected by this recommendation and by sending a request to the applicable manufacturers for information regarding the installation of liferaft ceiling stowage compartments. On February 3, 2000, Safety Recommendation A-99-10 was classified "Open - Acceptable Response." Other accident reports mentioned suggestions that were not formulated into safety recommendations:

... in the view of the number of items that were disrupted in the cabin, which could have either caused direct injuries to occupants or to have affected the evacuation rate in the event that a quicker rate had been needed (for example, if there had been fire or panic would have appeared), it was suggested that some additional measures could be taken to better restrain the ceiling panels and the PSU covers. (ADB Ref. 20041128A)<sup>116</sup>

The accident review did not find any occurrence related to stretchers causing injuries in an accident. It is concluded that the risk related to this threat is low.

The accident database used in the study does not contain occurrences where passengers were struck by luggage when opening the overhead bin. There were 35 events describing dislodging of items from overhead bins causing injuries to passengers and cabin crew provided by the UK CAA during the 16th CSSG meeting<sup>119</sup>

#### Research and Rulemaking Activities

#### 1) Cabin disruption

A study by the Transportation Safety Board of Canada<sup>120</sup> found that debris was a significant obstruction to the evacuation process in four of the occurrences reviewed. As a result of debris, escape paths and access to exits were blocked, passenger movement was hindered, and the evacuation process was prolonged. The study cited several accidents where debris and passenger belongings hindered the evacuation.

In a safety study<sup>121</sup>, the NTSB asked passengers and flight attendants in the 30 cases receiving detailed investigations to indicate from a list what hindered the evacuation. 39 passengers and 1 flight attendant mentioned broken interiors and 16 passengers mentioned overhead bins. In general, passengers in the NTSB's study cases were able to access airplane exits without difficulty, except for the Little Rock, Arkansas, accident that occurred on June 1, 1999, in which interior cabin furnishings became dislodged and were obstacles to some passengers' access to exits.

#### 2) Overhead bin safety

A study<sup>122</sup> evaluated 462 occurrences (over an unknown period in the mid-1990s) of falling baggage in B757 aircraft documented by one major US airline, which included 397 incidents in which a person

was struck and 65 in which no one was struck. It was found that the overall injury rate was 30 percent and consisted of bruising and lacerations. Head injuries were the most prevalent. The study claims that head injuries caused by falling objects from overhead bins can lead to brain injuries that can affect patients months after the initial trauma. The study estimates 4,500 incidents of injuries from falling baggage each year in the U.S. and about 10,000 such events worldwide.

An accident to a Boeing 747<sup>123</sup> in 1996 involving an encounter with in-flight turbulence resulted in overhead bins being dislodged and other significant cabin disruption The accident resulted in 9 serious injuries and one fatality.

On 31 May 1996 the International Cabin Crew Association (ICCA) provided guidelines related to carry on baggage to the JAA Headquarters<sup>124</sup>. Among the operational aspects contained in the guidelines (baggage size, check-in procedures, etc), the following are linked to aircraft design and maintenance tasks:

- Installation of safety nets to prevent items falling out
- The checking of locking devices routinely for faults
- Installation of an additional feature to avoid inadvertent opening during take-off, landing and turbulence.

Boeing has carried out stowage bin design enhancements to improve article retention. These include installation of secondary restraint devices on shelf bins such as secondary doors or visors, nets, and deflector panels and thresholds.

It should be noted that current operational regulations only specify the size (hence the volume) of cabin luggage, but not the weight (mass).

Following the 1989 Kegworth B737 accident, the UK Air Accidents Investigation Branch recommended that the performance of both bins and latches be tested more rigorously, including the performance of bins "when subjected to dynamic crash pulses substantially beyond the static load factors currently required".<sup>125</sup> The GAO report<sup>126</sup> mentioned that "suggestions for making bins safer in an accident include adding features to absorb impact forces and keep bins attached and closed during structural deformation; using dynamic 16g longitudinal impact testing standards similar to those for seats; and storing baggage in alternative compartments in the main cabin, elsewhere in the aircraft, or under seats raised for that purpose."

A study carried out for the UK CAA<sup>127</sup> relating to the influence of structural factors on occupant survivability concluded:

"Up to 70% of impact related accidents involve overhead bin detachment. However, it does not appear to be a major factor in terms of occupant survival."

JAA has issued a Draft NPA affecting JAR 25.787(a) and (b), 25.789(a), and JAR 25.1301 on 20 February 2003, proposing the addition of a new ACJ 25.787(a) which contains design aspects of overhead stowage compartments:

Overhead stowage compartments (OSC) closed by a door, in passenger and crew compartments should be designed so as to

- provide a visual indication of the lock/latch position of the door
- provide reliable (tested) means, restraining the maximum placarded baggage weight under the corresponding flight, ground and emergency landing conditions
- have a ramp-type design of the compartment naturally pushing the luggage to the opposite side of the door
- limit the door (not necessarily the compartment) length to a maximum of 40 inches
- provide a pictogram or placard close to the release latch indicating that items may fall out during opening sequence

EASA has issued Terms of Reference No. CS-25/047 dated 08 December 2004, which discusses the transposition of the JAA NPA into EASA NPA. At the time this evaluation was conducted, this EASA NPA has not been issued. A preliminary Regulatory Impact Assessment<sup>128</sup> prepared for EASA, relating to Overhead Bin Safety Precautions, proposed that regulatory action should be taken

to reduce the risk of passengers and crew members sustaining injuries as a result of falling items stowed in Overhead Stowage Compartments. However, the RIA also suggested that: ...a limited study into the economic impact might be considered worthwhile."

There is no rule change planned by the FAA for any aspect of this threat group. The FAA has issued an airworthiness directive to improve bin connectors on Boeing 737 and Boeing 757 aircraft after failures were observed in the 1989 Kegworth B737 accident.

#### 3) Future Considerations

a) Installation of large glass structures inside cabins

The threat related to this cabin feature is the tendency of glass panels to shatter into sharp fragments in the case of failure in flight or in emergency landing conditions. This could either cause injuries to occupants or hinder evacuation. Examples of such structures are: glass partitions, glass attached to the ceiling and wall/door mounted mirrors/glass panels.

The certification for the installation of glass structures inside the cabin is currently addressed by Special Conditions or Certification Review Items (for private use only: FAA Special Conditions No. 25-311-SC for B747-400, Interpretative Material for Tesla Air A330-200). The Special Conditions contained performance standards for large glass structures installed in occupied rooms or areas during taxi, take off, and landing, or rooms or areas that occupants have to enter or pass through to get to any emergency exit. The performance standards specify the material, fragmentation characteristics, strength, and retention. The performance standards, however, do not address failures related to rapid decompression.

b) The nature of damaged carbon fibre material increases the risks of injuries during evacuation

Composite structures that have shattered upon impact are likely to have produced breathable fibres. Released fibres or splinters are needle-sharp, and can cause skin and eye irritation. It is also a respiratory hazard much like asbestos<sup>129</sup>. The extent of the risk related to this threat is unknown. Further research would be required to investigate the risks and identify possible mitigation methods.

#### **Conclusions and Recommendations**

Information on impact loading that occurred in past accidents is not readily available and hence it is difficult to ascertain whether the threats related to cabin disruption could be addressed by amendments to CS-25 requirements. Whilst injury data related to cabin structural integrity is usually available, there are insufficient data to ascertain whether these cabin disruptions have actually hindered evacuation.

Evidence suggests that there is a need to improve the safety standards of overhead bins, which includes crashworthiness (detachment and failure of latches) and design to ensure safety during normal operation. It is therefore recommended that EASA carry out research into the feasibility and cost beneficial aspects of improved design standards for overhead bins, including their attachment and baggage retention both in-flight and post impact. It is also recommended that EASA give consideration to providing design guidelines related to overhead bin safety precautions, as proposed by the JAA in 2003.

Depending on how prevalent the installation of large glass structures in the cabin become, CS-25 may need to be modified to ensure an adequate level of safety. Such structures may be more common in the future with the proliferation of recreational areas in very large transport aeroplanes. At present, certification using Special Conditions (currently limited to aeroplanes for private use only) may be more feasible.

The injury risk related to fibres from damaged composite structures affecting occupants during evacuation has been identified. However, further research will be required to ascertain the extent of this risk and whether it can be mitigated by improvements in airworthiness requirements.

<sup>115</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, *Technical Report A-054/1999*, Accident to Boeing 757-200 G-BYAG at Girona Airport on 14 September 1999

Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, Technical Report A-070/2004, Accident of aircraft Boeing B-737, registration PH-BTC, at Barcelona Airport (Spain), on 28 November 2004 National Transportation Safety Committee, Department of Communications Republic Of Indonesia, Aircraft

Accident Report KNKT/02.01/03.03.011, PT. Lion Air, Boeing 737-200 PK-LID, Sultan Syarif Kasim II Airport, Pekanbaru, Riau, 14 January 2002

<sup>118</sup> National Transportation Safety Board, Aircraft Accident Brief DCA98MA023, American Airlines 1340 Boeing 727-223, N845AA, February 9, 1998, Chicago, Illinois <sup>119</sup> JAA Cabin Safety Study Group – Discussion Paper # 56, Overhead bins safety precaution, Issue 6, Date 14

November 2002

<sup>120</sup> Transportation Safety Board of Canada (1995) A Safety Study of Evacuations of Large, Passenger-Carrying Aircraft, Report Number SA9501 <sup>121</sup> National Transportation Safety Board (2001) Safety Study – Emergency Evacuation of Commercial Airplanes,

NTSB/SS-00/01. Washington D.C.: NTSB

<sup>122</sup> Rozmaryn, L.M., Sporting Goods, Oddly Shaped Items Have Highest Injury Rates in Study of Falling Overhead Baggage, Flight Safety Foundation – Human Factors & Aviation Medicine, Vol. 45 No. 3, May-June

1998 <sup>123</sup> Bureau Enquêtes-Accidents, (1996), F-TF960905, Rapport relatif à l'accident survenu le 5 septembre 1996 Decise 747 400 immatriculé F-GITF exploité par Air France,

JAA Cabin Safety Study Group - Summary Sheet # 56, Overhead bins safety precaution. Issue 7, Date 18 February 2003

Air Accidents Investigation Branch, Aircraft Accident Report No: 4/90. EW/C1095. British Midland Airways Boeing 737-400 G-OBME, 1/2 nm east of East Midlands Airport, 8 January 1989 <sup>126</sup> United States General Accounting Office (2003) Aviation Safety – Advancements Being Pursued to Improve

Airliner Cabin Occupant Safety and Health GAO-04-33, Report to the Ranking Democratic Member, Committee on Transportation and Infrastructure, House of Representatives. Washington, D.C.: US GAO <sup>127</sup> United Kingdom Civil Aviation Authority, Analysis of Structural Factors Influencing the Survivability of

Occupants In Aeroplane Accidents, (1996), CAA Paper 96011. United Kingdom Author

<sup>128</sup> European Aviation Safety Agency, (2006), Preliminary RIA CS-25.047 Overhead Bin Safety Precautions, Germany Author

<sup>129</sup> Australian Transport Safety Bureau (2007) Fibre composite aircraft – capability and safety, AR-2007-021. Canberra: ATSB

## Cabin Safety Threat:

## 15. Inadequate Seat – Floor Strength and Floor Deformation

SB01 / Passenger Seat Displacement/Detachment from Cabin Floor Following Impact

SB04 / Flight Crew Seat Displacement/Detachment from Cabin Floor Following Impact

J01 / Occupants' Crumple Zone Compromised by Cabin Floor Distortion Following Impact

J04 / Flight Crew's Crumple Zone Compromised by Cockpit Floor Distortion Following Impact

## Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to seat-floor strength and floor deformation are as follows:

CS 25.561 General

(a) The aeroplane, although it may be damaged in emergency landing conditions on land or water, must be designed as prescribed in this paragraph to protect each occupant under those conditions.

(b) The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing when –

(1) Proper use is made of seats, belts, and all other safety design provisions;

(2) The wheels are retracted (where applicable); and

(3) The occupant experiences the following ultimate inertia forces acting separately relative to the surrounding structure:

(i) Upward, 3.0g

(ii) Forward, 9.0g

(iii) Sideward, 3.0g on the airframe and 4.0 g on the seats and their attachments

(iv) Downward, 6.0g

(v) Rearward, 1.5g (see AMC 25.561(b) (3).)

(d) Seats and items of mass (and their supporting structure) must not deform under any loads up to those specified in sub-paragraph (b) (3) of this paragraph in any manner that would impede subsequent rapid evacuation of occupants. (See AMC 25.561(d))

There is no further explanation on what constitutes a "minor crash landing".

The AMC states:

AMC 25.561 General

In complying with the provisions of CS 25.561(b) & (c), the loads arising from the restraint of seats and items of equipment etc. should be taken into the structure to a point where the stresses can be dissipated (e.g. for items attached to the fuselage floor, the load paths from the attachments through to the fuselage primary structure should be taken into account).

AMC 25.561(d) - General

For the local attachments of seats and items of mass it should be shown by analysis and/or tests that under the specified load conditions, the intended retaining function in

each direction is still available.

CS 25.562 Emergency landing dynamic conditions

(a) The seat and restraint system in the aeroplane must be designed as prescribed in this paragraph to protect each occupant during an emergency landing condition when –

(1) Proper use is made of seats, safety belts, and shoulder harnesses provided for in the design; and

(2) The occupant is exposed to loads resulting from the conditions prescribed in this paragraph.

(b) **With the exception of flight deck crew seats,** each seat type design approved for occupancy must successfully complete dynamic tests or be demonstrated by rational analysis based on dynamic tests of a similar type seat, in accordance with each of the following emergency landing conditions. The tests must be conducted with an occupant simulated by a 77kg (170 lb anthropomorphic, test dummy sitting in the normal upright position:

(1) A change in downward vertical velocity,  $(\Delta v)$  of not less than 10.7 m/s, (35 ft/s) with the aeroplane's longitudinal axis canted downward 30 degrees with respect to the horizontal plane and with the wings level. Peak floor deceleration must occur in not more than 0.08 seconds after impact and must reach a minimum of 14 g.

(2) A change in forward longitudinal velocity ( $\Delta v$ ) of not less than 13.4 m/s, (44 ft/s) with the aeroplane's longitudinal axis horizontal and yawed 10 degrees either right or left, whichever would cause the greatest likelihood of the upper torso restraint system (where installed) moving off the occupant's shoulder, and with the wings level. Peak floor deceleration must occur in not more than 0.09 seconds after impact and must reach a minimum of 16 g. Where floor rails or floor fittings are used to attach the seating devices to the test fixture, the rails or fittings must be misaligned with respect to the adjacent set of rails or fittings by at least 10 degrees vertically (i.e. out of parallel) with one rolled 10 degrees.

(c) The following performance measures must not be exceeded during the dynamic tests conducted in accordance with sub-paragraph (b) of this paragraph:

(7) The seat must remain attached at all points of attachment, although the structure may have yielded.

(8) Seats must not yield under the tests specified in sub-paragraphs (b)(1) and (b)(2) of this paragraph to the extent they would impede rapid evacuation of the aeroplane occupants.

Flight crew seats are excluded from CS 25.562(b), unlike FAR 25.561(b) requirement below:

(b) **Each seat type design approved for crew or passenger** occupancy during takeoff and landing must successfully complete dynamic tests or be demonstrated by rational analysis based on dynamic tests of a similar type seat, in accordance with each of the following emergency landing conditions. The tests must be conducted with an occupant simulated by a 170-pound anthropomorphic test dummy, as defined by 49 CFR Part 572, Subpart B, or its equivalent, sitting in the normal upright position.

CS 25.785 Seats, berths, safety belts and harnesses

(b) Each seat, berth, safety belt, harness, and adjacent part of the aeroplane at each station designated as occupiable during take-off and landing must be designed so that a

person making proper use of these facilities will not suffer serious injury in an emergency landing as a result of the inertia forces specified in CS 25.561 and CS 25.562.

(f) Each seat or berth, and its supporting structure, and each safety belt or harness and its anchorage must be designed for an occupant weight of 77 kg (170 pounds), considering the maximum load factors, inertia forces, and reactions among the occupant, seat, safety belt, and harness for each relevant flight and ground load condition (including the emergency landing conditions prescribed in CS 25.561). In addition –

(1) The structural analysis and testing of the seats, berths, and their supporting structures may be determined by assuming that the critical load in the forward, sideward, downward, upward, and rearward directions (as determined from the prescribed flight, ground, and emergency landing conditions) acts separately or using selected combinations of loads if the required strength in each specified direction is substantiated. The forward load factor need not be applied to safety belts for berths.

(3) For the determination of the strength of the local attachments (see AMC 25.561(c)) of – (i) Each seat to the structure; and (ii) Each belt or harness to the seat or structure; a multiplication factor of 1.33 instead of the fitting factor as defined in CS 25.625 should be used for the inertia forces specified in CS 25.561. (For the lateral forces according to CS 25.561(b)(3) 1.33 times 3.0 g should be used.)

#### Accident Experience and Safety Recommendations

The accident review found 5 accidents where passenger seats were detached following impact and resulted in at least 11 minor injuries, 28 serious injuries, and 5 fatal injuries. There were 2 accidents where flight crew seats were detached, resulting in 1 minor injury and 1 fatal injury.

## 1) Seat detachment due to cabin floor failure

In the accident cited below, a maximum acceleration of 5.8g during impact was recorded by the flight data recorder. The two sets of seats detached in this accident were on the section of the cabin where the floor deformed.

The aircraft suffered major damage to the upper part of the fuselage, which was broken due to the displacement of the wing that detached from its fittings, moved the ceiling and left a major part of the cabin in the open. The central part of the cabin floor was badly damaged and deformed, causing several seats to detach from the tracks ... Major damage to some parts of the passenger cabin could be noticed, especially between seat rows 1 and 7. The floor was deformed and raised between rows 6 and 8, coincident with the part of the fuselage that ended in the open because the roof moved forward with the wing. The four seats of row 7 were detached. ... according to the information gathered, the first row occupied by passengers during the flight was row 7 (seats 7D and 7F, on the right side). The passenger seated there only suffered minor injuries (ADB Ref. 20030117A)<sup>130</sup>

In the following accident, the seats and the floor structure on which they were mounted have been certificated to withstand the following static decelerations: 4.5g downwards, 9g forward, and 1.5g lateral. The aircraft touched down at peak normal acceleration of 3.11g. There was no acceleration information recorded for the second touchdown following bounce and subsequent impacts. According to the report, most of the disruption was directly attributable to the structural damage on the fuselage.

...the floor beams between Seat Rows 5-7 were fractured on the left side, apparently due to local deformation of the cabin lower sidewall, and the associated floor panels

were appreciably distorted. This created a slope in the floor and areas of unevenness and increased flexibility but did not represent a significant incursion into the cabin space. It did appear to have contributed to the release of a number of seat row attachments. In the area of the rear cabin break the floor suffered local compression buckling and the floor beam at Sta 1200 displaced upwards. This created a steep lateral ridge, approximately 20 inch high on the left and 2 inch high on the right, severely displacing passenger seat rows in the area and causing some to detach.

The floor damage in the forward cabin associated with the fuselage forward break and fuselage deformation caused a number of attachments, or portions of the rails, for seat Rows 4L to 10L to release from the floor, although none of the rows completely detached. On the right hand side, four seat rows were severely damaged and two of these completely detached. At the fuselage rear break four seat rows detached from the floor (Rows 28L, 28R, 29L and 29R). They remained generally in place. Row 29L had been rammed against the forward wall of a toilet unit located immediately behind it and Rows 27L, 28L and 29L had been pushed into contact with each other due to the local concertina effect on the left side of the cabin. (ADB Ref. 19990914A)<sup>131</sup>

## 2) Seats detached at their fixings/seat tracks

In the following accident, considerable structural damage occurred on the fuselage and in the cockpit and passenger cabin, mainly due to the impact with the concrete platform of the upper part of the motorway embankment of between 1.5 and 2.0 metres in height during the final metres of the plane's route on the ground. The passenger seats of the accident aircraft were subjected to emergency landing tests (accelerations of 9g longitudinally and 6g vertically) during the aircraft's certification. Both the passenger cabin and the cockpit were affected by vertical deceleration and the initial impact with the ground in the order of 4g according to the data recorded on the DFDR before this became unusable. In accordance with the structural examination and with some analytical evaluation, it was estimated that some mean maximum longitudinal accelerations were reached in the order of 5.8g, combined with some mean vertical accelerations in the fuselage of 3.59g, which reached extreme values in the cockpit and tail in the order of 14g due to the angular rotation and the final impact with the motorway embankment

The passenger cabin crew, seated at the front right of the passenger cabin and facing backwards, was imprisoned by the rows of front seats, which broke away from their fixings, and the passengers sitting in them. The structural damage of the bottom of the fuselage caused two rows of front seats to break away on the right side and five on the left side, due to the cutting up of the longitudinal beams and connecting angleirons which constitute the bearing structure of the rails to which the seats are anchored. The injured and dead passengers were found seated in the front rows of seats, which had broken away as a result of the deformation and fracturing of the bottom part of the front fuselage. No broken seatbelts were found as a result of the impact. (ADB Ref. 20010829A)<sup>132</sup>

In another accident, a double-seat unit separated from its seat track which was a contributing factor to the death of its occupant. The FDR data shows that the highest normal acceleration recorded was approximately 2.6g during touchdown. The highest lateral acceleration recorded was approximately 0.05g just prior to touchdown. There are no acceleration data of subsequent impacts, which might be higher.

At 1300 hr, the AFC reported that a seat unit, which was later confirmed to be seat 1J and K, was found to be separated from the seat tracks and was lying on the ground immediately beside door R1 partly immersed in water. A passenger, who was certified dead on arrival at hospital, was restrained in seat 1K. The cause of death of the deceased on seat 1K was determined to be drowning. However, traces of sand and grass were also found in his trachea, which suggested that he was knocked unconscious at the time of the accident, but continued to breathe in a mixture of water, sand and grass. (ADB Ref. 19990822A)<sup>133</sup>

In the following accident, the floor was destroyed, affecting seats 17A, 17B, and 18A through F. It should be noted that seats 17B, 18A, and 18B were in the area where the fuselage separated and immediately exposed to lethal impact forces. The accident report states that the accident was not survivable for those passengers seated in that area, and hence were not considered in this evaluation. There is no information on the g forces that occurred in this accident.

Six passengers seated on the left side of the first class section (seats 3A and B, 4A and B, and 5A and B) were ejected in their seats through the large hole. (Five of these six passengers survived.) [In this area, the fuselage sidewall was destroyed]... Seven passengers (seated in 17A and B, 18A and B, and 18D through F) were ejected in their seats into the area between the fuselage sections—aft of row 16 on the left, aft of row 17 on the right, and forward of row 19. (Four of these seven passengers survived.) (ADB Ref. 19990601A)<sup>134</sup>

The seats on the accident aircraft comply with FAA TSO C-39a ("up 4.5g, down 8.1g, side 3.0g, aft 1.5g"). In the Survival Factors Group Chairman's Factual Report of this accident<sup>135</sup>, other seat failures and seat detachments were listed. Below are some of the seat detachments listed:

The seat track was separated at the aft leg attachment on seat 4B. [Seat 3B] was found on the left side of the fuselage approximately 90 feet from its original location in the cabin. Both seat legs were displaced aft and inboard, and the aft track fittings were intact. The aft track fitting lock ring was separated. [Seat unit 5AB] was found on the left side of the fuselage approximately 24 feet from its original location in the cabin. The track lips for the forward and aft seat legs were damaged. The outboard track was damaged at the interface of the aft seat fitting, and the track had separated at the forward seat leg fitting. [Seat unit 7AB] legs were separated from the seat tracks, the floor beneath seat unit 7AB was buckled. [Seat unit 8AB] was separated from the seat tracks. [Seats 28AB, 28DEF, 29DEF, 30DEF] forward and aft seat legs were separated from the seat track.

## 3) Flight crew seats and floor strength

There were two accidents where flight crew seats were detached from their fixings on the floor, which might have contributed to 1 minor injury and 1 fatal injury:

Both seats experienced high vertical forces during the event. The captain seat was displaced from its normal position. The floor of the seat base had fractured, allowing the chair to detach from the base. The nut attaching the centre screw to the bottom of the base on the first officer seat had pulled through the retainer. The force necessary to pull the nut through the retainer was mathematically calculated. It was determined that a vertical acceleration of a minimum of 16 g was likely reached before the seat broke. The seats were designed to withstand 5.7 g vertically and 9 g longitudinally. (ADB Ref. 20050802A)<sup>136</sup>

In addition the crumpling of the fuselage at rib F10 compressed the pilots' seats towards the front, to a greater extent the captain's seat on the left. The pilot's seat had broken one of its four floor-fixings. [Findings:] 9. The flight crew seats are certified to a lower standard than the cabin seats, which may have been a factor in the injuries incurred by the captain. ... The breaking and cutting up of the front lower part of the fuselage did not reach the floor of the cockpit, but due to the crumpling and compression towards the back by that final impact, the cockpit space was affected in the longitudinal and vertical direction, imprisoning the lower limbs of the pilots against the front instrument panel. (ADB Ref. 20010829A)<sup>132</sup> – The forces in this accident are described earlier in this section. In this accident, the flight deck floor was deformed.

In the following accident, the flight deck floor was deformed and displaced the first officer's seat:

The flight deck remained undamaged, with the exception of fracturing and deformation of the floor on the right side and some floor deformation at the rear. [The First Officer's] seat had been displaced as a result of cockpit floor deformation and he had some difficulty in locating the required switches in the darkness. (ADB Ref. 19990914A)<sup>131</sup>

#### **Research and Rulemaking Activities**

## 1) Seat-floor strength and floor deformation

Improving the ability of aeroplane floors to retain seats during an accident is one of the "Potential Impact Safety Advancements" identified by the US General Accounting Office (GAO). The report cited the Kegworth B737 accident, where only 21 of the 52 "16g-compatible" triple seats remained fully attached to the cabin floor; 14 of those that remained attached were in the wing spar area where the floor structure is stronger<sup>137</sup>. The Air Accidents Investigation Branch found that: "*There is considerable potential for improving the survivability of passengers in this type of impact by improving the structural integrity of the cabin floor so as to retain the seats in their relative positions and by detail design improvements to the seats themselves." <sup>138</sup> The safety recommendations issued to address this are as follows:* 

4.26 The certification requirements for cabin floors of new aircraft types should be modified to require that dynamic impulse and distortion be taken into account and these criteria should be applied to future production of existing designs (Made 30 March 1990).

4.27 The CAA should initiate research, in conjunction with the European airworthiness authorities, into the feasibility of a significant increase in cabin floor toughness beyond the level of the current JAR/FAR seat requirements (Made 30 March 1990).

The GAO report stated that several reports have recommended structural improvements to floors, which included:

- A case study of 11 major accidents in which it was found that floor issues were a major cause of injury or fatalities in 4 accidents and a minor cause in 1 accident.
- A benefit analysis<sup>139</sup> carried out for FAA and CAA estimated the past benefits of 16g seats in U.S. accidents between 1984 and 1998 and found no hypothetical benefit from 16g seats in a number of accidents because the floor was extensively disrupted during impact. The study stated that "Due to the extensive disruption to the floor during the impact sequence, a number of accidents analyzed would not have any potential for lives being saved with the introduction of 16-g seats."

A study sponsored by the French civil aviation authority (DGAC)<sup>140</sup> recommended future research on the resistance of the floor by considering location of the seat on cabin floor, stiffer seats to introduce higher loads into the structure and possible warpage.

'Seat – Floor Strength' is one of the proposed new initiatives for research projects by JAA, listed to assist the transition to EASA. The objective is to look at structural design to ensure retention of seats in seat tracks. However, FAA officials said have they have no plans to change floor strength requirements<sup>137</sup>.

## 2) Flight deck floor deformation

Flight crew seats are not required to be subjected to the dynamic tests set out in CS 25.562(b). Although FAR 25.562(b) still includes flight crew seats, as many as 20 Exemptions were issued by the FAA (12 granted, 6 partially granted, 2 denied) permitting a relief from floor warpage testing requirements for flight crew seats. They are primarily for large transport aeroplanes. The argument was that floor warpage has not been a significant factor in flight deck seat detachment during survivable crash conditions. In the ELOS, it was stated that "the FAA now considers that requiring testing of pilot seats with floor warpage cannot be justified on narrow body and larger airplanes. The FAA is currently developing a proposal to amend the regulations accordingly".

#### **Conclusions and Recommendations**

Although the 16g seat requirement would improve attachment of seats to the floor tracks, inadequate cabin floor strength may reduce the benefits of the improved seats. Current CS-25 and FAR 25 requirements state that floors have to be able to withstand impact forces likely to occur in "emergency landing conditions," (i.e. 9g of longitudinal static load). Stronger floors may improve the performance of 16g seats and further enhancements to those seats would likely require improved floor strength.

Further research on structural design that can ensure retention of seats, in line with 16g-seat requirements, may be required. Additionally, it is recommended that consideration be given to reviewing the requirement 25.562(b) that excludes flight crew seats.

<sup>&</sup>lt;sup>130</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, *Technical Report A-002/2003,* Accident of aircraft Fokker 50. registration PH-FZE, at Melilla Airport (Spain), on 17 January 2003

Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, Technical Report A-054/1999, Accident to Boeing 757-200 G-BYAG at Girona Airport on 14 September 1999

<sup>&</sup>lt;sup>2</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, translated from Informe Técnico A-048/2001, Accidente ocurrido el día 29 de agosto de 2001 a la aeronave CASA CN-235 matricula EC-FBC, en Ias proximidades del Aeropuerto de Málaga (Málaga)
 <sup>133</sup> Accident Investigation Division – Civil Aviation Department Hong Kong, Aircraft Accident Report 1/2004,

Report on the accident Boeing MD11 B-150 at Hong Kong International Airport on 22 August 1999 <sup>134</sup> National Transportation Safety Board, Aircraft Accident Report, Runway Overrun During Landing – American

Airlines Flight 1420, McDonnell-Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999

<sup>&</sup>lt;sup>135</sup> National Transportation Safety Board, Survival Factors Group Chairman's Factual Group Report, Accident DCA99MA060, Little Rock Arkansas, June 1, 1999, American Airlines, McDonnell Douglas MD-82 N215AA Transportation Safety Board of Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire,

Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005 <sup>137</sup> United States General Accounting Office (2003) Aviation Safety – Advancements Being Pursued to Improve

Airliner Cabin Occupant Safety and Health GAO-04-33, Report to the Ranking Democratic Member, Committee on Transportation and Infrastructure, House of Representatives. Washington, D.C.: US GAO <sup>138</sup> UK Air Accidents Investigation Branch, Aircraft Accident Report No. 4/90 (EW/C1095), British Midland

Airways Ltd, Boeing 737-400 G-OBME, 1/2 nm east of East Midlands Airport

<sup>&</sup>lt;sup>139</sup> Cherry, R., Warren, K. & Chan, A. (2000) Benefit Analysis for Aircraft 16-g Dynamic Seats, Final Report, U.S. Department of Transportation (DOT/FAA/AR-00/13) and UK Civil Aviation Authority (CAA Paper 99003). Washington D.C./London: FAA/UK CAA

<sup>&</sup>lt;sup>140</sup> Gallard, J.P., Dusigne, M. & Malherbe, B. (1999) Research Program For Civil Aviation Seat Floor Attachment Strength, Final Synthesis, Test Report N°S00/5802000/F/A. Toulouse: CEAT

## Cabin Safety Threat:

## 16. Restraint Systems and Injury Criteria

GB01 / Insufficient Flight Crew Protection against Impact with Flight Deck Components

GB05 / Difficulty in Releasing Seatbelt

GB06 / Releasing Seatbelt under Abnormal Fuselage Orientation

GB10 / Seatbelt Failure during Impact Sequence

GA11 / Seatbelt Failure during Turbulence/Extreme Flight Manoeuvre

GB09 / Risks Related to Unavailability or Inadequate Child Restraint Systems

GB19 / Unavailable or Inadequate Restraint Systems for Disabled Passengers

GB16 / Head Impact Injuries to Passenger behind Interior Cabin Wall

GB11 / Lower Limb Injuries Sustained during Impact Sequence

GB12 / Insufficient Occupant Impact Protection Related to Non-forward Facing Seats (Side-Facing, angular) - Multiple and Single Seating

GB14 / Insufficient Occupant Impact Protection Related to Face-to-Face Seating arrangement

GB18 / Insufficient Occupant Impact Protection Related to Stacked Seating

GB17 / Outdated Occupant Injury Criteria

## Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to this threat group are as follows:

CS 25.561

(b) The structure must be designed to give each occupant every reasonable chance of escaping serious injury in a minor crash landing when –

(1) Proper use is made of seats, belts, and all other safety design provisions;

CS 25.562

(a) The seat and restraint system in the aeroplane must be designed as prescribed in this paragraph to protect each occupant during an emergency landing condition when –

(1) Proper use is made of seats, safety belts, and shoulder harnesses provided for in the design; and

(2) The occupant is exposed to loads resulting from the conditions prescribed in this paragraph.

b) With the exception of flight deck crew seats, each seat type design approved for occupancy must successfully complete dynamic tests or be demonstrated by rational analysis based on dynamic tests of a similar type seat, in accordance with each of the following emergency landing conditions. The tests must be conducted with an occupant simulated by a 77kg (170 lb anthropomorphic, test dummy sitting in the normal upright position:

(1) A change in downward vertical velocity,  $(\Delta v)$  of not less than 10•7 m/s, (35 ft/s) with the aeroplane's longitudinal axis canted downward 30 degrees with respect to the horizontal plane and with the wings level. Peak floor deceleration must occur in not more than 0•08 seconds after impact and must reach a minimum of 14 g.

(2) A change in forward longitudinal velocity ( $\Delta v$ ) of not less than 13•4 m/s, (44 ft/s)

with the aeroplane's longitudinal axis horizontal and yawed 10 degrees either right or left, whichever would cause the greatest likelihood of the upper torso restraint system (where installed) moving off the occupant's shoulder, and with the wings level. Peak floor deceleration must occur in not more than 0•09 seconds after impact and must reach a minimum of 16 g. Where floor rails or floor fittings are used to attach the seating devices to the test fixture, the rails or fittings must be misaligned with respect to the adjacent set of rails or fittings by at least 10 degrees vertically (i.e. out of parallel) with one rolled 10 degrees.

(c) The following performance measures must not be exceeded during the dynamic tests conducted in accordance with sub-paragraph (b) of this paragraph:

(1) Where upper torso straps are used tension loads in individual straps must not exceed 794 kg.(1750lb) If dual straps are used for restraining the upper torso, the total strap tension loads must not exceed 907kg (2000 lb)).

(2) The maximum compressive load measured between the pelvis and the lumbar column of the anthropomorphic dummy must not exceed 680 kg. (1500lb)

(3) The upper torso restraint straps (where installed) must remain on the occupant's shoulder during the impact.

(4) The lap safety belt must remain on the occupant's pelvis during the impact.

(5) Each occupant must be protected from serious head injury under the conditions prescribed in sub-paragraph (b) of this paragraph. Where head contact with seats or other structure can occur, protection must be provided so that the head impact does not exceed a Head Injury Criterion (HIC) of 1000 units. The level of HIC is defined by the equation –

HIC = 
$$\left\{ (t_2 - t_1) \left[ \frac{1}{(t_2 - t_1)} \int \frac{t_2}{t_1} a(t) dt \right]^{2.5} \right\}_{max}$$

Where –

t1 is the initial integration time,
t2 is the final integration time, and
a(t) is the total acceleration vs. time curve for the head strike, and where
(t) is in seconds, and (a) is in units of gravity (g).

(6) Where leg injuries may result from contact with seats or other structure, protection must be provided to prevent axially compressive loads exceeding 1021 kg (2250 lb) in each femur.

#### CS 25.785

(b) Each seat, berth, safety belt, harness, and adjacent part of the aeroplane at each station designated as occupiable during take-off and landing must be designed so that a person making proper use of these facilities will not suffer serious injury in an emergency landing as a result of the inertia forces specified in CS 25.561 and CS 25.562.

(d) Each occupant of a seat (see AMC 25.785(d)) that makes more than an 18-degree angle with the vertical plane containing the aeroplane centreline must be protected from head injury by a safety belt and an energy absorbing rest that will support the arms, shoulders, head and spine, or by a safety belt and shoulder harness that will prevent the head from contacting any injurious object. Each occupant of any other seat must be protected from head injury by a safety belt and, as appropriate to the type, location, and angle of facing of each seat, by one or more of the following:

(1) A shoulder harness that will prevent the head from contacting any injurious object.

(2) The elimination of any injurious object within striking radius of the head.

(3) An energy absorbing rest that will support the arms, shoulders, head and spine.

(e) Each berth must be designed so that the forward part has a padded end board, canvas diaphragm, or equivalent means, that can withstand the static load reaction of the occupant when subjected to the forward inertia force specified in CS 25.561. Berths must be free from corners and protuberances likely to cause injury to a person occupying the berth during emergency conditions.

(f) Each seat or berth, and its supporting structure, and each safety belt or harness and its anchorage must be designed for an occupant weight of 77 kg (170 pounds), considering the maximum load factors, inertia forces, and reactions among the occupant, seat, safety belt, and harness for each relevant flight and ground load condition (including the emergency landing conditions prescribed in CS 25.561). In addition –

(1) The structural analysis and testing of the seats, berths, and their supporting structures may be determined by assuming that the critical load in the forward, sideward, downward, upward, and rearward directions (as determined from the prescribed flight, ground, and emergency landing conditions) acts separately or using selected combinations of loads if the required strength in each specified direction is substantiated. The forward load factor need not be applied to safety belts for berths.

(3) For the determination of the strength of the local attachments (see AMC 25.561(c)) of – (i) Each seat to the structure; and (ii) Each belt or harness to the seat or structure; a multiplication factor of 1•33 instead of the fitting factor as defined in CS 25.625 should be used for the inertia forces specified in CS 25.561. (For the lateral forces according to CS 25.561(b)(3) 1•33 times 3•0 g should be used.)

(g) Each crewmember seat at a flight-deck station must have a shoulder harness. These seats must meet the strength requirements of subparagraph (f) of this paragraph, except that where a seat forms part of the load path, the safety belt or shoulder harness attachments need only be proved to be not less strong than the actual strength of the seat. (See AMC 25.785 (g).)

(h) Each seat located in the passenger compartment and designated for use during take-off and landing by a cabin crewmember required by the Operating Rules must be –

(6) Equipped with a restraint system consisting of a combined safety belt and shoulder harness unit with a single point release. There must be means to secure each restraint system when not in use to prevent interference with rapid egress in an emergency.

(i) Each safety belt must be equipped with a metal-to-metal latching device.

EU-OPS 1.320 Seats, safety belts and harnesses

2. An operator shall make provision for, and the commander shall ensure that multiple occupancy of aeroplane seats may only be allowed on specified seats and does not occur other than by one adult and one infant who is properly secured by a supplementary loop belt or other restraint device.

ACJ OPS 1.730(a)(3) within TGL-44 contains guidance material for child restraint devices and addresses their acceptability (which includes supplementary loop belts), references to other standards, location, installation, and operation.

The FAA however does not require child restraint devices:

Sec. 121.311(b): ... Notwithstanding the preceding requirements, a child may:

(1) Be held by an adult who is occupying an approved seat or berth, provided the child has not reached his or her second birthday and the child does not occupy or use any restraining device; or

(2) Notwithstanding any other requirement of this chapter, occupy an approved child restraint system furnished by the certificate holder or one of the persons described in paragraph (b)(2)(i) of this section ...

## Accident Experience and Safety Recommendations

The accident review only identified issues related to safety belts and did not find occurrences associated with other threats addressed in this group. This does not necessarily mean that occupant injuries relating to other impact protection issues did not occur. Identification, of such issues, is difficult since detailed impact injury information in accident reports is often minimal.

The following issues were identified during the accident review:

- Difficulty in releasing seatbelt was found in 2 accidents (19990822A<sup>141</sup>, 19990601A<sup>142</sup>). In 19990601A one passenger had difficulty because she was trying to open it in the manner of an automobile seat belt. In 19990822A the aircraft was inverted and this resulted in passengers experiencing difficulties in releasing the seatbelts. The restraining effect of the seatbelts, and of unfastening them and falling to the ceiling from the inverted position, appears to be consistent with the reports of persons suffering from injuries to the neck, shoulder, back, chest, ribs, waist, hip, pelvis or buttocks.
- Failure of seatbelts during the impact sequence was found in 1 accident (19980209A<sup>143</sup>) two passengers were involved, one of which sustained minor injuries. Failure of seatbelts during turbulence was found in 1 accident (19980418A<sup>144</sup>) two passengers were involved and both received serious injuries. The causes of these failures were undetermined but are considered as isolated cases.
- Flight crew seat belts not providing adequate protection against impact with flight deck components was found in 1 accident (19990914A<sup>145</sup>). The commander was rendered unconscious during the ground run when his head struck the unpadded frame of the flight deck windshield. The recommendation issued was as follows:

REC 28/04. It is recommended that the FAA require the B757 aircraft manufacturer to take measures aimed at improving the protection of flight crew members subjected to inertial loading while restrained by their harness, against impact with flight deck components, with the shoulder harness selected to either <<lock>> or <<manual>>.

## **Research and Rulemaking Activities**

## 1) Non-conventional seats

## a) Side facing seats (single- and multiple-place)

A study carried out for Transport Canada<sup>146</sup> found that multiple-place side-facing seats are the most frequent subject of application for Exemptions on smaller transport aeroplanes (less than 60 seats passenger capacity). These seats are essentially related to corporate/executive interior configurations, which can involve both large and smaller transport aeroplanes.

The installation of multiple-place side-facing seats is addressed in the FAA SFAR No. 109 'Special Requirements for Private Use Transport Category Airplanes', which adopts the latest FAA policy on this subject. The FAA has not been able to define criteria for multiple-place side-facing seats and therefore, installation of such seats in non-private use operation will still need to be addressed with Exemptions. EASA has been addressing such seats by issuing Deviations.

Single-place side-facing seats are not addressed by Exemptions or Deviations; they are addressed by Special Conditions instead. This is because the criteria are considered to provide the same level of safety for occupants of single-place side-facing seats as that of forward or aft-facing seats. The review found six FAA Special Conditions that addressed single-place side-facing seats.

#### b) Face-to-face seating arrangement

This threat was identified during the brainstorming session. No research on this subject was identified. The Cabin Safety Study Group is of the opinion that it is "unacceptable to accept injuries for face-to-face seating arrangement". JAA had been in the process of developing a proposed NPA on this subject.

## c) Stacked seating

This type of seating consists of "bunk-beds" stacked from floor to ceiling. The bunk beds would be transformed from seats after takeoff. The intention of such a configuration is to introduce an "economy sleeper cabin" specifically on long-haul flights<sup>147</sup>. It is understood that currently, stacked seating is a still at a conceptual stage.

## 2) Restraint systems

## a) Child restraint systems

The supplementary loop belt – a length of seatbelt webbing with two loops that is installed over a seatbelt – is considered an acceptable child restraint system in ACJ OPS 1.730(a)(3) and is used in some European countries. It is understood that the United States, Canada, and Germany have already banned the use of supplemental loop belts. This difference in legislation has created confusion for passengers and difficulties to operators of international flights.

The supplementary loop belt will provide some restraint to an infant during turbulence or mild longitudinal emergency loading such as a rejected take off. However, research carried out for the ATSB<sup>148</sup> found that it offers no protection to the infant in a severe forward deceleration: "*Although retained during dynamic testing, the infant dummy underwent significant forward excursion resulting in severe impact of the dummy's head with the forward seat back. In addition, the adult dummy folded over the infant trapping and crushing it in the process.*" It is even less effective for a new-born infant as their skeletal structure would be unable to cope with any significant load from the 5 cm wide webbing<sup>149</sup>. This is consistent with dynamic testing carried out by the FAA Civil Aerospace Medical Institute (CAMI)<sup>150</sup>. Excessive abdominal pressure from the belt was also recorded on the child test dummy.

The Kegworth (UK) accident (8 January 1989)<sup>151</sup> provided clear evidence of the inadequate level of protection afforded by supplemental loop belts. In this accident, one infant and his mother suffered fatal injuries which were more severe than those sustained by occupants of neighbouring seats. The infant was restrained by a supplemental loop belt with his mother. The pertinent finding and recommendation of the accident investigation are as follows:

The injuries to the mother and child in seat 3F highlighted the advantages of infants being placed in child seats rather than in a loop-type supplementary belt.

[It is recommended that:] The CAA implement a programme to require that all infants and young children, who would not be safely restrained by supplementary or standard lap belts, be placed in child-seats for take-off, landing and flight in turbulence. (Made 30 March 1990, amended 8 August 1990)

A JAA Working Group has carried out work on Child Restraint Systems (CRS) primarily on guidance material and the development of JTSO material. The EASA standards defining the approval criteria for Child Restraint Devices are included in ETSO-C100b, which is technically similar to the FAA TSO C100b. However, the FAA has developed a revision to this standard - TSO-C100c. One particular concern of the JAA Working Group was the adequacy of

the supplementary loop belt. The Child Restraint WG agreed that it should be replaced by a system that gives infants the same level of protection as adults and the legal rights to demand it<sup>152</sup>. The WG would consider recommending banning the use of loop belts, as the improved Guidance Material provides an alternative to the loop belt thereby providing the authorities with justification to prohibit its use.

## b) Disabled passenger restraint systems

This issue was identified during the brainstorming session. No research or rulemaking activities associated with this issue have been identified.

## c) Inflatable restraint systems

Nine Special Conditions have been issued by the FAA over the period 2000-2008 regarding the certification of inflatable lapbelts (B777, Jetstream 4101, CL-600-2C10 and A318/A319/A320/A321). Inflatable lapbelts are the most frequent subject of FAA Special Conditions (relating to Cabin Safety). The Special Conditions were issued for lapbelts used for single-place side-facing seats and seats behind cabin bulkheads. A study also found that inflatable restraints could mitigate most injury risks faced by passengers in multiple-place side-facing seats<sup>153</sup>.

The Special Conditions address situations relating to inflatable lapbelts that must be considered (e.g. a child, a pregnant woman, a passenger holding an infant), airbag failures, inadvertent airbag deployment, influence on occupant egress, wear and tear, protection from HIRF and lightning, power supply, release of hazardous gas/particulate matter, protection from fire, means for cabin crew to verify the integrity of the activation system, and flammability requirements.

In a 2003 article<sup>154</sup>, BAE Systems estimated that by the end of 2003, 18 airlines would be flying with approximately 2,600 seats equipped with the inflatable lapbelt. The system is very desirable for airlines as seating capacity can be safely increased by its installation on bulkhead-facing seat rows. On one configuration of the Airbus A340-600, 18 additional seats could be installed by using inflatable lapbelts.

## d) Lower limb restraint systems

Injuries to lower limbs due to impact are not necessarily fatal, but they are likely to immobilise passengers, which can be particularly critical in accidents involving fire or smoke requiring evacuation of the cabin. 'Lower limb restraint system' was one of JAA's 'proposed new initiatives for research projects'.

The European Transport Safety Council (ETSC) recommended research to be carried out in order to determine the impact load tolerance of the lower body, with particular attention to leg fracture loads<sup>155</sup>. The ETSC states that FAA, CAMI and the National Highway Traffic Safety Administration (NHTSA) have proposed to set up a data collection initiative on human impact tolerance of the lower body.

A study on injury prevention in transport aviation accidents<sup>156</sup> reviewed 11 transport category aircraft accidents that occurred between 1985 and 1994 and found that lower-extremity injuries were extensive in many of the partially survivable accidents reviewed. It was stated that "*Injury mechanisms included the "kick-up" type of injury where the tibia and fibula impacted the seat in front as legs flailed, pelvic injury from the occupant's femur being driven back into the pelvis following knee impact with the seat in front, and femur fractures from bending moments generated as the occupant was loaded down and forward across the front seat tube." The recommendation of this research did not address lower limb restraint systems. It recommended research on the potential lower-extremity injury patterns with 16-G seating, and revision of the performance and design standards so that lower-extremity injury risk is appropriately assessed and mitigated.* 

## e) Difficulty in releasing seatbelts

An FAA study examined the effects of lift latch release angles to egress time and found them to be

negligible<sup>157</sup>. However, the study did not address the difficulty in releasing the belt if the occupant was in a folded posture due to post crash injuries, debris, or aircraft inversion. It is stated that such scenarios could make it difficult to release a high-angle buckle due to interference with the abdomen.

#### **Conclusions and Recommendations**

Single-place side-facing seats are no longer exclusive to private-use aeroplanes and such seating has been addressed by Special Conditions. It is likely that the installation of such seating will increase in the future and hence CS-25 may need to accommodate this. Liaison with the FAA on any future rulemaking on this subject is recommended.

FAA SFAR 109 addresses the installation of multiple-place side-facing seats on private use aeroplanes. Since EASA has no equivalent of an FAA SFAR, consideration should be given to developing a means for adopting the contents of SFAR 109 into the airworthiness requirements to reduce certification costs for private use aeroplanes incorporating multiple-place side-facing seats.

It is recommended that the EASA continue to develop standards defining the approval criteria for Child Restraint Devices (as ETSO-C100b) taking into account the new FAA TSO-C100c. Consideration should also be given to banning the use of supplementary loop belts, especially since conflicting legislation has been posing problems in international air operations.

Inflatable lapbelts are increasingly used in Transport Category Aeroplanes and currently they require Special Conditions for their certification. It is recommended that consideration be given by EASA to establish the standards for such equipment, possibly in CS-ETSO, to ensure that they provide at least the same level of safety as conventional seatbelts or any configurations replaced by such systems (e.g. minimum distance or padding for seats behind bulkhead).

Further research is required to investigate the mechanism of lower limb injuries during impact, taking into consideration the latest requirements for occupant protection (seats, restraint systems, etc), in order to ascertain the need for addressing lower limb injury criteria in CS-25.

Although some issues in releasing the seat belts have been identified, there is currently no evidence that they present a high safety risk. No recommendation has been made on this subject.

<sup>&</sup>lt;sup>141</sup> Accident Investigation Division – Civil Aviation Department Hong Kong, Aircraft Accident Report 1/2004, Report on the accident Boeing MD11 B-150 at Hong Kong International Airport on 22 August 1999

<sup>&</sup>lt;sup>142</sup> National Transportation Safety Board, Aircraft Accident Report, Runway Overrun During Landing – American Airlines Flight 1420, McDonnell-Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999

<sup>&</sup>lt;sup>143</sup> National Transportation Safety Board, Aircraft Accident Brief DCA98MA023, American Airlines 1340 Boeing 727-223, N845AA, February 9, 1998, Chicago, Illinois

<sup>&</sup>lt;sup>144</sup> National Transportation Safety Board, NTSB Identification: NYC98FA094, Tower Air B747-200 registration: N623FF, April 18, 1998, Over Atlantic Ocean

<sup>&</sup>lt;sup>145</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, Technical Report A-054/1999,

Accident to Boeing 757-200 G-BYAG at Girona Airport on 14 September 1999 <sup>146</sup> RGW Cherry & Associates Limited (2006). An Evaluation of Equivalent Levels of Safety Findings and Exemptions Relating to Cabin Safety Regulations for Smaller Transport Aeroplanes, 0945/R/000343/KK, Prepared for Transport Canada.

Welcome to sardine air: Airline introduces triple bunk beds in economy, MailOnline, 07 August 2007 <sup>148</sup> Gibson, T., Thai, K. & Lumley, M. (2006). *Child Restraint in Australian Commercial Aircraft, Aviation Safety* 

Research Grant Report B2004/0241. Canberra: ATSB <sup>149</sup> Civil Aviation Safety Authority Australia. Civil Aviation Advisory Publication AAP 235-2(1) Carriage and

restraint of small children in aircraft. December 2002 <sup>150</sup> DeWeese, R. & Gowdy, V. (1994). The Performance of Child Restraint Devices in Transport Airplane Passenger Seats. Washington, D.C.: FAA

<sup>151</sup> Air Accidents Investigation Branch, *Aircraft Accident Report No: 4/90, EW/C1095, British Midland Airways* Boeing 737-400 G-OBME, ½ nm east of East Midlands Airport, 8 January 1989

<sup>152</sup> JAA Cabin Safety Study Group Summary Sheet #77, Child Restraint Systems Issue 11, dated June 2003 <sup>153</sup> DeWeese, R. & Moorcroft, D. (2007). Assessment of Injury Potential in Aircraft Side-Facing Seats Using the

ES-2 Anthropomorphic Test Dummy, DOT/FAA/AM-07/13. Washington, D.C.: FAA <sup>154</sup> Inflatable Restraints Installed on Some Transport Aircraft, Flight Safety Foundation – Cabin Crew Safety, Vol. 38 No. 4, July-August 2003

<sup>38</sup> No. 4, July-August 2003
 <sup>155</sup> European Transport Safety Council (1996). Increasing the Survival Rate in Aircraft Accidents - impact protection, fire survivability and evacuation. Brussels: ETSC
 <sup>156</sup> Grierson, A.E. & Jones, L.E. (2001). Recommendations for Injury Prevention in Transport Aviation

 <sup>156</sup> Grierson, A.E. & Jones, L.E. (2001). *Recommendations for Injury Prevention in Transport Aviation* Accidents, 2001-01-2658.
 <sup>157</sup> DeWeesse, R. & Cowdy, M. (2000). *Human Factors* for the statistical states of the states of

<sup>157</sup> DeWeese, R. & Gowdy, V. (2002) *Human Factors Associated With the Certification of Airplane Passenger Seats: Seat Belt Adjustment and Release, DOT/FAA/AM-02/11.* Washington, D.C.: FAA

## Cabin Safety Threat:

# 17. Optimum Ditching Parameters Cannot Be Achieved Under Certain Emergency Conditions (N01)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

Ditching crashworthiness is addressed in CS 25.563 (not a Cabin Safety requirement), CS 25.561(a), and CS 25.801, as follows:

CS 25.561(a)

The aeroplane, although it may be damaged in emergency landing conditions on land or water, must be designed as prescribed in this paragraph to protect each occupant under those conditions.

CS 25.563 Structural ditching provisions

Structural strength considerations of ditching provisions must be in accordance with CS 25.801 (e).

CS 25.801 Ditching

(a) If certification with ditching provisions is requested, the aeroplane must meet the requirements of this paragraph and CS 25.807(e), 25.1411 and 25.1415(a).

(b) Each practicable design measure, compatible with the general characteristics of the aeroplane, must be taken to minimise the probability that in an emergency landing on water, the behaviour of the aeroplane would cause immediate injury to the occupants or would make it impossible for them to escape.

(c) The probable behaviour of the aeroplane in a water landing must be investigated by model tests or by comparison with aeroplanes of similar configuration for which the ditching characteristics are known. Scoops, wing-flaps, projections, and any other factor likely to affect the hydrodynamic characteristics of the aeroplane, must be considered.

(d) It must be shown that, under reasonably probable water conditions, the flotation time and trim of the aeroplane will allow the occupants to leave the aeroplane and enter the life rafts required by CS 25.1415. If compliance with this provision is shown by buoyancy and trim computations, appropriate allowances must be made for probable structural damage and leakage. If the aeroplane has fuel tanks (with fuel jettisoning provisions) that can reasonably be expected to withstand a ditching without leakage, the jettisonable volume of fuel may be considered as buoyancy volume.

(e) Unless the effects of the collapse of external doors and windows are accounted for in the investigation of the probable behaviour of the aeroplane in a water landing (as prescribed in subparagraphs (c) and (d) of this paragraph), the external doors and windows must be designed to withstand the probable maximum local pressures.

#### Accident Experience and Safety Recommendations

The accident review found two accidents where the crew could not execute the prescribed aircraft configuration to ensure successful ditching, which resulted in structural failures that did not allow sufficient time for the occupants to evacuate. Both aircraft were Shorts Brothers SD3-60. Extracts from the accident reports are as follows:

The flight crew ditched the aircraft in shallow water in the Firth of Forth, close to the shoreline. The aircraft was severely damaged on impact with the water and the forward fuselage section became submerged... The aircraft impacted the water in a 6.8° nose up attitude at an airspeed of 86 kt on a heading of 109 °M. It came to rest on the sea

bottom in a nose down attitude with the forward section of the fuselage submerged, 65 metres offshore, in a water depth of about six metres... It is clear that the required water entry conditions of low speed, low descent rate and defined pitch angle range can only be met whilst engine power remains available and with full flap selected. Some degree of advanced warning of an imperative need to ditch is therefore necessary, to enable the aircraft to be landed in accordance with the conditions established during the model testing... The first indication that the crew had of a problem was the actual loss of power. Thereafter, without being able to restore power in the available short time span, they were unable to achieve the appropriate combination of parameters, i.e. the optimum tested configuration, needed to ensure successful water entry. In addition, model testing is carried out assuming a defined, reasonably smooth, sea state. This was not present on the occasion of the accident. Indeed a rough, confused sea was reported. Under such conditions, the structural strength of any aircraft is unlikely to be sufficient to enable it to alight without severe damage and occupants can be expected to experience high deceleration forces during water entry. (ADB Ref. 20010227A)<sup>158</sup>

The accident report states the findings for this particular issue as follows:

17. No procedure was available for ditching the aircraft other than with one or both engines operating.

18. No realistic procedure could be envisaged for successfully ditching the aircraft after the loss of both engines, as the optimum touchdown parameters, which had been derived from model testing, could not be attained without the use of at least one operative engine and the flaps at the landing setting. The flap system was rendered inoperative in this instance. In addition, the sea state was rough, which was not conducive to a successful ditching.

The same circumstances were found in another ditching accident that involved a Shorts Brothers SD3-60.

The crew initiated the ditch with flaps up due to no power [available] to operate the flaps and when the committee reviewed the a/c manual it has been found that ditching can be [performed] by 30 deg flaps and no information about ditching with zero flaps, while in this case the crew tried to do their best to ditch with zero flaps. All eye witnesses [who] have been interviewed after the accident agreed about the two engines flame out... [The aircraft was] destroyed by impact and sank in few minutes... Tail unit break down at station 508... also [the aircraft's] nose was destroyed at station 47 and the lower skin panel has separated, sea water came into a/c from both forward and aft openings, wreckage sank in few minutes and rested on sea bed upside down at 38 meters deep... Twenty one passengers died in the accident mainly due to drowning. (ADB Ref. 20000113A)

The report on the investigation of the accident to an ATR-72 that experienced a complete loss of power due to fuel exhaustion and ditched off the coast of Capo Gallo, Palermo, Sicily states:

The ditching procedure given in ATR 72 manuals, as usually given for other aircraft types, is structured so the crew can normally rely on engine power to perform the final control of parameters fundamental for aircraft flight... The ditching manoeuvre is per se an emergency manoeuvre and, if performed without engine thrust in the approach phase, it is quite difficult to complete it adequately. It is difficult to choose the optimum heading compared to the wave motion, to set the aircraft in the ideal attitude without loosing control, not having the engine thrust available. The structure of procedure shown in FCOM does not take into account the ditching causes. As previously seen, the handling of a ditching without engines running can be more complex than the situation with absence of thrust; it is in fact more difficult to coordinate all elements necessary to perform a good ditching maneouvre (speed, vertical speed, attitude, direction, moment and point of contact with the sea). Therefore it is advisable to integrate information available in FCOM and QRH emergency procedures, in order to consider also the

possibility of ditching without thrust from both engines.

Tests carried out in the simulator have shown, above all, how it may be difficult for a flight crew to manage aircraft behaviour, in terms of speed and attitude, in serious failure conditions such a double shutdown and subsequent limitations, as occurred on flight TUI 1153. (ADB Ref. 20050806A)<sup>160</sup>

The recommendation made following this accident is as follows:

SAFETY RECOMMENDATION ANSV-171443-05151A107

Addressee: EASA.

Justification: The structure of "ditching" procedure shown in FCOM does not take into account the causes of ditching. In case of failure of both engines, it is quite difficult for the flight crew to adapt to recommendations shown in the emergency procedure. In absence of thrust, and without primary indications of aircraft instruments due to the subsequent power supply failure, it is in fact more difficult to coordinate all elements necessary to perform a good ditching procedure (speed, vertical speed, attitude, direction, instant and point of contact with the sea).

Text: Consider the possibility of integrating information available in emergency procedures concerning the ditching, in order to consider also the possibility of ditching without both engines operating.

#### **Research and Rulemaking Activities**

The review carried out in this study did not identify any research or current/past EASA or FAA rulemaking activities pertinent to this cabin safety threat.

#### **Conclusions and Recommendations**

The three accidents referenced above demonstrate how the complete loss of power precluded the flight crew from attaining the optimum touchdown parameters, which were derived from model testing during certification. The ditching requirements do not specify that these "optimum" parameters should be attainable under emergency conditions that are likely to call for ditching, such as a complete loss of engine power. The operations manual did not include ditching procedures under such conditions.

The accident review shows that this threat could contribute to the fatal injuries of the occupants. Although the accident review only found this type of threat on two aircraft types, others may have the same failure conditions.

It is recommended that EASA give consideration to investigating the feasibility of taking into account possible emergency conditions, such as a complete loss of engine power, during ditching approval. Furthermore, the operations manual should include ditching procedures for the emergency conditions considered.

<sup>&</sup>lt;sup>158</sup> UK AAIB, Aircraft Accident Report No: 2/2003 (EW/C2001/2/6), Shorts SD3-60, G-BNMT, near Edinburgh Airport on 27 February 2001 <sup>159</sup> Federal Department of the Environment, Transport, Energy and Communications, *Final Report of the* 

Investigation Committee of the Libyan Civil Aviation Authorities concerning the accident of the aircraft Shorts SD3-60, HB-AAM on 13.01.2000 nearby Marsa Brega, Libya, Nr. 1732 <sup>160</sup> Agenzia Nazionale per la Sicurezza del Volo, Final Report – Accident Involving ATR 72 Aircraft Registration

TS-LBB, Ditching off the Coast of Capo Gallo (Palermo – Sicily), August 6<sup>th</sup>, 2005

## Cabin Safety Threat:

## 18. Occupant Protection from Post-crash Fire and Smoke

T01 / Smoke/toxic gas inhalation from post-crash fire/smoke

O01 / Smoke/toxic gas inhalation contributed by the use of new material and large plastic materials on seats, table tops and cabin interior

FB01 / Fire penetration through fuselage break (causing thermal injuries)

FB02 / Fire penetration through door/hatch opened during impact sequence (causing thermal injuries)

FB03 / Fire penetration through unknown path(s) (causing thermal injuries)

FB04 / Fire penetration through other path (e.g. ventilation duct) (causing thermal injuries)

FB06 / Fire penetration through door/hatch opened by occupants (causing thermal injuries)

T02 / High toxicity of new aircraft structures or systems materials

S06 / Skin and eye irritation caused by composite fibre dust in post-crash fires

O02 / High flammability of magnesium alloy seats (post-crash fires)

## Current Applicable CS-25 Requirements and Associated Regulatory Material

Currently, the only requirement addressing occupant protection during post-crash fires is CS 25.853:

CS 25.853 For each compartment occupied by the crew or passengers, the following apply:

(a) Materials (including finishes or decorative surfaces applied to the materials) must meet the applicable test criteria prescribed in Part I of Appendix F or other approved equivalent methods, regardless of the passenger capacity of the aeroplane.

(d) Except as provided in sub-paragraph (e) of this paragraph, the following interior components of aeroplanes with passenger capacities of 20 or more must also meet the test requirements of parts IV and V of appendix F, or other approved equivalent method, in addition to the flammability requirements prescribed in sub-paragraph (a) of this paragraph:

(1) Interior ceiling and wall panels, other than lighting lenses and windows;

(2) Partitions, other than transparent panels needed to enhance cabin safety;

(3) Galley structure, including exposed surfaces of stowed carts and standard containers and the cavity walls that are exposed when a full complement of such carts or containers is not carried; and

(4) Large cabinets and cabin stowage compartments, other than underseat stowage compartments for stowing small items such as magazines and maps.

#### Accident Experience and Safety Recommendations

#### 1) Smoke/toxic gas inhalation

Based on the accident review, smoke/toxic gas inhalation during post-crash fires has caused many injuries and fatalities. It was assessed that over the review period 1998 to 2007, smoke/toxic gas inhalation has resulted in at least 135 and possibly 147 fatalities in three fatal accidents. The following extracts describe the threats faced in some of the accidents:

#### Taipei Boeing 747 October 2000

Most of the survivors said they suffered from smoke inhalation during evacuation. Survivors seated in the main and upper deck cabins all said that they had to lie down for fresh air. The 2L and upper deck galley cabin crewmembers used wet towels to cover their noses and mouths to aid in breathing. According to the survivor statements, during the initial evacuation there was very dense and irritating smoke in the cabin. Surviving passengers stated that just taking one breath of this smoke-filled air caused them to start choking immediately. The toxic gas came from burning fuel, burning cabin equipment, and passengers' belongings. According to survivor interviews, the upper deck quickly filled with dust and smoke. Because of the 'chimney effect', smoke entered the upper deck very quickly. Since passengers could not evacuate all at once, the restricted access to the exits created a life-threatening situation that would require smoke protection devices to survive. The concept of smoke protection devices is not new and has been studied for many years. The carriage of safety devices, such as smoke hood, protective breathing equipment, fire extinguishers and flashlights, by flight crews and cabin crews is now a standard practice; however, in this particular accident, none of the crewmembers had protective smoke masks available. The Safety Council notes that cabin crews were trained to wear the smoke protection devices only when fighting fires and the flight crews were trained to wear smoke protection devices when there was smoke in the cockpit. To be effective, smoke protection devices for the passengers would have to be portable, light weight; stowable, provide adequate visibility, variable size, and easy to use. The Safety Council believes that the aviation industry and government authorities should further evaluate the need for equipping airliners with smoke protection devices for crewmembers and passengers. (ADB Ref. 20001031B)<sup>16</sup>

#### Irkutsk A310 July 2006

Thirteen individuals suffered carbon monoxide poisoning and eight received heat burns. 23 individuals [of the 60 who were hospitalized] who had suffered mechanical traumas were subjected to the effect of high temperatures and carbon monoxide poisoning. Of the 120 passengers who died, 119 died as a result of acute carbon monoxide poisoning in conjunction with oxygen insufficiency in the inhaled air (in one case, the poisoning was accompanied by trauma to the skull and brain) and one female passenger died from severe trauma combined with burns to the body. Forensic medical experts concluded that one [flight attendant] died from acute carbon monoxide poisoning. The concentration of carboxyhemoglobin in her blood was 85%. The three unidentified flight attendants, died as a result of acute carbon monoxide poisoning... Another flight attendant, while helping passengers inside the cabin, died from acute carbon monoxide poisoning.

The safety recommendations issued by the investigating organisations of the above accidents regarded the use of smoke hoods or other protection means for occupants during evacuation:

#### Irkutsk A310 July 2006

5.4. To EASA and other Certifying Authorities together with the Manufacturers of Large Transport Aircraft:

5.4.3. To evaluate the usefulness of cabin crew smoke hood devices in assisting the evacuation of airplanes; to evaluate the possibility of equipping large transport airplanes with devices for passengers and/or flight attendants to be used in case of an emergency evacuation without suffering from the effects of smoke and toxic fumes. (ADB Ref. 20060708A)<sup>162</sup>

Taipei Boeing 747 October 2000

To International Civil Aviation Organization (ICAO): 5. Encourage and support the establishment of research by governments and industry to improve passenger smoke protection and improve emergency evacuation slide performance in heavy winds and

post-accident fire. (3.2-[29, 35]) -ASC-ASR-02-04-44 (ADB Ref. 20001031B)<sup>161</sup>

#### 2) Thermal Assault on occupants in post crash fires

The accident review found that thermal injuries caused by fire in the cabin were caused by fuselage burnthrough, fire penetration through fuselage breaks, fire penetration through door/hatch opened during impact sequence, and door/hatch opened by occupants. The following are excerpts from some of the accident reports describing the threats:

#### Lexington Canadair RJ100 August 2006

Most of the passengers in the overwing area of the cabin did not experience similar forces; however, the large amount of fuel, fuel vapor, and fire forced into the cabin by the aft tree strike made the cabin environment immediately unsurvivable for those passengers... the environment inside the airplane deteriorated quickly as a result of the postcrash fire and smoke, which did not allow sufficient time or means for those occupants to evacuate. (ADB Ref. 20060827C)<sup>163</sup>

#### Brest Canadair RJ100 June 2003

He saw a lot of flames through the opening and let go of the door. Seeing that evacuation of the aeroplane was possible via the front he went in that direction. The flames began to enter through the open emergency door. (ADB Ref. 20030622A)<sup>164</sup>

Taipei Boeing 747 October 2000

*The 2R outboard crewmember saw flames entering the cabin from both sides of the ventilation duct at the sidewall.* (ADB Ref. 20001031B)<sup>161</sup>

No safety recommendations pertinent to Thermal Assault on occupants in post crash fires have been identified.

#### 3) Future Considerations

The following future post-crash fire threats need to be taken into consideration:

- Smoke/toxic gas inhalation contributed to by the use of new materials and large areas of plastic materials on seats, table tops and other areas in the cabin interior
- Window size may increase in future aircraft designs. It should be noted that the current requirements relating to fuselage burnthrough protection do not address protection from burnthrough of windows.
- Toxicity of new aircraft structures or systems' materials
- Skin and eye irritation caused by composite fibre dust in post-crash fires
- Flammability of magnesium alloy seats

#### Research and Rulemaking Activities

The NTSB found that 306 (66 percent) of the 465 fatalities in partially survivable U.S. aviation accidents from 1983 through to 2000 died from impact forces, 131 (28 percent) died from fire and smoke, and 28 (6 percent) died from other causes<sup>165</sup>. However, other studies carried out on the world fleet of aircraft suggest that fatalities from in-flight and post-crash fires are likely to be in the region of 60% to 70%<sup>166</sup>. The FAA and Transport Canada are currently commissioning a study to evaluate the proportion of fire fatalities in aircraft accidents over the period 1967 to 2006.

The literature review identified several means intended to enhance protection to occupants during a post-crash fire.
### 1) Cabin Water Mist (Spray)

Research on Cabin Water Mist or Cabin Water Spray systems was initiated from a Recommendation issued by the UK AAIB following the accident at Manchester Airport on 22 August 1985 (ADB Ref. 19850822A<sup>167</sup>):

4.27 A research program should be undertaken to establish the effect of water mistspray extinguishing systems on the toxic/irritant constituents of fire atmospheres.

Tests carried out by the US FAA and UK CAA showed that in a post-crash cabin fire event, water mist is effective in cooling the cabin, wetting the materials, and slowing the progress of fire<sup>168</sup>. The system was shown to result in significant delays in the onset of cabin flashover, providing a more survivable cabin atmosphere and additional escape time.

Several concerns have been raised in the past regarding the possible adverse effects of the operation of "cabin water spray" during evacuation<sup>169</sup>, such as:

- 1. Reduced visibility due to water mist and/or smoke dispersion in the cabin during evacuation.
- 2. Possible interference from noise generated by the CWM system with evacuation commands.

However, results of evacuation trials suggest that, for the specific scenarios investigated (in the test programme), the use of "cabin water spray" systems would not be likely to cause any significant adverse consequences for emergency evacuation of the aircraft<sup>169</sup>. The test programme however, did not address the effect on evacuation of wetting of the cabin interior and escape slides or the effect of water on floor proximity lighting.

A number of physiological hazards were identified and examined by the International Cabin Water Spray Research Management Group, as follows:

- Inhalation of Hot Moist Air
- Inhalation of Particulate and Water Droplets
- Hypothermia in Evacuees
- Post-evacuation hypothermia

In the conclusions of the research programme on cabin water spray<sup>168</sup>, the International Cabin Water Spray Research Management Group stated that the system was likely to be effective and presented no insurmountable problem areas. It was estimated that cabin water spray systems would save an average of 14 lives per year world-wide, or 6 lives in the US, Canada and European countries of the JAA (at the time) combined. However the cost per life saved was assessed to be in the order of \$22m to \$32m. The European Transport Safety Council<sup>170</sup> review stated that "the figures underestimated the number of lives that could be saved, and with costs minimised if features are introduced at the design stage, future aircraft should be equipped accordingly."

A more recent study carried out for the FAA based on improved accident data suggested that the life saving potential of Cabin Water Mist systems in post crash fires to aircraft configured with fully effective enhanced fuselage burnthrough protection was likely to be in the region of 34 lives per year world-wide<sup>171</sup>. As a rough order of magnitude assessment an increase in the number of lives saved per year from 14 to 34 would have reduced the estimate of cost per life saved to \$9m to \$13m (this should be compared with the current FAA assessment of the value of life at \$5.8m). These figures cannot be considered as definitive since there are other factors that need to be accommodated in making a more dependable cost benefit assessment. These factors include:

- The increase in airline traffic
- The reduction in accident rate
- The potential life saving benefits of the use of water mist for combating in-flight fires
  - The potential use of on-board water that may be used for cargo compartment

- fire suppression systems
- Advances in systems design (e.g. water mist nozzles)

The JAA issued a Draft Notice of Proposed Amendment (NPA) for Cabin Water Spray Systems in May 1992<sup>172</sup>. Due to the adverse assessment of benefit no further regulatory work has been carried out since this date. However, Transport Canada, supported by the US FAA and UK CAA, has been funding a research project to investigate the feasibility of the installation of a Cabin Water Mist system as part of an aircraft integrated fire protection system<sup>173</sup>. One of the outcomes of this research project is a technical specification for a Cabin Water Mist system<sup>174</sup>.

Cabin Water Mist systems could potentially be used for suppressing in-flight fires, however, concerns exist regarding the effects of the water mist on the aircraft systems, particularly electrical systems. Research carried out by the University of Science and Technology of China<sup>175</sup> states found that "fine water mist was effective in extinguishing in cabinet electronic fires, as well as fires in a computer room, without causing short circuits or other damages to electrical and electronic components".

#### 2) Enhanced fuselage burnthrough protection

To improve fuselage burnthrough protection, the US FAA has issued a Final Rule for enhanced burnthrough protection of thermal acoustic insulation materials used in transport category airplanes (Docket No. FAA–2000–7909. Amdt. Nos. 25–110, 91–275, 121–289, 125–43, 135–85. FAA; 2003). Compliance is required for aircraft manufactured after 2 September 2009.

EASA has amended CS-25 at Amendment 6 to reflect the FAR 25 requirement. The NPA advising of the proposed amendment to CS.25.856 requiring enhanced burnthrough protection of thermal acoustic insulation materials led to concerns being raised that the use of Thermal Acoustic Insulation as a fire barrier may not provide the overall level of fuselage burnthrough protection sought. As a result EASA commissioned a research study aimed at assessing whether more cost beneficial means might be found of achieving the safety intent.<sup>176</sup>

It is generally understood that the use of Thermal Acoustic Insulation as a fire barrier may not provide complete protection and may not be the most cost beneficial means of achieving the safety intent. Additionally, advances in technology (e.g. carbon composite fuselages) should also be taken into account. The EASA study concluded that:

"CS 25.856(b) "Thermal /acoustic insulation materials" introduced by NPA 2008-13 should be deleted and replaced by a new objective rule. The new rule is likely to provide improved protection to occupants of aircraft, with metallic and non-metallic fuselages, at minimal cost increase."

A Regulatory Impact Assessment, supporting this conclusion, was also provided to EASA.

# 3) Smoke hoods

Following the accident at Manchester Airport, on 22 August 1985, the AAIB recommended to the UK CAA the formulation of a requirement for the provision of smoke hoods/masks to afford passengers an effective level of protection during fires which produce a toxic environment within the aircraft cabin.

As stated in CAP 593<sup>177</sup>, the UK CAA accepted this Recommendation and gave urgent consideration to the formulation of requirements for the design and provision of smoke hoods/masks for passengers. On 18 July 1986 the UK CAA published a discussion document relating to the possible introduction of smoke hoods which summarised the argument for and against them and was in close discussion with other international authorities. In December 1987 in the light of major collaborative research carried out in the UK, USA, Canada and France a decision was made by these countries in unison that a mandatory requirement for the carriage of smoke hoods could not be justified at that time<sup>178</sup>. Nevertheless, the UK CAA continued with completion of its specification for a smoke hood defining both the equipment performance and installation requirements. This was issued on 9 May 1988 (CAA Specification No 20 Passenger Protective Breathing Equipment (PPBE)

# - Smoke Hoods).

In a 1991 report<sup>179</sup>,the CAA concluded that "The Authority is concerned that in a crash situation, with passengers experiencing shock and perhaps panicking, any delay in putting on a smoke hood, particularly by parents of young children or partners helping each other, would reduce the benefit (of smoke hoods). It would only require one or two people to get into difficulty with their smoke hoods, for the whole evacuation to be in jeopardy. This, the Authority feels, is an unacceptable safety risk and it is for this reason that it has decided not to require the provision of passenger smoke hoods in British-registered aircraft."

The European Transport Safety Council review on increasing the survival rate in aircraft accidents<sup>170</sup> stated that the delay in evacuation time due to the use of smoke hoods may only have detrimental effects in the event of flashover and that flashover was considered *"a relatively rare event"*. The review recommended the use of smoke hoods to increase fire survivability.

#### Proposed Potential Solutions

Based on safety recommendations and the literature review, the following methods are considered for mitigation of the post-crash fire and smoke threat:

- (i) Cabin Water Mist
- (ii) Enhanced fuselage burnthrough protection
- (iii) Smoke hood

These proposed potential solutions were evaluated as follows:

T01Smoke/toxic gas inhalation from post-crash fire/smokeSUBSTANTIALL YLIMITED POTENTIALLIKELY01Smoke/toxic gas inhalation contributed by the use of new material and large plastic materials on seats, table tops and cabin interiorSUBSTANTIALL YNOLIKELYFB0 1FB 02 FB0 3FB 04F B06Fire penetration through door/hatch opened during impact sequence, door/hatch opened by occupants, fuselage break, or other pathsSUBSTANTIALL YNOPOSSIBT02High toxicity of new aircraft structures or systems materialsSUBSTANTIALL YNOLIKELYS06Skin and eye irritation caused by composite fibreSUBSTANTIALL YNOLIKELY	ID	CABIN SAFETY THREATS	Cabin Water Mist	Enhanced fuselage burnthrough protection	Smoke hoods
O01 O03Smoke/toxic gas inhalation contributed by the use of new material and large plastic materials on seats, table tops and cabin interiorSUBSTANTIALL YNOLIKELYFB0 1FB 02 FB0 3FB 04F B06Fire penetration through 	01	Smoke/toxic gas inhalation from post-crash fire/smoke	SUBSTANTIALL Y	LIMITED POTENTIAL	LIKELY
FB0 1FB 02 FB0 impact sequence, door/hatch opened during impact sequence, door/hatch opened by occupants, 	001 003	Smoke/toxic gas inhalation contributed by the use of new material and large plastic materials on seats, table tops and cabin interior	SUBSTANTIALL Y	NO	LIKELY
High toxicity of new aircraft structures or systems     SUBSTANTIALL Y     NO     LIKELY       Skin and eye irritation     Solo     Caused by composite fibre     LIKELY     NO     LIKELY	B0 FB 2 B0 FB 4F 806	Fire penetration through door/hatch opened during impact sequence, door/hatch opened by occupants, fuselage break, or other paths	SUBSTANTIALL Y	NO	POSSIBLY
See caused by composite fibre	02	High toxicity of new aircraft structures or systems materials	SUBSTANTIALL Y	NO	LIKELY
dust in post-crash fires	606	Skin and eye irritation caused by composite fibre dust in post-crash fires	LIKELY	NO	LIKELY
O02High flammability of magnesium alloy seatsPOSSIBLYNOPOSSIB	002	High flammability of magnesium alloy seats	POSSIBLY	NO	POSSIBLY

#### **Conclusions and Recommendations**

Based on the review of the current applicable CS-25 requirements, accident experience, literature and past/current rulemaking activities, and the evaluation of the proposed potential solutions or regulatory change, it was concluded that occupant protection during post-crash fire and smoke may need to be addressed in airworthiness requirements. It is recommended that a Regulatory Impact Assessment be carried out on the systems that are likely to afford protection during post-crash fire/smoke events, such as the installation of Cabin Water Mist and the use of passenger smoke hoods.

Systems and Enhanced Fuselage Burnthrough Protection

UK Civil Aviation Authority, Draft NPA to JAR- 25 Cabin Water Spray Systems (Issue 2) May 1992.

<sup>173</sup> RGW Cherry & Associates Limited (2008) 0989/R/000444KK, Integrated Fire Protection Research -Prepared for Transport Canada. <sup>174</sup> RGW Cherry & Associates Limited (2007) 0958/T/000385/KK, Technical Specification for a Cabin Water Mist

System – Prepared for Transport Canada. <sup>175</sup>LIU Jianghong, LIAO Guangxuan, LI Peide, FAN Weicheng & LU QiangProgress (2003) Progress in research

and application of water mist fire suppression technology, Chinese Science Bulletin 2003 Vol. 48 No.8 718 725 <sup>176</sup> RGW Cherry & Associates Limited (2009) 4207/R/000456/KK, Burnthrough Resistance of Fuselage (EASA

Service Contract Number EASA 2008.C19)

Passenger Protective Breathing Equipment from analysis of past accidents

<sup>179</sup> UK Civil Aviation Authority (1991) CAP 586, Improving Passenger Survivability in Aircraft Fires: A Review. Gatwick: UK CAA

<sup>&</sup>lt;sup>161</sup> Aviation Safety Council Taiwan, Crashed on a partially closed runway during takeoff, Singapore Airlines Flight SQ 006, Boeing 747-412, 9V-SPK at Chiang Kai-shek Airport, Taoyuan, Taiwan, October, 31, 2000 Interstate Aviation Committee, Final Report on the Results of the Investigation of the Accident A-310-324 F-OGYP OAO Aviakompania Sibir 8 July 2006

<sup>&</sup>lt;sup>163</sup> National Transportation Safety Board, Accident Report NTSB/AAR-07/05, Attempted Takeoff From Wrong Runway, Comair Flight 5191, Bombardier CL-600-2B19, N431CA, Lexington, Kentucky, August 27, 2006

Bureau d'Enquêtés et d'Analyses pour la Sécurité de l'Aviation Civile. Accident on 22 June 2003

at Guipavas (21) to the Bombardier Canadair CL-600 2B 19 registered F-GRJS operated by Brit Air, Report Translation f-js030622a. <sup>165</sup> National Transportation Safety Board (2001) Survivability of Accidents Involving Part 121 U.S. Air Carrier

Operations, 1983 Through 2000, NTSB/SR-01/01. Washington, D.C.: NTSB

RGW Cherry & Associates Limited (2003) 0923/R/000203/KK, Trends in Occupant Survival in Aircraft Accidents - Phase 1 Feasibility Study and Report of Findings

UK Air Accidents Investigation Branch, Aircraft Incident Report No: 8/88, Report on the accident to Boeing 737-236, G-BGJL at Manchester International Airport on 22 August 1985.

<sup>&</sup>lt;sup>168</sup> UK Civil Aviation Authority (1993) International Cabin Water Spray Research Management Group – Conclusions of Research Programme, CAA Paper 93012. United Kingdom: Civil Aviation Authority.

Bottomley, D. M., Muir, H. C., Lower, M. C. (1993) Aircraft Evacuations: The Effect of a Cabin Water Spray System upon Evacuation Rates and Behaviour, CAA Paper 93008. United Kingdom: Civil Aviation Authority.

European Transport Safety Council (1996) Increasing the Survival Rate in Aircraft Accidents - impact protection, fire survivability and evacuation. Brussels: ETSC <sup>171</sup> RGW Cherry & Associates Limited (2002) *1704/R/000140/KK A Benefit Analysis for Cabin Water Spray* 

UK Civil Aviation Authority (1991) CAP 593 Air Accidents Investigation Branch (AAIB) Recommendations: Progress Report 1990 CAA Responses to AAIB Recommendations received up to 31 December 1989, presented to the Secretary of State for Transport September 1990. Gatwick: UK CAA <sup>178</sup> CAA Paper 87017 Smoke Hoods: Net Safety Benefit and FAA report DOT/FAA/CT-88/03 Study of Benefits of

#### Cabin Safety Threat:

#### **19. Oxygen System Protection from In-Flight and Postcrash Fires**

S01 / Exploding Oxygen Bottles during Post-Crash Fire

S03 / Increased Severity of Post-Crash Fire due to the Increasing Size of Oxygen Systems Associated with Larger Aeroplanes

FA16 / Increased Risk or More Severe In-Flight Fire Associated with the Increased Size of Oxygen Systems on Larger Aeroplanes

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to protection of aircraft oxygen systems are as follows:

25.869 (c) (See AMC 25.869(c).) Oxygen equipment and lines must -

(1) Not be located in any designated fire zone.

(2) Be protected from heat that may be generated in, or escape from, any designated fire zone, and

(3) Be installed so that escaping oxygen cannot cause ignition of grease, fluid, or vapour accumulations that are present in normal operation or as a result of failure or malfunction of any system.

CS 25.1453 (b) Oxygen pressure sources and tubing between the sources and shut-off means must be –

(1) Protected from unsafe temperatures; and

(2) Located where the probability and hazard of rupture in a crash landing are minimised.

#### Accident Experience and Safety Recommendations

The accident review found one accident where the top of one of the passenger oxygen bottles exploded during post-crash fire. Extracts from the accident report describing the event are as follows:

The top of one of the passenger oxygen bottles exploded during the post-crash fire; the top was blown approximately 84 m (276 feet) across Etobicoke Creek. Next to the cargo door, coincident with the location of the passenger oxygen cylinders, was a large hole in the fuselage wall that bore signs of explosive force. (ADB Ref. 20050802A)<sup>180</sup>

No recommendations on this particular issue were made.

#### **Research and Rulemaking Activities**

The VLTA Conference<sup>181</sup> identified oxygen systems as one of the fire protection issues that need to be studied during VLTA design development and certification:

The presence of bulk  $O_2$  on board and its possible contribution to in-flight and post-crash fires.

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

#### Discussion

Oxygen cylinders are vulnerable to explosion if exposed to fire or impact damage. Oxygen facilitates the spread of fire or increases its intensity.

The vulnerability of onboard bulk oxygen to post crash or in-flight fire is dependant upon its location within the aircraft. The risk of a major explosion is dependant on the quantity stored and whether it is stored in one place or distributed around the aircraft.

CS 25.1453 requires that oxygen pressure sources are protected from unsafe temperatures, although this is unlikely to be interpreted to include post crash fires. The oxygen cylinder explosion in the Toronto A340 accident (ADB Ref. 20050802A) demonstrates the vulnerability to post crash fire. However, the accident report does not state whether the explosion worsened the fire or increased the threat to the escaping occupants.

CS 25.1453 also requires that oxygen pressure sources are located where the probability and hazard of rupture in a crash landing are minimised.

Only when an aircraft is equipped with a gaseous passenger oxygen system is the quantity of oxygen stored dependant upon the aircraft size and passenger capacity. This is because for any size of aircraft, including VLTA, the majority of the required oxygen can potentially be supplied by a chemically generated system, which minimises the amount of bulk oxygen required to be stored. However, it is likely that the flight crew oxygen system would be supplied from an oxygen pressure vessel even on aircraft having a chemical oxygen supply for the passenger compartment.

Two new aircraft types, the Boeing 787 and Airbus A350XWB, are to be equipped with a new type of oxygen system, the BE Aerospace Pulse® system, which delivers oxygen based on a person's breathing cycle and has oxygen stored in small vessels, one at each PSU. This type of system may be relatively well protected from crash impact damage compared with much larger bulk oxygen cylinders that are often located beneath the cabin floor, but might pose a greater overall risk in a cabin fire, albeit with a smaller explosion. A definitive comparison of the relative threats and risks from each method of gaseous oxygen storage would need to be addressed by research. However, it is likely that both of these methods of oxygen storage would present a greater risk of explosion in a fire than chemical oxygen systems.

#### **Conclusions and Recommendations**

It is recommended that research be carried out to establish the explosion risks presented by different passenger emergency oxygen storage systems when subjected to cabin fire or post crash impact. The research should address:

- 1. A comparison between the risks to occupants presented by gaseous and chemical oxygen systems.
- 2. Whether large (centralised) oxygen storage vessels should be excluded from aircraft.
- 3. Whether large (centralised) oxygen storage vessels should be excluded from the pressure hull.
- 4. Whether small oxygen storage vessels located at each PSU (e.g. B787 & A350) present a greater risk than large (centralised) storage vessels.
- 5. Whether there should be a limit for the total amount of gaseous oxygen carried onboard aircraft. (Effectively requiring chemical oxygen for the passenger compartment.)

 <sup>180</sup> Transportation Safety Board of Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005
 <sup>181</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16 October 1998.

# Cabin Safety Threat:

# 20. In-flight Fires

FA05 / In-Flight Fire in Hidden Areas

FA12 / In-Flight Fire Involving On-Board Loose Items

FA13 / In-Flight Fire (Hidden and Visible) Related to the Increased Installation of IFE Systems and Other Services (Galley Equipment, Bar Equipment, Seat Features) Associated with Longer Flights and Larger Aeroplanes

FA14 / Increased In-Flight Fire Risks Associated with the Use of Magnesium Alloy Seats

FA15 / In-Flight Fire Risks Related to the Increasing Use of Lithium Batteries (in PEDs, etc) and Fuel Cells

FA17 / Increased Risk of Fire Associated with Newer Aircraft Having Cabin Altitude of 6000 ft (flammability is higher at lower altitude)

FA18 / In-Flight Fire Properties of Carbon Composite Material Different to that of Aluminium Structures

# Current Applicable CS-25 Requirements and Associated Regulatory Material

Fire protection for other than the lavatory and cargo compartment is addressed in CS 25.851 (Fire extinguishers), 25.853 (Compartment interiors), 25.859 (Combustion heater fire protection), 25.863 (Flammable fluid fire protection), 25.865 (Fire protection of flight controls, engine mounts, and other flight structure), 25.867 (Fire protection: other components), and 25.869 (Fire protection: systems). Flammability standards for Thermal Acoustic Insulation materials (25.856) are addressed in CS-25 Amendment 6 effective on 6<sup>th</sup> July 2009.

Appendix F Part VI of CS-25 Book 1 contains test criteria and procedures for showing compliance with those requirements. The FAA is currently considering simplifying the structure of Appendix F.

# Accident Experience and Safety Recommendations

# 1) Hidden Fires

The accident review found 7 accidents involving hidden fires over the study period.

ADB REF.	LOCATION AND DAMAGE	CAUSE
20020513A <sup>182</sup>	Toronto Boeing 767 May 2002 The fire was located below the floor level of the aft cargo compartment. It burned holes through the structural floor beam web and consumed the Thermal Acoustic Insulation (TAI) on both sides of the floor beam, damaged the underside of the floor board, potable water lines, heater ribbons, and associated electrical wiring. There were no injuries to the passengers or crew.	The B110 heater ribbon attached to the water supply line failed at the site of a recent water line repair, which allowed the elements of the heater ribbon to electrically arc, providing a source of ignition to surrounding materials. <b>Other factors</b> : contamination of TAI and the lack of an industry standard for detecting/accessing/cleaning it at that time.

20001129B <sup>183</sup>	Atlanta DC9 November 2000 Fire damage was concentrated in an area just aft of the electrical disconnect panel located at FS 237 (left forward), which is a junction panel for seven wire bundles. Heat discoloration on the fuselage exterior, beneath the lavatory service panel. Seat tracks under seats 1A and 1C buckled from heat exposure. Carpeting in front of seats 2A and 2C was burned and melted, floor in the aisle next to row 3 was spongy and buckled. 13 passengers sustained minor injuries	The cause was the leakage of lavatory fluid from the airplane's forward lavatory onto electrical connectors, which caused shorting that led to a fire. <b>Other factors:</b> the inadequate servicing of the lavatory and the failure of maintenance to ensure reinstallation of the shield over the fuselage station 237 disconnect panel.
20001129A <sup>184</sup>	Dulles MD 80 November 2000 Coating of metalized Mylar of the insulation in the area between rows 7AB and 11AB burned away. The top section of the overhead bins was burned, but there was no damage to the interior of the bins. A 1-inch wide wire bundle along the top of the overhead bins exhibited localized areas of soot and heat damage. There were no injuries to the passengers or crew.	<b>Cause</b> : the operator's inadequate maintenance procedure to disconnect the Omega navigational system, which resulted in coaxial cables being cut and not properly protected. A factor in the incident was the lightning strike.
20001115B <sup>185</sup>	Copenhagen Boeing 757 November 2000 In the cabin, the only place there was any damage or sign of extreme heat was where the lightning had penetrated the fuselage skin. The plastic covering the insulation blanket was burned/glowed away. Some of the melted plastic could be observed on wirings and cables. The insulation blanket was singed. There were no injuries to the passengers or crew.	Cause: lightning that penetrated fuselage skin and singed the insulation blanket covering.
20000808A <sup>186</sup>	<b>Greensboro DC9 August 2000</b> Relay R2-53, the left heat exchanger cooling fan relay, was severely heat damaged, as were R2-54 and the other relays in this	<b>Cause</b> : a phase-to-phase arc in the left heat exchanger cooling fan relay, which ignited the surrounding wire insulation and other combustible materials within the electrical power centre panel.

APPENDIX 8 – CABIN SAFETY THREATS EVALUATED IN DETAIL				
	area. Of the 58 passengers and 5 crewmembers on board, 3 crewmembers and 5 passengers received minor injuries from smoke inhalation.	<b>Other factors:</b> neither flight attendant on board the flight attempted to locate the source of the smoke in the cabin or to use any of the firefighting equipment available to them. AirTran's flight attendant training program does not include any drill involving hidden fires but does include a drill that uses a visible, open flame.		
19990917A <sup>187</sup>	Covington MD 88 September 1999 Smouldering insulation blanket in the cargo compartment adjacent to a static port heater. There were no injuries to the passengers or crew.	<b>Cause</b> : deteriorated wire insulation and shorting at a short radius bend to the electrical wiring in the right side alternate static port heater, which resulted in electrical arcing and a fire sustained by overlaying thermal acoustic insulation. The Thermal Acoustic Insulation material is the subject of AD action.		
19980902A <sup>188</sup>	Swissair MD 11 September 1998 The fire likely started within the confines of a relatively small area above the right rear cockpit ceiling just forward of the cockpit rear wall. The in-flight fire resulted in the loss of control of the aeroplane. It crashed to the sea, killing all 229 occupants on board.	<b>Cause</b> : It is most likely that the fire started from a wire arcing event that ignited the nearby MPET-covered insulation blankets that are easily ignited and were prevalent in the area. The Thermal Acoustic Insulation material is the subject of AD action.		
<ul> <li>Following the investigation of the accident in Toronto to the Boeing 767 in May 2002 (ADB Ref. 20020513A) the following safety recommendations were made by the Canadian TSB:</li> <li>The Department of Transport take action to reduce the short term risk and eliminate the long term risk of heater ribbon installation failures starting fires, and coordinate and encourage a similar response from other appropriate regulatory authorities. (A02-04)</li> <li>The Department of Transport take action to reduce the short term risk and eliminate the long term risk of contaminated insulation materials and debris propagating fires, and coordinate and encourage a similar response from other appropriate regulatory authorities. (A02-04)</li> </ul>				
In a letter dated 06 February 2003, the FAA's Seattle Aircraft Certification Office indicated that they agree in part with TSB Recommendation A02-04. In a letter dated 19 March 2003, the FAA's Seattle Aircraft Certification Office indicated that they agree with TSB Recommendation A02-05.				
Following the investigation into the accident in Atlanta to the DC9 in November 2000 (ADB Ref. 20001129B), the following safety recommendations were made by the US NTSB:				

Require all DC-9 operators to visually inspect the electrical connectors at fuselage station 237 for evidence of lavatory rinse fluid contamination and for the presence of a drip shield above the disconnect panel in accordance with Boeing Alert Service Bulletin DC9-24A190. Connectors with internal contamination should be replaced. (A-02-13)

Issue a flight standards information bulletin to principal inspectors of DC-9 operators that discusses the circumstances of the accident involving AirTran flight 956 and stresses the importance of properly servicing and draining lavatory waste tanks and sealing floor panels in areas of probable fluid contamination, as indicated in Boeing Service Letter DC-9-SL-53-101. (A-02-14)

Based on the accident to the DC9 at Greensboro in August 2000 (ADB Ref 20000808A) (and other accidents involving in-flight fires), the Accident Investigating Authorities made several safety recommendations (A-01-83, A-01-84, A-01-85, A-01-87) to the FAA on 4 January 2002, regarding improved crewmember training for fighting in-flight fires. The FAA issued Advisory Circular 120-80 (In-Flight Fires) in response to these safety recommendations, with great emphasis on dealing with hidden fires. One safety recommendation addresses access to hidden areas:

Develop and require implementation of procedures or airplane modifications that will provide the most effective means for crewmembers to gain access to areas behind interior panels for the purpose of applying extinguishing agent to hidden fires. As part of this effort, the FAA should evaluate the feasibility of equipping interior panels of new and existing airplanes with ports, access panels, or some other means to apply extinguishing agent behind interior panels. (A-01-86) - Open - Acceptable Response

The investigation into the Swissair accident resulted in several safety recommendations being made relating to thermal acoustic insulation materials (A-99-07, A-99-08), in-flight fire training standards (A00-20), emergency checklist procedures for odour/smoke of unknown origin (A00-18, A00-19). Of particular interest in this study is Recommendation A-00-16, A-00-17, and A-01-04:

That appropriate regulatory authorities, in conjunction with the aviation community, review the adequacy of in-flight firefighting as a whole, to ensure that aircraft crews are provided with a system whose elements are complementary and optimized to provide the maximum probability of detecting and suppressing any in-flight fire.(A-00-16) – Satisfactory in Part

That appropriate regulatory authorities, together with the aviation community, review the methodology for establishing designated fire zones within the pressurized portion of the aircraft, with a view to providing improved detection and suppression capability.(A-00-17) – Satisfactory Intent

That for the pressurized portion of an aircraft, flammability standards for material used in the manufacture of any aeronautical product be revised, based on realistic ignition scenarios, to prevent the use of any material that sustains or propagates fire.(A01-02) -Satisfactory Intent

That a certification test regime be mandated that evaluates aircraft electrical wire failure characteristics under realistic operating conditions and against specified performance criteria, with the goal of mitigating the risk of ignition.(A01-03) – Satisfactory in Part

That as a prerequisite to certification, all aircraft systems in the pressurized portion of an aircraft, including their sub-systems, components, and connections, be evaluated to ensure that those systems whose failure could exacerbate a fire in progress are designed to mitigate the risk of fire-induced failures.(A-01-04) – Satisfactory in Part

# 2) Other in-flight fires

The accident review did not identify the other in-flight fire threats addressed in this section. Most of the other types of in-flight fires such as cabin fires (e.g. galley fires, IFE/seat fires, lavatory fires, etc) were reported as incidents. A study on cabin crew fire training carried out on behalf of the UK CAA found that over the period of 2002-2006, there were 316 in-flight fire occurrences (incidents) on UK registered aeroplanes<sup>189</sup>. The bar chart below describes the rate of the occurrences (note: UK fleet accumulating approximately 6,204,000 flights in the analysis period):



# **Research and Rulemaking Activities**

#### 1) Hidden Fires

Based on a study carried out by the  $\text{ATSB}^{190}$ , in-flight fires was the fourth highest accident cause in terms of the resultant number of fatalities over the period 1992 to 2001 – 339 deaths. Catastrophic in-flight fires are invariably caused by fires originating in hidden areas that are inaccessible to the flight and cabin crew.

A benefit analysis for enhanced protection from fires in hidden areas on transport aircraft has been carried out for the FAA and UK CAA<sup>191</sup>. The benefit analysis found that, based on data for the world fleet of Western-built aircraft over the period 1991 to 2000, enhanced protection from fires within hidden areas in the aircraft cabin could save 52 lives per year. Of this, 34 lives per year are likely to be saved from enhanced flammability standards of thermal acoustic insulation. Hence it would seem that Thermal Acoustic Insulation materials are likely to be the primary causes of fire propagation in hidden areas. Consideration has been given by the Authorities and Industry to combating this threat by both passive and active means:

Passive fire protection:

- **Thermal acoustic insulation material and effects of contamination**. Both the FAA and EASA have taken regulatory action to improve the flammability standards of Thermal Acoustic Insulation materials by amending CS/FAR 25.856(a). Whilst current in-service aircraft are not all compliant with the standards specified in 25.856(a), the hidden fires issue has been addressed in terms of newly certificated aircraft. However, concern remained as to the flammability of these materials when subjected to contamination. Two initiatives have been undertaken resulting from these concerns:
  - 1. A Thermal Acoustic Insulation Contamination & Aging Task Group has been formed under the auspices of the International Aircraft Materials Fire Test Working Group. The future activities of the Task Group are currently under discussion and a study<sup>192</sup> has been carried out on behalf of Transport Canada to assist in deciding upon the future direction to be taken.
  - 2. The procedure currently being adopted by the industry to mitigate the potential for fire

hazards resulting from electrical faults is based on the FAA Advisory Circular 25-27<sup>193</sup> and the Enhanced Zonal Analysis Procedures (EZAP) defined in ATA MSG-3 "Operator/Manufacturer Scheduled Maintenance Development"<sup>194</sup>.

Subject to the Industry and Authority review being carried out under the auspices of the Thermal Acoustic Insulation Contamination & Aging Task Group it would seem that the EZAP process provides a practical solution for mitigating the threat from TAI contamination. If this view is generally accepted then no further amendment to CS-25, relating to Thermal Acoustic Insulation, is considered necessary.

- Wiring material. The FAA is currently developing an improved fire test method and criteria for aircraft electrical wiring.<sup>195</sup> The findings suggest that "Wire bundle specimens amplified the results of the single-wire specimens due to additional fuel (material), and radiant/contact heat interaction between the bundled wires". This suggests that wire bundles, instead of single wires, should be used in the flammability test. The study also recommended the 30-degree radiant heat panel test for electric wire as a replacement for the Bunsen Burner tests specified in Chapter 4 in the *Aircraft Materials Fire Test Handbook* and Appendix F Part I (1v) and (3). When this work is finalised it is likely to result in EASA needing to give consideration to amending Appendix F of CS-25 to reflect any changes introduced into FAR part 25 for improved flammability testing of electrical wiring.
- **Ducting material**. The FAA has developed an improved flammability test standard for aircraft ducting materials. The current test requirement used to approve ducting materials is the 12-second vertical Bunsen burner test (FAR 25, Appendix F Part I (b)(4)). However, the FAA Research has established that *"the current FAA vertical Bunsen burner test requirement could not adequately discriminate between materials that performed poorly and materials that performed well under realistic fire scenarios"*. Therefore, an alternative radiant heat panel test method was developed. It was demonstrated that this method was effective in evaluating the inflight fire resistance qualities of aircraft ducting196. EASA may need to give consideration to amending Appendix F of CS-25 to reflect any changes introduced into FAR-25 for improved flammability testing of ducting materials.
- Arc Fault Interrupter. Current circuit breakers may need to be replaced by 'intelligent' circuit breakers, which could recognise the rapid current and/or voltage signature associated with arcing faults. Based on the investigation of four in-flight fires from damaged electrical wiring, the AAIB issued Safety Recommendation 2003-128: "... that the EASA expedite a requirement for the replacement of existing type circuit breakers by arc fault circuit breakers..." (Safety Recommendation 2003-108 is similar but directed to the FAA). There has been much research carried out into Arc Fault Interrupters primarily in the United States. Additionally a flammability test rig has been developed by Transport Canada to simulate the threat posed by Arc Faults on aircraft wiring and electrical equipment. However, prior to EASA embarking on regulatory activity it may be necessary to carry out further research to determine the extent to which such devices should be used and the risk of any potential disbenefits that they might exhibit.

Active fire protection:

- The use of inert gases in hidden areas. FAA and Transport Canada has been conducting studies on using the inert gas available for fuel tank inerting on hidden areas such as overhead areas. Tests on a B727 by the FAA found that an inert atmosphere can be produced in a 13 foot section above the cabin ceiling using 2 Nitrogen Enriched Air insertion points in times between 1.8 to 3.1 minutes, and in a 22-foot section with 4 NEA insertion points in 1 to 1.7 minutes<sup>197</sup>. The research is still on-going. It is recommended that EASA participate in this research in order to ensure that any future regulatory activity in this area is harmonised with the FAA and Transport Canada.
- Installation of discharge ports for delivering extinguishing agent from a handheld fire extinguisher. A study by the FAA found that the use of ceiling-mounted discharge ports

- combined with hand-held extinguishers was more promising against fires in the more confined and smaller-volume overhead area typical of a narrow-body aircraft compared to that of a wide-body aircraft<sup>198</sup>.
- Advanced fire detection system in hidden areas. In light of the Swissair accident, Swissair and SR Technics undertook a study that focused on developing an early warning smoke detection system in the avionics compartment, the cockpit overhead area, and the first-class galley overhead zone. The study resulted in the adoption of the "MD-11 Modification Plus" program, which contains the installation of smoke detectors and a Video Camera Monitoring System in those areas<sup>188</sup>.
- **The use of portable thermal detection cameras.** Such a tool may improve the cabin crew's ability to detect hidden fires. The effectiveness of these devices is likely to depend on the size and location of a fire. For example, a fire immediately behind a cabin sidewall panel may cause sufficient heating of the panel to be visible with the thermal imaging device, whereas a fire high up in an attic may not heat the ceiling panel and would therefore not be detected.

Significant reliance is placed on the cabin crew to deal with in-flight fires. Many safety recommendations resulting from accident investigations of in-flight fire accidents were directed to cabin crew training. Whilst cabin crew may be able to deal with most visible fires in cabin, fires in areas not accessible from the cabin may still pose a serious threat to flight safety.

#### 2) Other in-flight fires

#### a) Flammability requirements for on-board loose items

On November 28, 1993, shortly after push-back from the passenger loading ramp at the Montreal International (Pierre Elliott Trudeau) Airport, Quebec, a fire erupted in an overhead baggage bin of a Boeing 727 operated by a U.S. air operator. The fire was extinguished by the cabin crew, and the passengers were evacuated. Several passengers were treated for minor injuries including smoke inhalation.<sup>199</sup>

In the above accident, the fire originated from several blankets made of 100% polyester stored in the overhead compartment, which had been deliberately lit, most likely with a match.

Currently there is no flammability requirement for items such as blankets or pillows. They are an optional item, provided by the air operator, for the convenience and comfort of passengers. The accident resulted in the development of a test method for blankets by the FAA (report DOT/FAA/AR-96/15 "The Development of a Test Method for Aircraft Blankets"). SAE (ARP) 5627 – "Flammability Test Method for Aircraft Comfort Blankets" provides criteria to ensure that any comfort blanket that passes a test will be less likely to be the original fuel source for an aircraft fire.

# b) In-Flight Fire Risks Related to the Increasing Use of Lithium Batteries (in PED, etc) and Fuel Cells.

The following are incidents involving lithium batteries as cited in a presentation by the FAA<sup>200</sup>:

- One incident involving an explosion caused by a lithium battery in a personal device ("Fresh Air Buddy") occurred in the aircraft cabin at altitude causing an emergency landing.
- Another incident involving this equipment occurred in the airport.
- A laptop fire occurred in an airport gate area whilst it was charging.
- A JetBlue passenger aircraft made an emergency landing due to a fire in an overhead compartment caused by batteries in a bag of AV equipment.
- Another incident involved a laptop and spare Lithium-Ion battery that started burning in the overhead bin before pushback.
- o A Lithium battery exploded in an aircraft cabin as a cameraman switched batteries.
- Multiple incidents involving explosions of batteries.
- Battery-powered drill accidentally activated in checked baggage, overheated and caught fire in checked baggage on the ramp.

#### • Multiple incidents involving bulk transport of batteries.

At present, these are considered not to pose a major in-flight fire threat; however, the number of PEDs carried on-board aircraft is likely to increase in future. FODCOM 12/2008 issued by the UK CAA contains guidance and a checklist on dealing with cabin fires caused by lithium batteries in portable electronic devices.

Another potential threat is the increasing use of micro fuel cells for PEDs and fuel cell aeroplane APUs. Tests on fuel cartridges carried out by the FAA<sup>201</sup> found that all of the fuel cartridges present some fire hazard but Halon 1211 can easily control the flammable liquids and gasses from fuel cartridges. The FAA are planning more flammability tests on individual units, bulk shipments, fuel cells in use powering electronic equipment, and fuel cells charging batteries.

Restriction on charging of PEDs in flight may be considered to reduce the likelihood of such fires. Cabin crew training and sufficient guidelines from the authorities are likely to mitigate this threat; however one particular concern is that extinguishing a small lithium battery fire may expend all the in-cabin fire extinguishers.

#### 3) Future Considerations

# a) In-Flight Fire (Hidden and Visible) Related to the Increased Installation of In Flight Entertainment (IFE) Systems and Other Services (Galley Equipment, Bar Equipment, Seat Features) Associated with Longer Flights and Larger Aeroplanes.

This threat was identified in a study carried out for the UK CAA<sup>189</sup>. The study also found that, based on the review of UK Mandatory Occurrence Reports in the period 2002-2006, in-flight fire caused by IFE is the third most frequent in-flight fire occurrence. Galley fire is the most frequent in-flight fire occurrence. With larger aircraft/longer flights, the galley equipment is likely to be more extensive, with the potential to increase the already high frequency of galley fire occurrences. This concern was also raised during the VLTA Conference<sup>202</sup>.

#### b) Increased In-Flight Fire Risks Associated with the Use of Magnesium Alloy Seats.

Due to the potential for weight savings, magnesium alloys have been suggested as a substitute for aluminium alloys in seat structure and other applications. Although different magnesium alloys have varying susceptibility to ignition, once ignited, magnesium is very challenging to cope with using fire extinguishers currently available on aircraft. Current regulations do not address the use of flammable metal in large quantities in the cabin. The use of magnesium alloy is currently the subject of a task group of the International Aircraft Materials Fire Test Working Group<sup>203</sup>. The FAA is currently carrying out research and tests in this area addressing both the post crash<sup>204</sup> and in-flight fire scenarios.

# c) Increased Risk of Fire Associated with Newer Aircraft Having Cabin Altitude of 6000 ft (flammability is higher at lower altitude).

Most in-service experience of (uncontrollable) in-flight fires occurred at the altitude which the aircraft are pressurised to (i.e. approximately 8000 feet). New design aeroplanes are now lowering cabin altitude for passenger comfort to around 6000 feet. Given that flammability of materials is higher at lower altitude, a concern is raised that this could significantly increase the likelihood of uncontrollable fires. This study identified no research carried out on this subject as yet.

# d) In-Flight Fire Properties of Carbon Composite Material Different to that of Aluminium Structures.

Currently, there is no requirement on composite materials used outside the cabin, cargo compartment, and fire zones. The most used structural composite is carbon/epoxy, and this material has relatively poor fire resistance and can pose a serious fire hazard<sup>190</sup>. However, a number of advanced structural composites with superior fire properties have been identified and used in new

design aeroplanes. An aluminium panel transmits heat in a radial direction very effectively<sup>205</sup>; hence it does not react when exposed to a hidden fire source in flight<sup>206</sup>. When subjected to fire/heat, the behaviour of a composite panel is different to an aluminium panel; therefore, it must be proven that the materials chosen on a non-aluminium aircraft must provide at least an equivalent level of safety. Further research on damage due to hidden fires, effects of electric arcs and the composite material's post fire residual mechanical properties are required. FAA and CEAT Fire Safety Department have been carrying out research in this area.

#### **Conclusions and Recommendations**

It is recommended that EASA give consideration to:

- 1. Addressing fire protection in hidden areas in CS-25. It is recommended that EASA continue its participation in the joint efforts of authorities and industries in this area.
- 2. Participating in the research into the likely future threats related to the increasing installation of electrical systems, the use of magnesium alloy seats, the increasing use of lithium batteries and fuel cells, the effect of lower cabin altitude on the risks of in-flight fires, and in-flight flammability properties of non-aluminium aircraft structures. Any efforts made in these areas should correspond with on-going research and initiatives by other authorities and industry.
- 3. Carrying out further research to determine the extent to which Arc Fault Interrupters should be used and the risk of any potential disbenefits that they might exhibit.
- 4. Participating in the research being carried out by the FAA and Transport Canada into inerting of hidden areas in order to ensure that any future regulatory activity in this area is harmonised with these Authorities.
- 5. Monitoring and participating where appropriate, into research and development into:
  - a. Hidden fire detection systems, for example video cameras in overhead areas and portable thermal detection cameras for use by cabin crew
  - b. Installation of discharge ports for delivering extinguishing agent from a handheld fire extinguisher

The FAA is currently developing improved fire test methods and criteria for aircraft electrical wiring and ducting materials. Radiant panel tests may replace the existing Bunsen burner tests specified in Appendix F of CS-25. It is recommended that EASA give consideration to amending CS-25 to reflect any changes that may occur in FAR part 25 in this respect.

<sup>&</sup>lt;sup>182</sup> Transportation Safety Board of Canada, Aviation Investigation Report A02O0123 Cargo Bay Fire, Air Canada Boeing 767–300 C–GHML, Toronto/Lester B. Pearson International Airport, Ontario 13 May 2002

National Transportation Safety Board, NTSB Identification DCA01MA005, Airtran Airways Douglas DC-9, registration: N826AT, November 29, 2000, Atlanta, GA

National Transportation Safety Board, NTSB Identification: IAD01IA017, American Airlines McDonnell

Douglas DC-9-82, registration: N3507A, November 29, 2000 in Dulles, VA <sup>185</sup> Danish Aircraft Accident Investigation Board, Report No. HCL 67/00 Incident, Boeing 757-236 OY-GRL, Copenhagen Airport, Kastrup, 15 November 2000

National Transportation Safety Board, NTSB Identification: DCA00MA079, Airtran Airlines Douglas DC-9-32, registration: N838AT, August 08, 2000 in Greensboro, NC

National Transportation Safety Board, NTSB Identification: NYC99IA231, Delta Air Lines, McDonnell Douglas MD-88 registration: N947DL, September 17, 1999, Covington, Kentucky

<sup>&</sup>lt;sup>188</sup> Transportation Safety Board of Canada, Aviation Investigation Report, In-Flight Fire Leading to Collision with Water, Swissair Transport Limited, McDonnell Douglas MD-11 HB-IWF, Peggy's Cove, Nova Scotia 5 nm SW, 2 September 1998, Report Number A98H0003

Asmayawati, S., Butcher, N., Cherry, R. (2009) CAA Paper 2009/01 Cabin Crew Fire Training. Gatwick: UK

CAA <sup>190</sup> Mouritz, A.P. (2004) Fire Safety of Advanced Composites for Aircraft, ATSB Research and Analysis Report

<sup>191</sup> RGW Cherry & Associates (2002) A Benefit Analysis for Enhanced Protection from Fires in Hidden Areas on Transport Aircraft, CAA Paper 2002/01 - DOT/FAA/AR-02/50

RGW Cherry & Associates (2009), Summary of Thermal Acoustic Contamination Issues, 0997/R/000464/KK <sup>193</sup> Federal Aviation Administration Advisory Circular, USA, *Development of Transport Category Airplane* Electrical Wiring Interconnection Systems Instructions for Continued Airworthiness Using an Enhanced Zonal Analysis Procedure, AC No: 25-27. November 2007: U.S. Department of Transportation, Federal Aviation Administration. <sup>194</sup> Air Transport Association of America, Inc., ATA MSG-3 *"Operator/Manufacturer Scheduled Maintenance*"

Development", Revision 2003.1, 2003, Author.

Federal Aviation Administration, Development of and Improved Fire Test Method and Criteria for Aircraft Electrical Wiring (Update), Presented to The International Aircraft Material Fire Testing Working Group by John Reinhardt, 17-18 June 2009 <sup>196</sup> Reinhardt, J.W. (2008) *Development of an Improved Fire Test Method for Aircraft Ducting Materials,* 

DOT/FAA/AR-08/4. Washington, D.C.: FAA

Federal Aviation Administration, Hidden Fire Testing, Presented to the International Aircraft Systems Fire Protection Working Group by Dave Blake, 2-3 April 2008

Marker, T.R. (2004) A Preliminary Examination of the Effectiveness of Hand-Held Extinguishers against Hidden Fires in the Cabin Overhead Area of Narrow-Body and Wide-Body Transport Aircraft, DOT/FAA/AR-TN04/33. Washington, D.C.: FAA

<sup>199</sup> Transport Canada, Air Carrier Advisory Circular No. 0126R, 2006.11.30, Service Blankets, retrieved from http://www.tc.gc.ca/CivilAviation/commerce/circulars/AC0126.htm

Federal Aviation Administration, Battery Fires in Air Transportation, Presented at the Fifth International Cabin Safety Conference by Bill Wilkening, October 2007

Federal Aviation Administration, Fuel Cell Flammability - Fuel Cartridge Assessment, Presented to the International Aircraft Systems Fire Working Group by Harry Webster, 19 November 2008 <sup>202</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16

October 1998 <sup>203</sup> FAA Fire and Cabin Safety Research Technical Center Website, http://www.fire.tc.faa.gov/

<sup>204</sup> Federal Aviation Administration, Update on Flammability Testing of Magnesium Alloy Components, Presented to the International Aircraft Materials Fire Test Working Group by Tim Marker, 17 June 2009

<sup>205</sup> Federal Aviation Administration, In-Flight Burn Through Tests – Aluminum vs. composite materials,, Presented to the International Aircraft Systems Fire Working Group by Harry Webster, 20 November 2008 <sup>206</sup> Federal Aviation Administration, *Composite Fuselage Flame Propagation*, Presented to the International

Aircraft Systems Fire Working Group by Robert Ian Ochs, 17 June 2009

#### Cabin Safety Threat:

#### 21. Fires in Class E Cargo Compartments

FA01 / No Fire Suppression System in Class E Cargo Compartment

DO2 / Inappropriate Smoke/Fume Removal Procedure

D04/ Inadequate Performance of Class E Cargo Compartment Smoke Detection System



#### CS 25.831 Ventilation

If accumulation of hazardous quantities of smoke in the cockpit area is reasonably probable, smoke evacuation must be readily accomplished, starting with full pressurisation and without depressurising beyond safe limits.

#### AMC 25.851(b) Built-in Fire Extinguishers

5. (e). A Class E compartment is particular to an all-cargo aeroplane. Typically, a Class E compartment is the entire cabin of an all-cargo aeroplane; however, other compartments of such aeroplanes may be classified as Class E compartments. A fire in a Class E compartment is controlled by shutting off the ventilating airflow to or within the compartment. Additionally, most cargo aeroplanes have smoke/fire procedures that recommend that the crew turn off the ventilating air, don their oxygen equipment, and gradually raise the cabin altitude, between 6096 m (20,000 feet) and 7620 m (25,000 feet), to limit the oxygen supply and help control a fire until the aeroplane can descend to land.

#### Accident Experience and Safety Recommendations

The accident review found one accident where the absence of a fire suppression system in a Class E cargo compartment has presented a safety risk. The accident involved an in-flight fire in the main 'above floor' cargo compartment. In the same accident, the performance of the Class E cargo compartment fire detection system was found to be inadequate. Extracts from the accident report describing the event are as follows:

The accident airplane was not required to be equipped with a fire suppression system, and, as a result, the fire, which began as a smouldering fire in one of the cargo containers, was able to develop into a substantial fire that burned through the container and ceiling liner while the airplane was airborne (ADB Ref. 20060207A)<sup>207</sup>

Following the investigation of accident ADB Ref. 20060207A, the following findings were made:

5. The increased airflow that resulted from the Fumes Evacuation checklist actions diluted the smoke and inhibited its detection by either the smoke detection system or flight crewmembers and provided the fire with additional oxygen.

6. The aviation industry initiative on smoke, fire, and fumes provides specific guidance on when and how flight crews should respond to evidence of a fire in the absence of a cockpit smoke and/or fire warning.

10. The current certification test standards and guidance for smoke or fire detection systems on board many aircraft are not adequate because they do not account for the effects of cargo and cargo containers on airflow around the detection sensors and on the containment of smoke from a fire inside a container.

11. The threat from cargo fires could be mitigated by the installation of fire suppression systems.

Probable Cause: The National Transportation Safety Board determines that the probable cause of this accident was an in-flight cargo fire that initiated from an unknown source, which was most likely located within cargo container 12, 13, or 14. Contributing to the loss of the aircraft were the inadequate certification test requirements for smoke and fire detection systems and the lack of an on-board fire suppression system.

Following the investigation of accident ADB Ref. 20060207A, the following safety recommendations

were made to the FAA. The NTSB's account of the FAA's initial responses are included:

Provide clear guidance to operators of passenger and cargo aircraft operating under 14 Code of Federal Regulations Parts 121, 135, and 91K on flight crew procedures for responding to evidence of a fire in the absence of a cockpit alert based on the guidance developed by the 2004 smoke, fire, and fumes industry initiative. (A-07-97)

(On May 27, 2008, the FAA issued Information for Operators (InFO) message 08034, Design and Content of Checklists for In-Flight Smoke, Fire and Fumes (SFF). This InFO directed checklist designers to a template for developing a non-alerted smoke, fire, and fumes checklist and to a description of the philosophy used to develop the template. Issuance of the InFO meets the intent of this recommendation; consequently, Safety Recommendation A-07-97 is classified Closed Acceptable Action.)

Ensure that the performance requirements for smoke and fire detection systems on cargo airplanes account for the effects of cargo containers on airflow around the detection sensors and on the containment of smoke from a fire inside a container, and establish standardized methods of demonstrating compliance with those requirements. (A-07-98)

(The FAA replied that it would investigate the effects of cargo and cargo containers on airflow around smoke and fire detection sensors by conducting tests at the FAA's William J. Hughes Technical Center and by using a computer model of computational fluid dynamics. In addition, the FAA stated that it would review the technical standards order (TSO) for cargo containers with regard to containment of smoke from a fire inside a cargo container. Pending completion of the research and analysis of the effects of cargo and cargo containers on airflow around smoke and fire detection systems and incorporation of appropriate revisions to the TSO based on this research and analysis, Safety Recommendation A-97-98 is classified Open Acceptable Response.)

Require that fire suppression systems be installed in the cargo compartments of all cargo airplanes operating under 14 Code of Federal Regulations Part 121. (A-07-99)

(The FAA stated that it would review the guidance on Class E cargo-compartment fire protection and operators' procedures for cargo-compartment fire containment to determine the effectiveness of the fire protection systems. The FAA will also review the service history of Class E cargo compartments and evaluate requiring the installation of fire suppression systems in Class E compartments. The Safety Board recognizes that the actions described are the first steps that the FAA needs to take to implement the recommended regulatory change. Pending the establishment of a requirement that all cargo compartments of all cargo aircraft be equipped with fire suppression systems, Safety Recommendation A-97-99 is classified Open Acceptable Response.)

#### Research and Rulemaking Activities

Halon, the primary fire extinguishing agent used aboard aircraft, has been linked with environmental damage and thus further production of Halon has been banned. While there are sufficient stocks of Halon for the short-term, an alternative agent or suppression system must be developed for use in aircraft cargo compartments. In support of this, the FAA has developed a Minimum Performance Specification<sup>208</sup> (MPS) which any alternative system must meet.

The Commercial Aviation Safety Team (CAST) was founded in 1998 with a goal to reduce the commercial aviation fatality rate in the United States by 80 percent by 2007. By 2007 CAST was able

to report that by implementing the most promising safety enhancements, the fatality rate of commercial air travel in the United States was reduced by 83 percent. Today CAST continues to apply its integrated, data-driven strategy to reduce commercial aviation fatality risk in the United States and promote new government and industry safety initiatives throughout the world. The CAST Safety Plan<sup>209</sup> is a working document that tracks the organization's progress implementing safety enhancements. This document recommends the following safety enhancement related to fire protection in cargo aircraft:

127. RR - Cargo - Fire Containment: Improved cargo containers should be developed to contain (or suppress) fires originating in shipped cargo. Standards for fire containment/suppression should be developed, and containers standardized. New containers should be implemented whenever containers are replaced. Consideration should be given to using improved containers for as much cargo as is feasible.

The FAA commissioned RGW Cherry & Associates Limited to conduct a "Cost-Benefit Analysis for the Installation of Fire Suppression Systems in Cargo Compartments of Cargo Airplanes"<sup>210</sup>. This study concluded the following:

It is concluded that Halon fire suppression systems, or alternatives that are likely to be developed for below floor cargo compartments, are unlikely to be cost beneficial for the cargo compartments of cargo aircraft. Fire suppression systems, of the kind currently being considered for the cargo compartments of combi aircraft, may prove to be cost beneficial, particularly on larger cargo aircraft.

It is understood that the FAA will be considering non-conventional fire suppression systems, such as those installed inside the cargo container, etc.

#### **Conclusions and Recommendations**

1. Based on the review of the current applicable CS-25 requirements, accident experience, literature, and past/current rulemaking activities, it was concluded that further research is required to address the threats related to the absence of a fire suppression system in Class E cargo compartments. It is suggested that further research into fire protection on cargo containers be conducted, including different types of fire suppression systems. Liaison with the FAA in addressing this issue is recommended.

2. Accident evidence<sup>207</sup> shows that if a flight crew were to be faced with evidence of a fire (e.g. smoke/fumes), but the smoke detection system did not activate, the flight crew may inadvertently increase the airflow at the fire by conducting a smoke clearance procedure (ventilation), rather than carrying out a fire suppression procedure (ventilation reduction) to starve the fire of oxygen. Following the 2006 DC-8 accident<sup>207</sup> which involved an in-flight fire within a Class E cargo compartment, the NTSB recommended that the FAA should *"Provide clear guidance to operators of passenger and cargo aircraft operating under 14 Code of Federal Regulations Parts 121, 135, and 91K on flight crew procedures for responding to evidence of a fire in the absence of a cockpit alert based on the guidance developed by the 2004 smoke, fire, and fumes industry initiative."* This has been carried out.

However, it is considered that such guidance falls within the remit of the Flight Manual and as such should be included within CS-25. It is therefore recommended that EASA considers adding appropriate guidance material within CS-25, regarding the inclusion within Flight Manuals and Flight Crew Operating Manuals, of flight crew procedures for responding to evidence of a fire in the absence of a cockpit alert.

3. Following the 2006 DC-8 accident<sup>207</sup> involving an in-flight fire within a Class E cargo compartment, in which the fire detection system was inhibited by airflow around the detection sensors, it is recommended that EASA monitor the FAA research and analysis being carried out into the effects of cargo and cargo containers on airflow around smoke and fire detection systems. This threat is

considered adequately addressed by CS-25 since CS 25.855 (f) states "There must be means to prevent cargo or baggage from interfering with the functioning of the fire protective features of the compartment".

<sup>210</sup> RGW Cherry & Associates Limited. (2009). 1715/R/000431/KK Issue 3, A Cost-Benefit Analysis For The Installation Of Fire Suppression Systems In Cargo Compartments Of Cargo Airplanes. United Kingdom: Author.

<sup>&</sup>lt;sup>207</sup> National Transportation Safety Board,, NTSB/AAR-07/07 PB2007-910408, Inflight Cargo Fire United Parcel Service Company Flight 1307 McDonnell Douglas DC-8-71F, N748UP, Philadelphia, Pennsylvania, USA, *February 7, 2006.* <sup>208</sup> US Federal Aviation Administration (2005) DOT/FA-A/AR-TN05/20, *Minimum Performance Standard for* 

Aircraft Cargo Compartment Halon Replacement Fire Suppression Systems (2<sup>nd</sup> Update). Washington, D.C.: FAA. <sup>209</sup> The Commercial Aviation Safety Team (2007) *CAST Safety Plan*. United States: Author.

### Cabin Safety Threat:

# 22. In-Flight Fire in Remote or Isolated Compartments (FA06)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

Other than the interior flammability requirement in CS 25.853(d) and (e), there are no other CS-25 Cabin Safety requirements addressing in-flight fire protection for remote or isolated compartments.

#### Accident Experience and Safety Recommendations

The accident review carried out in this study did not identify events associated with this cabin safety threat.

#### Research and Rulemaking Activities

This threat was identified during the brainstorming session. Installation of multiple areas isolated from (the main) passenger compartment is a novel and unusual design feature and is not adequately addressed by the current airworthiness requirements.

Isolated or remote compartments<sup>b</sup> have been the subject of Certification Review Items (CRI) in the form of Special Conditions. As mentioned in one CRI related to a VIP configuration<sup>211</sup>, the most significant concern raised by isolated compartments is related to timely fire detection. The Special Condition has included the following fire protection requirements:

- Each isolated compartment must incorporate a smoke detection system that meets the requirements of 25.858. A visual and audible indication of a smoke detection, that identifies in which compartment the smoke has been detected, must be provided to the flight crew or to the cabin crew.
- In addition to what is prescribed by 25.851, at least one hand fire extinguisher appropriate to the kinds of fires likely to occur and associated protective breathing equipment must be provided in close proximity of the doors that lead from each emergency exit area to each isolated compartment.
- It must be demonstrated that there is sufficient access in flight to enable a crew member to effectively reach any part of the isolated compartment with the content of a hand fire extinguisher.
- It must be demonstrated that no hazardous quantities of smoke, flames or extinguishing agents will enter any compartment that could be occupied by the crew members or passengers.
- If a waste container is installed, it must meet the relevant requirements of 25.853[h].
- Smoking is not permitted in isolated compartments. Appropriate placards must be installed to indicate these restrictions.

These fire protection provisions are generally the same for crew rest compartments<sup>212,213,214,215,216,217,218,219,220,221</sup>. Some of the Special Conditions on crew rest compartments also mention the use of built-in fire extinguishing systems that comply with the requirements in CS 25.851(b).

<sup>&</sup>lt;sup>b</sup> Isolated compartment: isolated from the rest of the cabin by means of internal doors, curtains, or partition. Remote compartment: other areas not necessarily physically separated from the rest of the cabin but are in remote locations with respect to passenger compartments. Some of those areas might not be occupied during the entire flight or be occupied only during taxi, takeoff and landing.

As raised at the Very Large Transport Aeroplane Conference<sup>222</sup> in 1998, there will inevitably be potential for areas in VLTA being unoccupied and unsupervised for longer periods of time compared with existing aircraft. Additionally, crew may not always have sight or control of passengers during flight. Therefore, detection systems will be required and with a high degree of accuracy and timely notification. Some of the recommendations arising from the VLTA conference on fire protection are as follows: In view of fire protection aspects which may be compounded, altered or have unique benefit due to the size, shape and configuration of VLTA aircraft, there was general agreement that the following issues need to be studied during VLTA design development and certification: 4- Smart systems for the crew to detect smoke and fire in hidden or unoccupied areas. 7- Detection and suppression in large compartment used for carry-on baggage and electrical equipment. 6- The amount and location of fire emergency and survival equipment for use by the crew. The FAA has issued SFAR No. 109 'Special Requirements for Private Use Transport Category Airplanes Regulatory Information'<sup>223</sup>, which contained fire protection requirements as follows: 12. Materials for Compartment Interiors. Compliance is required with the applicable provisions of Sec. 25.853, except that compliance with appendix F, parts IV and V, to part 25, need not be demonstrated if it can be shown by test or a combination of test and analysis that the maximum time for evacuation of all occupants does not exceed 45 seconds under the conditions specified in appendix J to part 25. 13. Fire Detection. For airplanes with a type certificated passenger capacity of 20 or more, there must be means that meet the requirements of Sec. 25.858(a) through (d) to signal the flightcrew in the event of a fire in any isolated room not occupiable for taxi, takeoff and landing, which can be closed off from the rest of the cabin by a door. The indication must identify the compartment where the fire is located. This does not apply to lavatories, which continue to be governed by Sec. 25.854. 15. Hand-Held Fire Extinguishers. (a) For airplanes that were originally type certificated with more than 60 passengers, the number of hand-held fire extinguishers must be the greater of--(1) That provided in accordance with the requirements of Sec. 25.851, or (2) A number equal to the number of originally type certificated exit pairs, regardless of whether the exits are deactivated for the proposed configuration. (b) Extinguishers must be evenly distributed throughout the cabin. These extinguishers are in addition to those required by paragraph 14 of this SFAR, unless it can be shown that the cooktop was installed in the immediate vicinity of the original exits. **Conclusions and Recommendations** The review of certification documents has shown that fire protection in remote or isolated compartments not permanently occupied during flight is required and therefore consideration should be given to amend the airworthiness requirements to reflect this. Since Special Conditions have been issued to address this matter, additional requirements for such installations will not incur additional costs to aircraft manufacturers/modifiers or operators and certification costs may even be reduced. It is recommended that this proposal be considered for evaluation via a Regulatory Impact Assessment.

<sup>211</sup> European Aviation Safety Agency, Isolated Compartments Special Conditions 24 November 2008

<sup>212</sup> European Aviation Safety Agency, Airbus A350 Certification Review Item, Ref. D-04 (Draft), dated 21 August

2008 <sup>213</sup> European Aviation Safety Agency, Crew Rest Compartments Special Conditions for Boeing Model 787 series (no date) <sup>214</sup> Federal Aviation Administration, *Final Special Conditions No. 25-169-SC Boeing Model 777-200 Series* 

Airplanes; Overhead Crew Rest Compartment <sup>215</sup> Federal Aviation Administration, Final Special Conditions No. 25-01-01-SC Boeing Model 777-200 Series

Airplanes; Overhead Crew Rest compartment

Federal Aviation Administration, Final Special Conditions No. 25-216-SC-A Boeing Model 777-200 Series Airplanes; Overhead Crew Rest Compartments <sup>217</sup> Federal Aviation Administration,, Final Special Conditions No. 25-260-SC Boeing Model 777 Series

Airplanes; Overhead Crew Rest Compartment Occupiable During Taxi, Take-off, and Landing <sup>218</sup> Federal Aviation Administration, Final Special Conditions No. 25-230-SC Boeing Model 777-200 Series Airplanes; Overhead Crew Rest compartment

Federal Aviation Administration, Final Special Conditions No. 25-281-SC; Airbus Model A330, A340-200 and A340-300 Series Airplanes; Lower Deck Mobile Crew Rest (LD-MCR) Compartment <sup>220</sup> Federal Aviation Administration, Final Special Conditions No. 25-331-SC; Boeing Model 777-200 Series

Airplanes; Forward Lower Lobe Crew Rest Compartment (CRC)<sup>221</sup> Federal Aviation Administration, Final Special Conditions No. 25-332-SC; Boeing Model 767-300 Series

Airplanes: Forward Lower Lobe Crew Rest Module (CRM)

<sup>2</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16 October 1998

Federal Aviation Administration, SFAR No. 109, Special Requirements for Private Use Transport Category Airplanes Regulatory Information

# Cabin Safety Threat:

# 23. Assist Means Reliability and Design

Y02 / Assist Means Fails to Remain Inflated

Y03 / Exit Opened with Assist Means in Disarmed Mode

Y06 / Using the Slide in an Adverse or Abnormal Aircraft Attitude

Y09 / Assist Means Do Not Inflate

Y10 / Assist Means Obstructed or Its Shape Altered

Y13 / Assist Means Do Not Deploy (or Partially Deploy) due to Technical Reasons

Y15 / Dual-Lane Slide Used as Single Lane

Y16 / Assist Means Blown by Wind

Y18 / Assist Means Fails to Inflate Automatically

Y20 / Slide Burnt by External/Ground Pool Fire

Y21 / Deployment of Slide into Cabin

Y24 / Slide Disconnects from Door or Slide Pack Falls Off

Y17 / Injuries Related to Using the Slide during Evacuation (No Slide Failure)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to assist means are as follows:

*CS* 25.803 (a) Each crew and passenger area must have emergency means to allow rapid evacuation in crash landings, with the landing gear extended as well as with the landing gear retracted, considering the possibility of the aeroplane being on fire.

CS 25.810 Emergency egress assist means and escape routes

(a) Each non-over-wing landplane emergency exit more than 1.8 m (6 feet) from the ground with the aeroplane on the ground and the landing gear extended and each non-over-wing Type A exit must have an approved means to assist the occupants in descending to the ground.

(1) The assisting means for each passenger emergency exit must be a selfsupporting slide or equivalent; and, in the case of a Type A exit, it must be capable of carrying simultaneously two parallel lines of evacuees. In addition, the assisting means must be designed to meet the following requirements.

(i) It must be automatically deployed and deployment must begin during the interval between the time the exit opening means is actuated from inside the aeroplane and the time the exit is fully opened. However, each passenger emergency exit which is also a passenger entrance door or a service door must be provided with means to prevent deployment of the assisting means when it is opened from either the inside or the outside under non-emergency conditions for normal use.

(ii) It must be automatically erected within 10 seconds after deployment is begun.

(iii) It must be of such length after full deployment that the lower end is selfsupporting on the ground and provides safe evacuation of occupants to the ground after collapse of one or more legs of the landing gear.

(iv) It must have the capability, in 46 km/hr (25-knot) winds directed from the most critical angle, to deploy and, with the assistance of only one person, to remain usable

after full deployment to evacuate occupants safely to the ground. (v) For each system installation (mock-up or aeroplane installed), five consecutive deployment and inflation tests must be conducted (per exit) without failure, and at least three tests of each such five-test series must be conducted using a single representative sample of the device. The sample devices must be deployed and inflated by the system's primary means after being subjected to the inertia forces specified in CS 25.561(b). If any part of the system fails or does not function properly during the required tests, the cause of the failure or malfunction must be corrected by positive means and after that, the full series of five consecutive deployment and inflation tests must be conducted without failure.

Detailed slide design and performance requirements are contained in a Technical Standard Order TSO C69c (FAA) or ETSO-C69c (EASA). ETSO-C69c is the same as the current FAA TSO-C69c which has been effective since 18 August 1999.

#### Accident Experience and Safety Recommendations

#### 1) Slide Reliability and Design Affecting Evacuation Process

The accident review found several problems with slide reliability and design that have affected the speed of evacuation. The problems are summarised in the following table:

NO.	SLIDE PROBLEMS	IDENTIFIED IN ACCIDENT REVIEW
1.	Assist means do not deploy (or partially deploy) due to technical reasons	4 accidents (20050802A <sup>226</sup> , 20040721C <sup>227</sup> , 20020811A <sup>228</sup> , 20001031B <sup>229</sup> )
	The causes identified were as follows: Jamming of release pin, improper installation, slides might have expired and not inspected, fractured inflation hose, and fuse pins remained connected near the base of the girt skirts.	1 safety recommendation from 20001031B, directed to IATA, FAA, and JAA to provide support to an international joint government/industry program to develop possible improvements to emergency evacuation and procedures (ASC-ASR-02-04-48, - 52 & -56)
	In one accident (20050802A), two passengers incurred serious injuries due to the non-deployment of the slide – one when he jumped from the exits, the other when pushed out of the exit by other passengers.	
	In two incidents <sup>224,225</sup> the slides did not deploy due to a malfunction caused by a Velcro fastener that became hooked on a clip on the inside of the decorative cover.	
2.	Assist means in disarmed mode	3 accidents (20060708A <sup>230</sup> , 20030702B <sup>231</sup> ,
	The main cause of this problem was cabin	20000927B )
	Crew error.	No safety recommendations $(200000144)^{235}$
3.	Assist Means do not inflate	2 accidents (20020114B <sup>-1,1</sup> , 19990914A <sup>-1,1</sup> )
	The causes identified were as follows: Slide drop to the ground was insufficient to cause inflation, and unknown cause.	1 safety recommendation from 20020114B (to ensure escape slides function and are certified properly)
	In an incident involving a DC10 in Manchester, UK on 8 March 1998 <sup>233</sup> , three slide/rafts did not inflate properly.	

4	1.	Assist means not automatically inflated	1 accident (19990824A <sup>236</sup> )
		The cause of this problem was not identified.	No safety recommendations
		This problem also occurred in an accident involving a B747 at Detroit, Michigan, on 11 February 1987, an MD-83 at East Granby, Connecticut on 12 November 1995, and a B737 at Grand Rapids, Michigan on 18 November 1996 <sup>225</sup> .	
5	5.	Assist means fails to remain inflated	3 accidents (20060708A, 20050802A, 20030702B)
		The causes of this problem were as follows: damaged by sharp metal objects/debris on the ground, punctured by a blunt edged object.	No safety recommendations
		In one of the accidents (20030702B), an evacuee sustained a fractured vertebra when the slide she was on deflated.	
6	6.	Using the slide in an adverse or abnormal aircraft attitude	4 accidents (20051208A <sup>237</sup> , 20050802A, 19990923A <sup>238</sup> , 19990914A)
		The causes of these problems were failure of one or more landing gears, and the aeroplane resting on uneven terrain.	No safety recommendations
		Steep slides were usually avoided in evacuations that did not feature a life- threatening situation. But when they were used, the evacuees were more likely to sustain injuries.	
		Shallow slides, on the other hand, slowed down the evacuation for the following reasons: the evacuees had to "scoot" down the slide, became trapped in a folded portion of the slide, became bunched up at the bottom of the slides, or because the slides became filled with water from the rain.	
7	7.	Assist means obstructed or its shape altered	4 accidents (20051208A, 20050802A,
		The causes of this problem were as follows:	20041128A , 20030702B)
		vehicle, and slide twisted after deployment	PEC 26/05. It is recommended to the EAA that the
		due to it being delayed inside the slide compartment.	REC 26/05. It is recommended to the FAA that the expected modification of the escape slide of door 1 R of Boeing 737 aircraft to avoid the twisting of the slide after inflation and deployment is made mandatory for all the affected aircraft when it becomes available.
ε	3.	Assist means blown by wind	3 accidents (20050415A <sup>240</sup> , 20010306B <sup>241</sup> , 20001031B)
		The wind speeds during the evacuation in these accidents were: 18 knots from 320 deg	1 safety recommendation from 20001031B
		16 knots gusting to 24 knots from 010 deg, and in excess of 25 knots.	To the Boeing Company and IATA: 1. Provide
		During the evacuation of an American Airlines A300B4-605R on July 9, 1998 <sup>224</sup> , the 4R slide/raft was blown on its side by the wind and could not be used until it was stabilised by someone on the ground.	information, including cautions to be observed, when required to operate emergency evacuation slides in wind gusts that exceed the certified limit. (3.2-[34]) -ASC-ASR-02-04-35 & -49

ę	9.	Slide burnt by external/ground pool fire	1 accident (20001031B)
			1 safety recommendation from 20001031B (-ASC- ASR-02-04-48, -52 & -56 see No. 1 of this table)
1	0.	Uncommanded deployment of slide into cabin	3 accidents (20020331A <sup>242</sup> , 20001031B, 20000305A <sup>243</sup> )
		The causes of this problem were: Lateral impact forces exceeded the design limit	2 safety recommendations from 20001031B and 20000305A:
		(1.5g), failure of slide cover latch brackets in the forward slide compartments, and the inflation lanyard snagged on the mini-nuts as the door began to move.	<ul> <li>To US FAA &amp; JAA: 2. Review emergency slide design to reduce the potential for uncommanded inflation resulting from lateral impact forces. (3.2- [35]) -ASC-ASR-02-04-53 &amp; 57 (20001031B)</li> </ul>
		The inadvertent deployment of a slide into the cabin has blocked exits or aisles (20020331A, 20000305A), prevented the cabin crew from performing their duties during evacuation (20001031B), and caused injuries (20001031B).	<ul> <li>Issue an airworthiness directive to require all operators of Boeing 737-300 through -500 series airplanes to replace the slide cover latch brackets on forward slide compartments with the type of slide cover latch brackets installed on the forward slide compartments of Boeing 737-600 through -900 series airplanes. (A-01-12) (2000305A) – Closed-Acceptable Action</li> </ul>
1	1.	Slide disconnects from door or slide pack falls off	3 accidents (20031218A <sup>244</sup> , 20030617A <sup>245</sup> , 20010317A <sup>246</sup> )
		The causes of this problem were as follows: crew pulled wrong handle (disengage handle instead of manual inflation handle) due to inadequate training equipment, failure of slide bar system, and excess chamfer on girt bar.	3 safety recommendations from 20031218A and 20010317A. A safety recommendation from 20031218A was directed at training and procedures. The safety recommendations shown below are from 20010317A:
			Immediately issue an emergency airworthiness directive to require operators of overwater-equipped Airbus Industrie A319, A320, and A321 airplanes with manually chamfered girt bars to (1) Ensure that the dimensions of the trigger locking mechanism and the stationary portion of the girt bars conform to the design specifications; (2) Perform a reliable functional test to demonstrate the proper engagement of manually chamfered girt bars under realistic door opening conditions; and (3) Repair or replace any girt bars that do not meet the dimensional requirements or do not pass the functional test, before the airplanes are returned to service. (A-01-27) – Closed-Acceptable Alternate Action
			Issue an airworthiness directive to require operators of overwater-equipped Airbus Industrie A319, A320, and A321 airplanes with machine-chamfered girt bars to, by the next scheduled maintenance activity, (1) Ensure that the dimensions of the trigger locking mechanism and the stationary portion of the girt bars conform to the design specifications; (2) Perform a reliable functional test to demonstrate the proper engagement of the girt bars under realistic door opening conditions; and (3) Repair or replace any girt bars that do not meet the dimensional requirements or do not pass the functional test, before the airplanes are returned to service. (A-01- 28) - Closed - Acceptable Alternate Action

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12.	Dual lane slide used as single lane	1 accident (20050802A)
	The cause of this problem was as follows: There are no clear visual cues to indicate that some dual-lane slides actually have two lanes.	No safety recommendations
s a re	esult of their safety study <sup>247</sup> , the Canadian TS	SB issued the following recommendation:
Since 7 of 15 evacuations requiring slides were hindered as a result of problems related to deployment and/or angle of inclination, it appears that the intent of the current Airworthiness Standard is not being achieved. Given that the use of effectively deployed escape slides may be critical to the success of an aircraft evacuation, the Board recommends that:		
The Department of Transport, in concert with industry, re-evaluate the performance of escape slides on all large passenger-carrying aircraft registered in Canada, to confirm that they can be functionally deployed in accordance with the criteria of the Airworthiness Standard. A95-03		
Transport Canada's response to this recommendation was that a substantial rewrite of TSO-C69 was in process. It is understood that this was referring to the current TSO.		
Based on several accidents where slide problems had occurred, the NTSB issued recommendations A-99-99 to -103 <sup>248</sup> , as follows:		
Discontinue the practice of allowing inadvertent and actual slide or slide/raft deployments to be used as a method of demonstrating compliance with an air carrier's Federal Aviation Administration-approved maintenance program. (A-99-99) - Closed - Acceptable Action		
	For a 12-month period, require that all demonstrate the on-airplane operation of al door opening assist mechanisms and slide each type of airplane (minimum of one demonstrations should be conducted on an the entire evacuation system can be prop results of the demonstrations (including an should be documented for each component FAA. (A-99-100) - Open - Unacceptable Res	I operators of transport-category aircraft I emergency evacuation systems (including or slide/raft deployment) on 10 percent of airplane per type) in their fleets. These airplane in a controlled environment so that erly evaluated by qualified personnel. The explanation of the reasons for any failures) of the system and should be reported to the sponse
	Revise the requirements for evacuation maintenance procedures in air carrier mainte evacuation systems on the basis of an anal Safety Recommendation A-99-100. Part representatives from aircraft and slide crewmember and maintenance association Response	system operational demonstrations and enance programs to improve the reliability of ysis of the demonstrations recommended in icipants in the analysis should include manufacturers, airline operators, and ons. (A-99-101) - Open - Unacceptable
Based on reports of component or system failures discovered in the demonstration program recommended in Safety Recommendation A-99-100, establish an effective method of identifying recurring or potentially recurring failure modes and ensuring that		

Ensure that all personnel accomplishing any installation, repairs, or inspections of emergency evacuation systems receive training to ensure that they have proper knowledge of the operation and installation of the systems. (A-99-103) - Closed -Acceptable Action

those failures are adequately addressed by issuing airworthiness directives or taking

other appropriate actions. (A-99-102) - Open - Unacceptable Response

#### 2) Slide Design and Injuries Sustained During Evacuation

The accident review found 9 accidents where 'Injuries Related to Using the Slide during Evacuation (No Slide Failure)' has presented a risk to the safety of the occupants. Extracts from the accident reports describing the events are as follows:

Some passengers had minor injuries as a result of the emergency evacuation. Five females and four males reported on the injuries they sustained during their evacuations. Their injuries varied. Five of them were shortly hospitalized for medical examination and treatment (passengers 4C, 11 B, 1 2F, 1 8B and 26D). A former cabin attendant declared she had deliberately taken off her shoes before jumping into the slide. As a result she sustained small cuts on her toes. Reportedly there must have been at least three more passengers with bleeding cuts on their bare feet. (ADB Ref. 20041128A)<sup>239</sup>

One passenger sustained a fracture to her arm and another fractured her foot. Both were as a result of using the escape slides. The copilot, on descending the upper deck right (UDR) slide, holding a 3 kg BCF fire extinguisher, found that he was unable to control his speed and stability. During his descent he released the fire extinguisher, but momentum propelled him forward, subsequently landing heavily on his shoulder, fracturing his collar bone. A further four passengers and one cabin crewmember were treated for minor injuries. Of the remaining passengers, a number reported injuries in the form of cuts, abrasions, sprains and bruising. (ADB Ref. 20030702B)<sup>231</sup>

One passenger sustained minor lacerations and scrapes on the right hand, and another passenger sustained a broken right ankle. The passenger with the broken ankle underwent surgery for the injury, and was hospitalized for a period exceeding 48 hours. (ADB Ref. 20030416A)<sup>249</sup>

The captain ordered an emergency evacuation utilizing the airplane's four evacuation slides. All slides functioned normally; however, during the egress a passenger sustained a fractured bone in her right foot. One passenger sustained a serious injury, while one flight attendant and five passengers sustained minor injuries. (ADB Ref. 20021109A)<sup>250</sup>

An emergency evacuation was performed during which one passenger received a broken arm. This passenger reported, "A flight attendant motioned to me to leave by the galley door by pointing with his finger. I crouched down as best I could and sat on the slide. The next memory I had was laying face down on the tarmac, in pain, wondering how I got there. My first instinct was to stand up and walk to the other passengers. A firefighter stopped me and said that I fell from a further distance than I thought I did and that I shouldn't move until I got checked out." At witness reported that the passenger stepped out onto the slide during the evacuation. The passenger bounced down the slide and fell over the side when approximately four to five feet off the ground. (ADB Ref. 20020124A)<sup>251</sup>

All eight slides deployed normally; however, during the evacuation, one passenger broke her ankle while exiting the bottom of the slide. She was transported to the hospital, treated for her injuries, and returned to the airport to continue on the flight. (ADB Ref. 20011029A)<sup>252</sup>

The passenger seated in 11H-suffered injuries while evacuating the aircraft via the evacuation slide raft. (An 80-year-old passenger seated in row 11 suffered serious wounds while sliding without assistance down the slide raft.) [Findings:] The flight attendant responsible for the L1, R1, L4 emergency exits failed to enlist passengers who had left the aircraft earlier to provide assistance to those following on the sideway. As a result, several passengers were injured sliding down the sideway (ADB Ref. 19990824A)<sup>236</sup>

One passenger was seriously injured during the emergency evacuation. A female "nonrevenue" passenger, who exited the airplane through the aft door slide, slid past the awaiting crew members, twisting her right ankle. The emergency slide from the aft door deploys at a steeper angle than the one for the forward door. Both slides are the same length; however, the aft door is higher above the ground than the forward door. The passenger was treated by medical personnel and transported to a local hospital. Subsequent medical reports and X-rays revealed that the passenger sustained a hairline fracture of a bone in her right ankle. (ADB Ref. 19981226A)<sup>253</sup>

Many passengers experienced minor evacuation injuries from contact with the slides or from contact with the coarse vegetation surrounding the aircraft's final stopping location. (ADB Ref. 19980521A)<sup>254</sup>

The report on the accident involving a B747-400 in Tokyo, May 1998 estimated that all the injuries (4 serious and 20 minor) occurred sliding down, or at the bottom of, the slide<sup>255</sup>.

In addition to the above occurrences, a study sponsored by the FAA<sup>261</sup> identified many others where evacuees sustained serious and minor injuries by using the slide. The following are some of the injuries described in the study:

- A 34 year old male passenger had a sprained left forearm caused by another passenger grabbing his arm (because he was assisting other passengers with exiting the slide at the bottom) ----- a 54 year old female passenger got minor abrasions & lacerations to left foot and right elbow. Also sprained left ankle upon landing on the pavement (cause was impact on the pavement at the bottom of the slide) – DFW International Airport, 14 May 2006
- 1 scraped knee while sliding down the slide Memphis, 18 December 2003
- 1 flight attendant suffered from slide abrasions Kahului, 5 October 2003
- 1. aggravated an old back injury upon landing at the bottom of the slide; 2. sliding down the slide; 3. sliding down the slide; 4. friction from sliding down the slide; 5. landing on the pavement at the bottom of slide; 6. passenger stated he fell forward onto the pavement after reaching the bottom of the slide; 7. impact with the pavement at the bottom of the slide, she was the first passenger off and nobody to catch her; 8. anxiety from evacuation – Dallas, 25 September 2003
- 1. Abrasions on elbows and knees from "tumbling" off forward right slide; 2. Abrasions to arm struck by another passenger while using forward right slide; 3. swollen knee, treated by family physician; 4. bruise on left leg; 5. abrasion on hand from forward right slide; 6. injured tailbone, landing on door sill before going down forward left slide; 7. Head, neck and back pain; 8. contusion on right arm; 9. strained hamstring in right thigh from jumping off of wing; 10. Fractured left ankle; 11. abrasion on knee; 12. injured tailbone and back; 13. twisted knee, lacerated knee; 14. abrasion and contusion on knee; 15. cuts and bruises; 16. cuts and bruises on right leg; 17. pelvic pain; 18. neck, back and shoulder pain; 19. bruise on right arm; 20. neck and back pain; 21. abrasion on left hand LGA, 26 March 2003
- A female passenger toppled and landed head first minor facial abrasions Atlanta, 23 August 2002
- A female passenger suffered from leg burns/abrasions from nylon/slide contact Memphis, 20 June 2002
- Serious include: 1. Leg Fracture; 2. Sprained Knee; 3. Back pain; Minors include: Abrasions and Contusions Miami, 20 November 2000
- 1. Friction burns on forearms from friction from slide surface; 2. Bruises and abrasions;
   3. Friction burns on calves of both legs; from friction from slide surface; 4. Sprain/strain of lower left leg from impact with the ground at the bottom of the slide Dallas, 17 July

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- One passenger broke her ankle because the passenger did not jump out the exit as directed, but rather sat down, and slid out. Two passengers received minor injury, one of which was a twisted knee – Grand Rapids, 18 November 1996

Hynes (1999)<sup>256</sup> found that the total estimated direct costs of injuries in precautionary emergency evacuations borne by airlines for the period analysed (1991-1993) were \$8.54 million per year for passenger injury costs plus \$1.83 million per year for administrative costs associated with processing injury claims.

#### Research and Rulemaking Activities

#### 1) Slide Reliability and Design Affecting Evacuation Process

A study by the National Aerospace Laboratory (NLR) Netherlands found that the fatality rate for evacuations involving slide problems was 1.7 times higher than the fatality rate for evacuations not involving slide problems<sup>257</sup> - however, it is unclear whether this higher fatality rate was a result of slide problems or whether the slide problems coincided with a higher fatality rate for other reasons in certain types of accident, for example accidents involving high impact or severe fire. The scope of the study was survivable accidents involving slide use in the period 1970-2003 (150 accidents). It was concluded that in 54% of the historical accidents involving evacuation slides reviewed in the study, one or more slides did not function properly.

A study carried out by the NTSB in  $2000^{258}$  found that in 7 of the 19 evacuations where slides were used (37%), at least one slide did not function properly. An older study by the NTSB (1974)<sup>259</sup> found that in 4 of 10 case study evacuations (40%), one or more slides did not operate correctly. A study carried out by the Canadian TSB<sup>247</sup> found that in 7 of the 15 evacuations where slides were used (47%), there were problems related to their deployment or to their angle of inclination. These problems occurred five times each. The UK CAA found that in the study of 62 actual emergency evacuations with slides involved (on incidents only) of UK registered aircraft in the period 1980-1994, 9 occurrences (15%) featured slide problems<sup>260</sup>.

NLR Study on 150 survivable aircraft accidents 1970-2003 <sup>257</sup>	NTSB <sup>258,259</sup> & TSB Study <sup>247</sup> (derived by NLR)	UK CAA Study on 268 maintenance/test slide deployments 1980-1994 <sup>260</sup>
<ul> <li>Slide inflation problems (28.1%)</li> <li>Aircraft attitude (15.7%)</li> <li>Other (13.5%)</li> <li>Wind (12.4%)</li> <li>Burnt slide (11.2%),</li> <li>Incorrect rigging of the slide (7.9%)</li> <li>Ripped slide (6.7%)</li> <li>Unknown (4.5%)</li> </ul>	<ul> <li>No (automatic) inflation of slide (46.9%)</li> <li>Problems due to wind (12.5%)</li> <li>Problems with slides due to extreme attitude of the aircraft (12.5%)</li> <li>No deployment of slide due to problems with emergency exit door (9.4%)</li> <li>Slide detached from aircraft (9.4%)</li> <li>Slide inflated inside aircraft (6.3%)</li> <li>Inadequate slide stability caused injury to evacuee(s) while descending (3.1%)</li> </ul>	<ul> <li>Incorrect assembly of the slides (29.1%)</li> <li>Grit-bar mechanism failure (14.9%)</li> <li>Mis-rigging (11.2%)</li> <li>Inflation device malfunctions (7.8%)</li> <li>Failure to deploy with no obvious cause (6%)</li> <li>Other/unknown (31%)</li> </ul>

The NLR study states that problems with slides continue to occur at a similar rate, despite recommendations regarding improvement in slide reliability made by accident investigation organisations.

The NLR study made the following recommendations:

- Disseminate these findings and conclusions [of the study] to all interested parties (including civil aviation authorities, transportation safety authorities, aircraft manufacturers, evacuation-slide manufacturers and airlines);
- Analyze the influence of strong gusts on the proper functioning of slides; and
- Analyze SDRs for slides to identify their relationship to problems found during accident evacuations and incident evacuations, and to monitor any influence of regulations that affect slide reliability.

#### 2) Slide Design and Injuries Sustained During Evacuation

A study sponsored by the FAA<sup>261</sup> examined available data regarding commercial aircraft slide deployments with particular focus on injuries to aircraft crew and passengers incurred during slide evacuations. The data show that over the study period (1 January 1996 – 30 June 2006), about 50% of emergency evacuations result in injuries. However, only about 10% of the injuries examined in the study may be classified as serious; the remaining 90% would be classified as minor and moderate. The study identified that evacuation injuries were usually related to evacuees' speed on the slides and at the bottom of the slides, which are a function of coefficient of friction as well as the orientation of the slide. The study found that a pile-up of evacuees at the bottom of the slide can cause serious injuries, and excessive speeds on the slide can easily cause skin burns and abrasions.

The study also identified a clear deficiency of recorded data and detailed information on emergency evacuation events.

The list of issues identified from the ARFF survey carried out in the study contained amongst others:

- Injuries to passengers and crew would be the biggest issue. Broken or sprained ankles and/or burns, mainly on the passengers' wrists, arms and backside due to the abrasiveness of the slides.
- The speed of initial passengers evacuating down slide with no ground assistance result in back ups and injuries.
- The serious head injuries etc. are most often caused by passengers landing on top of one another at the base of the slide.

One of the ARFF recommendations was "*Develop/design a more ergonomic slide angle and slide termination points thus decreasing [passenger] injury*".

According to a study on evacuee injuries in precautionary emergency evacuations<sup>262</sup>, in the period from January 1, 1988, through December 31, 1996, there were more than 500 precautionary emergency evacuations on transport aeroplanes (approximately one evacuation every six days). Each year as many as 6,000 persons were involved in these events. In many cases, passenger and crewmember injuries resulted from such evacuations, incurring large costs to passengers as well as airlines. It was found that 19 of the 109 (17.4%) precautionary evacuations that were analysed further resulted in injuries to 190 passengers and 3 crewmembers. The study concluded that preventing evacuee injuries associated with emergency evacuations can be accomplished in several ways, such as:

- (1) safety reducing the number of these events;
- (2) improving the design of aircraft emergency egress systems and emergency exits;
- (3) upgrading air carrier training programs and operations;
- (4) improving passenger safety information and education.

The study suggested upgraded information management systems on evacuation events and research dedicated to minimising the negative consequences of all emergency evacuations. This supports Hynes' study in 1999<sup>256</sup>,

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

#### Discussion

#### 1) Slide Reliability and Design Affecting Evacuation Process

The following issues are considered best addressed by amendments to CS-ETSO, improvements in installation/maintenance and checking, and improvements in training/operation procedures:

- Slide deployment and inflation problems. The NLR study found that slide inflation problems could be caused by many different factors, amongst others were empty inflation bottles and incorrect assembly of slide systems. The accident review found that improper installation, inadequate checking, and poor design or manufacture were generally the cause of slide deployment/inflation problems. Poor design should be addressed by improvements to ETSO-C69c.
- Assist means in disarmed mode. This issue will be best addressed with improvements in training and/or procedures.
- Assist means fails to remain inflated. ETSO-C69c specifies the required tensile strength, tear strength, and puncture strength. Additionally, "The device must be capable of resisting puncture and tear of the sliding and walking surfaces and supporting structure from objects normally carried or worn by passengers that could result in collapse of the device, prevent the device from performing its intended function, or both." Puncture by sharp objects such as debris on the ground was not addressed.
- Assist means shape altered. Twisting of slide after inflation should be addressed by ETSO-C69c.
- Slide burnt by external/ground pool fire. Fire resistance and its required test procedures are specified in ETSO-C69c.
- Inadvertent deployment of slide into cabin. This issue should be addressed in ETSO-C69c.
- Slide disconnects from door. This issue can be addressed by improvements in training and training equipment, procedures, and maintenance/installation practice.
- **Dual lane slide used as single lane**. This issue should be addressed in ETSO-C69c.

Consideration should be given in carrying out research or amending CS-25 for the following issue:

#### Assist means blown by wind

The following are cases featuring slide problems due to wind as identified in the accident sample reviewed by NLR<sup>257</sup>:

30-07-1971 San Francisco, USA B747-100 (20 knots) 02-01-1982 Sault Ste. Marie, Canada B737-200 (22 gusting to 36 knots) 12-05-1983 Regina, Sask, Canada DC-9-32 (18 gusting to 28 knots) 05-11-1983 Johannesburg, South Africa B747-B (6 knots) 25-03-1987 Chicago, USA DC10-10 (14 knots) 01-02-1990 Baltimore, USA DC10-10 (12 knots) 05-03-1994 Regina, Canada DC-9-32 (22 gusting to 27 knots) 24-12-1997 Schiphol, The Netherlands B757-200 (32 gusting to 42 knots) 09-07-1998 San Juan, Puerto Rico A300-600 (13 knots) 12-07-2000 Wien, Austria A310 (13 gusting to 17 knots) 30-11-2000 Shannon, Ireland B737-800 (28 gusting to 42 knots) ETSO/TSO C69c and CS 25.810(a)(1)(iv) require that an inflatable slide must have the capability, in 25-knot winds directed from the most critical angle, to deploy and, with the assistance of only one

25-knot winds directed from the most critical angle, to deploy and, with the assistance of only one person, to remain usable after full deployment to evacuate occupants safely to the ground. A study sponsored by the US FAA<sup>261</sup> made recommendations regarding first responders' actions to mitigate this problem, rather than slide design. However, whilst the first passengers down the slide could be instructed to help stabilise the slide, in reality they often walk away leaving the first responders to do the task – which may not be realistic if they are required to respond to more urgent threats such as

fires. There is no specification on the capability of the person holding the slide when such capability depends largely on the gender, age, size and physical condition of the person. Additionally, a survey of ARFF groups<sup>261</sup> revealed that the primary concern was the instabilities induced by winds during slide deployment – not after full deployment.

The NLR study<sup>257</sup> pointed out that existing literature indicated that mean wind speed exceeding 25 knots has a very low probability – about 6 instances per billion departures, as derived from measurements at 601 knots. Although this is a relatively low probability, it may not be possible to delay evacuation or divert an aircraft during an emergency because of high wind conditions. The study also suggested that the mean wind speed itself is not a decisive factor; wind direction and gusts can have a more adverse effect on slide stability. Gusts are not considered in the requirements.

Qualification of escape slides above 25 knots wind was one of the items listed in JAA's "Proposed New Initiatives – Evacuation Related"<sup>263</sup>.

#### 2) Slide Design and Injuries Sustained During Evacuation

Because accident rates have been decreasing (particularly in the western world), this has allowed more attention to be directed towards areas of safety that were previously not considered a priority, such as the reduction and mitigation of injuries during emergency evacuation. This is even more important when the high frequency of precautionary emergency evacuations and their associated costs are taken into consideration.

Better or more detailed instructions on the passenger safety card, as well as consistency in the commands issued by cabin crew on slide usage, may reduce the risk of injuries sustained by passengers. However this would depend on the passengers reading, understanding, and remembering the instructions on the safety card, and/or following the commands of the cabin crew.

Injuries could be reduced if passengers are routinely assisted off the bottom of the slide. However, there is no guarantee that passengers assigned by the cabin crew to give this assistance, would actually fulfil the task. It is unlikely that rescue/firefighting personnel would be available to assist very often and there would be insufficient numbers to fully assist in accidents involving very large transport aeroplanes, having many slides.

Since elderly people, who are likely to be more susceptible to slide injuries, will make up a greater proportion of the population in the future, the total number of slide injuries may rise.

A slide angle of approximately 48° can cause evacuees to hesitate before jumping onto the slide<sup>264</sup> and greater than 50° can cause injuries. On the other hand, a shallow angle of the slide, as shown by accident experience, can also slow the evacuation and cause injuries to evacuees. A study on evacuation injuries<sup>261</sup> concluded that "the optimum rate of descent for evacuees is usually achieved when the angle between the slide surface and the ground is approximately 30° to 50°. If the angle is much greater than 50°, the slide angle may be too steep, and this may result in evacuee injury upon impact with the ground." The study did not indicate whether this is applicable to slides of emergency exits with a particular sill height, or any sill height.

The severity of this threat is clearly dependant on the sill height of the emergency exit (hence the size of the aeroplane). A higher threat will exist on larger aeroplanes, but the threat may be minimal for smaller aeroplanes.

The "intelligent slide" technology used by A380 (developed by Airbus and Goodrich), which can adjust the length of the slide according to the fuselage angle, should be considered for use in other aeroplanes, particularly large aeroplanes, to address the issue related to steep angle of the slide in the event of a landing gear collapse.

#### 3) Availability of Data

Several studies have highlighted that the data on emergency evacuation events, which include slide usage and associated injuries, were very limited.<sup>256,261,262</sup> This data unavailability makes it difficult to
accurately assess the cost-benefit of any improvements made to the slide to reduce the risk of evacuee injuries. Therefore, it is recommended that there should be an enhanced reporting and information management system on evacuation events.

### **Conclusions and Recommendations**

If other exits are already unavailable due to unforeseen and unavoidable circumstances (e.g. fire outside the exits), slide problems that render the remaining exits unusable can seriously affect occupants' survivability. Therefore, it is very important that the slides be capable of operating properly. Although inadequate maintenance practices or operational checks and crew error might be accountable for the issues encountered in slide/raft operations in service, there is still room for improvement in the design and approval of the system. Most of the issues can be addressed in CS-ETSO but some existing CS-25 requirements may need to be amended, particularly with regard to the slide deployment under high wind conditions. It is recommended that consideration be given by EASA to investigate the actual circumstances addressed by CS 25.810(a)1)(iv) to determine the adequacy of the requirements specifically on the subject of gusts and the effects of winds/gusts on the slide during the deployment and the associated efforts required in stabilising the slide.

There are indications that injuries related to the use of the slide during evacuation can be addressed by improvements in slide design. It is therefore recommended that consideration be given by EASA to carry out further research on minimising evacuee injuries related to slide use by taking into account both operational and design aspects (such as minimum/maximum angle and optimum friction), with the intention on providing guidance material.

As concluded in several studies, there is a need to establish a reporting and information management system on evacuation events, not limited to accident-related evacuations but also precautionary evacuations, with sufficient details on the performance of the emergency systems and equipment as well as any injuries and costs incurred.

<sup>&</sup>lt;sup>224</sup> National Transportation Safety Board, *Accident Brief MIA98IA195, American Airlines A-300B4-605R, registration: N80057, July 09, 1998, San Juan* 

<sup>&</sup>lt;sup>225</sup> National Transportation Safety Board, Safety Recommendation A-33-33 through -103, Dec 9, 1999

<sup>&</sup>lt;sup>226</sup> Transportation Safety Board of Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005

 <sup>&</sup>lt;sup>227</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, *Technical Report IN-045/2004, In-flight engine failure involving a McDonnell Douglas MD-83, registration EC-FTS, operated by Spanair, on 21 July 2004 at Alicante Airport* <sup>228</sup> National Transportation Safety Board, *NTSB Identification NYC02FA160, Iberia Airlines Boeing 747-256,*

<sup>&</sup>lt;sup>228</sup> National Transportation Safety Board, *NTSB Identification NYC02FA160, Iberia Airlines Boeing 747-256, registration: EC-DNP, August 11, 2002, Jamaica, NY* 

<sup>&</sup>lt;sup>229</sup> Aviation Safety Council Taiwan, *Crashed on a partially closed runway during takeoff, Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, Chiang Kai Sek Airport, Taoyuan, Taiwan, October 31, 2000* 

 <sup>&</sup>lt;sup>230</sup> Interstate Aviation Committee, Final Report on the Results of the Investigation of the Accident A-310-324 F-OGYP OAO Aviakompania Sibir 8 July 2006
<sup>231</sup> Aviated ion Transport Oxfet Design and Content of the Accident A-310-324 F-

<sup>&</sup>lt;sup>231</sup> Australian Transport Safety Bureau, *Boeing 747-438, VH-OJU, Sydney Aerodrome, NSW, 2 July 2003* Investigation Report BO/200302980

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<sup>2000</sup> <sup>233</sup> Air Accidents Investigation Branch, AAIB Bulletin No: 2/2000 Ref: EW/C97/12/2, McDonnell Douglas DC-10-30 N68065, Manchester Airport, 8 March 1998

 <sup>&</sup>lt;sup>234</sup> National Transportation Safety Committee, Department of Communications Republic Of Indonesia, Aircraft Accident Report KNKT/02.01/03.03.011, PT. Lion Air, Boeing 737-200 PK-LID, Sultan Syarif Kasim II Airport, Pekanbaru, Riau, 14 January 2002

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<sup>236</sup> Aviation Safety Council, Accident Investigation Report ASC-AAR-00-11-001, UIA 873, B-17912, MD-90-30 cabin explosion and fire during landing roll Hua-Lien, Taiwan, August 24th, 1999 <sup>237</sup> National Transportation Safety Board, Runway Overrun and Collision Southwest Airlines Flight 1248 Boeing

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<sup>239</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, *Technical Report A-070/2004*,

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<sup>241</sup> National Transportation Safety Board, NTSB Identification IAD01IA034, Federal Express McDonnell Douglas DC-10 registration: N375FE, March 06, 2001, Boston, MA

<sup>242</sup> National Transportation Safety Board, NTSB Identification MIA02FA075, Delta Air Lines McDonnell Douglas MD-11, registration: N809DE, March 31, 2002, Charlotte, NC

<sup>243</sup> National Transportation Safety Board, Aircraft Accident Brief DCA00MA030, Southwest Airlines flight 1455 Boeing 737-300, N668SW, Boeing 737-300, N668SW, Burbank, California

<sup>244</sup> National Transportation Safety Board, Aircraft Accident Report, NTSB/AAR-05/01, Hard Landing, Gear

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National Transportation Safety Board, NTSB Identification NYC03LA016, American Airlines Accident occurred November 09, 2002 in Flushing, New York, McDonnell-Douglas MD-82 registration N452AA <sup>251</sup> National Transportation Safety Board, NTSB Identification CHI02LA069, Northwest Airlines Accident occurred

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National Transportation Safety Board, NTSB Identification FTW99LA054, Delta Airlines Accident occurred December 26, 1998 in DFW Airport, Texas, McDonnell-Douglas MD-88 registration N907DE

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<sup>259</sup> National Transportation Safety Board (1974) Special Study – Safety Aspects of Emergency Evacuations from *Air Carrier Aircraft, NTSB-AAS-74-3.* Washington, D,C.: NTSB <sup>260</sup> UK Civil Aviation (1995) *Escape slides. Data + Plus.* Gatwick: UK CAA

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## Cabin Safety Threat:

## 24. Exit Door Failures

X02 / Exit Door Cannot Be Opened or Is Difficult to Open due to Unknown Reasons

X04 / Exit Door Cannot Be Opened or Is Difficult to Open due to Frame Distortion

X06 / Exit Door Cannot Be Opened or Is Difficult to Open due to the Failure of Operating Mechanism

X13 / Exit Door Cannot Be Opened or Is Difficult to Open due to Interference with Interior Panel

## Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to emergency exit doors are as follows:

*CS* 25.783 (b): Opening by persons. There must be a means to safeguard each door against opening during flight due to inadvertent action by persons. In addition, for each door that could be a hazard, design precautions must be taken to minimise the possibility for a person to open the door intentionally during flight. If these precautions include the use of auxiliary devices, those devices and their controlling systems must be designed so that:

(1) no single failure will prevent more than one exit from being opened, and

(2) failures that would prevent opening of any exit after landing must not be more probable than remote.

CS 25.809 (b): Each emergency exit must be openable from the inside and the outside except that sliding window emergency exits in the flight crew area need not be openable from the outside if other approved exits are convenient and readily accessible to the flight crew area. Inward opening doors may be used if there are means to prevent occupants from crowding against the door to an extent that would interfere with the opening of the door. Each emergency exit must be capable of being opened, when there is no fuselage deformation –

(1) With the aeroplane in the normal ground attitude and in each of the attitudes corresponding to collapse of one or more legs of the landing gear; and

*CS* 25.809 (d): If a single power-boost or single power operated system is the primary system for operating more than one exit in an emergency, each exit must be capable of meeting the requirements of subparagraph (b) of this paragraph in the event of failure of the primary system. Manual operation of the exit (after failure of the primary system) is acceptable.

*CS* 25.809 (e): Each emergency exit must be shown by tests, or by a combination of analysis and tests, to meet the requirements of sub-paragraphs (b) and (c) of this paragraph.

*CS* 25.809 (g): There must be provisions to minimise the probability of jamming of the emergency exits resulting from fuselage deformation in a minor crash landing.

### Accident Experience and Safety Recommendations

#### 1) Exit door failures due to unknown reasons

The accident review found 4 accidents where one or more exit door(s) could not be opened for unknown reasons during evacuation. Extracts from the accident reports describing the events are as follows:

- **Malaga CASA 235 August 2001** The left rear exit door, 2L, was not used as it could not be opened. The rear left passenger door, of type 1 and larger than the type III emergency exits, remained closed after the complete evacuation of the passengers and crew. It could not be opened from the inside or the outside. With the exception of the ruck at rib 30 on the fuselage, no local deformations were found in the area of the passenger door. There were however some broken seats. The result of the analyses carried out has not been able to establish conclusively whether the rear left door should have reasonably remained operative under the accelerations reached in accordance with the airworthiness requirements under which the plane was certified, since the actual estimate of the accelerations proved very complicated due to the absence of measured values in the final section of the impact with the embankment. [Finding:] 18. The rear left passenger door remained jammed as a result of the impact of the aircraft, remaining closed during the evacuation despite attempts to open it. (ADB Ref. 20010829A)<sup>265</sup>
- **Girona Boeing 757 September 1999** The cabin crew had difficulty in opening some of the doors and were assisted by passengers. Emergency exit doors L3 and service door R4 could not be opened and RI door was only partly opened. (ADB Ref. 19990914A)<sup>266</sup>
- **Hualien MD90 August 1999** The R3 emergency exit in the mid section above the right wing failed to open. (ADB Ref. 19990824A)<sup>267</sup>
- Atlanta Boeing 737 November 1998 Passengers escaped through the left forward (L1), left aft (L2), and right aft (R2) doors and through the exits located over the wings. (The right forward [R1] door could not be fully opened.) (ADB Ref. 19981101B)<sup>268</sup>

### 2) Exit door failures due to frame distortion

The accident review found 5 accidents where frame distortion has caused the jamming of one or more exit door(s) during evacuation. Extracts from the accident reports describing the events are as follows:

- **Toronto A340 August 2005** Approximately four feet ahead of cabin door R4, there was a fold in the outer fuselage skin, indicating that the location was subjected to substantial bending forces during deceleration and break-up. The permanent deformation of the fuselage was very likely transmitted to the door frame. This would explain the difficulty the cabin crew experienced when attempting to open the R4 door. The door initially resisted opening and required two cabin crew members to push the door open. (ADB Ref. 20050802A)<sup>269</sup>
- **Minneapolis DC9 May 2005** The FO tried to open the sliding clearview window to his right, but it would only open part of the way. The ground crew person starting banging on the window with the fire axe, but with little success. "Three, four, five minutes" went by and then fire and rescue personnel arrived. (ADB Ref. 20050510C)<sup>270</sup>
- Hong Kong MD11 August 1999 Doors L1, R2, R3, L4 and R4 were jammed either closed or partially open due to damage sustained to the crown of the fuselage... In the early stage of the evacuation, some passengers and crew members attempted to open doors L1, R2, R3, L4 and R4 without success, and they subsequently followed other passengers to leave the aircraft via the available exits. (ADB Ref. 19990822A)<sup>271</sup>
  - Little Rock MD82 June 1999 The 1L door was displaced downward, and the forward portion

was twisted inboard and aft. The 1L door handle was found in the 10 o'clock position and could not be moved. Investigators were not able to open the door. The 1R door was found closed. The handle was in the two o'clock position and unmovable by investigators, and the door could not be opened. The flight attendant and several passengers entered the tail cone area, but the tail cone did not fall away from the airplane after the flight attendant and at least one passenger pulled the release handle. The flight attendant and passengers then kicked and jumped on the tail cone and created a gap between the fuselage and the tail cone (ADB Ref. 19990601A)<sup>272</sup>

The NTSB Safety Study<sup>273</sup> discussed this particular accident further:

Only two flight attendants reported any difficulty with opening floor level exit doors. These two attendants were on the MD-82 that incurred severe structural deformation when it crashed in Little Rock (case 45). One flight attendant reported that both of the forward floor level exit doors were inoperable because of crash forces. The two other Little Rock passengers attempted to open inoperable forward floor level exit doors. The second flight attendant reported that the floor level exit door leading to the tailcone exit could not be opened initially because of a deformation in the floor of the airplane. The door was eventually opened through the combined efforts of the flight attendant and two male passengers. Three Little Rock passengers attempted to open a floor level exit door leading to the tailcone; the door exit could not be opened because of a deformation in the floor of the airplane.

- **Quincy Beech 1900C November 1996**<sup>c</sup> Rescuers reported that they heard signs of life when they first reached the Beech 1900C, but they were unsuccessful in their attempts to open the air stair door. The [NTSB] Safety Board concludes that the most likely reason that the air stair door could not be opened is that the accident caused deformation of the door/frame system and created slack in the door control cable. (ADB ref 19961119A)<sup>274</sup>

## 3) Exit door failures due to failure of the operating mechanism

The accident review found 2 accidents where the failure of the operating mechanism has caused door jamming. Extracts from the accident reports describing the events are as follows:

- **Durban Jetstream 41 June 2005** After the aircraft came to rest, the cabin attendant attempted to open the rear cabin emergency door in order for the passengers to evacuate the aircraft, but the door operating mechanism was found jammed and the door failed to open. The passengers and crew then evacuated the aircraft from the forward main cabin entry door. (ADB Ref. 20050611A)<sup>275</sup>
- Lajes A330 August 2001 The evacuation was attempted using all emergency exits and evacuation slides. All doors and slides functioned normally, except for exit L3, which only opened approximately 20 to 25 centimetres. When the evacuation was ordered, the flight attendant seated at L3 position attempted to open door L3; however, the door handle did not rotate all the way up, and the door only opened approximately 20 to 25 centimetres. It also was reported that the power-assist did not appear to work. A photo taken of the door from outside the aircraft showed the L3 door partially opened and the escape slide slightly askew and apparently connected to both the floor and the door. Conclusive finding as to the cause of the door jam could not be made, primarily because of the missing components. Notwithstanding, interviews and photos confirm that the slide had not released completely from the door, and that the bustle rails/rail adapters may have jammed. There have been at least two, previously documented cases where the slide rails have jammed preventing opening of the door in the emergency mode. Studies of these previous occurrences by Goodrich indicated that the jamming might have been caused by incomplete installation of a pin forming part of the assembly. On 30 July 2001, to mitigate risks of improper installation, Goodrich published

<sup>&</sup>lt;sup>c</sup> Whilst this accident is outside of the accident review period it has been included in the study due to the particular relevance of the findings of the accident to this issue.

Service Bulletin Number 25-306, introducing a rework of the rail-associated components. Goodrich recommended compliance with the SB at the next scheduled unit maintenance. In conjunction with the Goodrich SB, Airbus issued SB's A330-25-3126 and A340-25-4152 (for the A330 and A340 respectively) dated 07 August 2001. Airbus also recommends compliance, but with no time frame specified. At the time of the accident (two weeks later), the Airbus non-mandatory bulletins had not been yet received by Air Transat. The Findings of the accident report state that jamming of the L3 emergency exit somewhat hampered the evacuation of the aircraft. (ADB Ref. 20010824C)<sup>276</sup>

## 4) Exit door failures due to interference with interior panel

Interference with interior panel which caused difficulty in opening window exits was found in one accident:

Teterboro Gulfstream IV December 2004 The copilot then went aft, and attempted to open the right forward window exit. The exit release handle moved, and the exit became loose in the opening, but would not free from the airplane. The copilot attempted the aft right window exit with the same result. The rectangular decorative interior trim panels attached to the exit hatches, extended behind the passenger service unit (PSU) panels that ran longitudinally down the fuselage, above the window exit panels, and prevented normal operation of the three window exits. (ADB Ref. 20041201B)<sup>277</sup>

The following NTSB Recommendations were made as a result of the Quincy Beech 1900C accident in November 1996 (ADB Ref. 19961119A):

A-97-103 Evaluate the propensity of Beech 1900C door/frame system to jam when it sustains minimal permanent door deformation and, based on the results of that evaluation, require appropriate design changes.

A-97-104 the NTSB recommends that the FAA: establish clear & specific methods for showing compliance with the freedom from jamming certification requirements.

A-97-105 the NTSB recommends that the FAA: consider the circumstances of the 11/19/96, Quincy Illinois, accident when developing methods for showing compliance with freedom from jamming requirements, & determine whether it is feasible to require that doors be shown to be free from jamming after an impact of similar severity.

Although all of these recommendations have been closed by the NTSB they do suggest that there is some lack of clarity on what is required by the requirements relating to exit jamming following *"a minor crash landing."* as defined in CS/FAR 25.809 (g)

No further recommendations relating to this subject were identified from the review.

### Research and Rulemaking Activities

A study carried out by the Canadian TSB<sup>278</sup>, relating to the evacuation of large passenger carrying aircraft concluded:

"The Board does not consider that specific safety action regarding operation of emergency doors or over-wing exits is warranted at this time. However, the Board is concerned that four evacuations were significantly delayed because crew could not deploy the airstairs, possibly due to their false expectations that the airstairs could be deployed without power"

A study carried out on behalf of Transport Canada<sup>279</sup>, relating to emergency evacuations

following a severe fire threat concluded that:

"The causes of unavailability of floor level exits identified by the study were:

- 1. Door jamming probably due to impact distortion or damage
- 2. Door Mechanism Mechanical failure
- 3. Passenger lack of understanding of method of opening
- 4. Flight Attendants inability to open.

Of these the most prevalent cause was door jamming probably due to impact distortion or damage constituting 71% of the identified causes of unavailability of floor level exits. There were no more than two occurrences identified for the other causes and as such no firm conclusions can be made concerning their significance. It was assessed that approximately 72 fatalities resulted from floor level exit failures based on all the accidents studied. For the known exit failures it was assessed that 18 of the 35 fatalities were as a consequence of exit jamming due to impact distortion or damage – i.e. approximately 50%. "

EASA have recently proposed an amendment to CS-25<sup>280</sup> to require that :

CS.25.813(c) (5) For aeroplanes with a passenger seating configuration of 41 or more, each Type III exit must be designed such that when operated to the fully open position, the hatch/door is automatically disposed so that it can neither reduce the size of the exit opening, the passageway(s) leading to the exit, nor the unobstructed space specified in subparagraph (c)(1)(ii) of this paragraph, to below the required minimum dimensions. In the fully open position it must also not obstruct egress from the exit via the escape route specified in CS 25.810(c). (See AMC 25.813(c)).

In support of this Regulatory activity Transport Canada and the UK CAA commissioned a Benefit Analysis related to Automatically Disposable Hatches (ADH) at Type III emergency exits<sup>281</sup>. This analysis concluded that there was likely to be a positive benefit provided by an ADH, however, the achieved benefit would be sensitive to exit failure rate. Subsequent accident analysis suggested that even though it might be expected that the more complex mechanism of an ADH might result in an increase in the exit jamming rate this increase was unlikely to result in the benefit provided by the improved hatch becoming negative. This assertion was based on the assumption that the jamming of an exit was random for any given impact conditions and that it was unlikely that the conditions resulting in exit jamming could result in multiple exits becoming jammed. A subsequent study suggested that exit jamming of conventional overwing exits was likely to be random.

The study carried out on behalf of Transport Canada <sup>279</sup>, relating to emergency evacuations following a severe fire threat suggested that exit jamming has resulted in fatalities. However, the magnitude of this threat and the degree to which it might be mitigated by amendments to the requirements cannot be determined without further research.

### Conclusions and Recommendations

Whilst as part of the EASA rulemaking activity for Automatically Disposable Hatches it was established that the accident experience suggested that impact conditions were unlikely to result in multiple overwing exit jamming, this was not established for floor level exits. The NTSB recommendation that the FAA should "...establish clear & specific methods for showing compliance with the freedom from jamming certification requirements" is now closed, however it does suggest that there may be some doubt as to the criteria that the aircraft manufacturer should use in showing compliance with CS 25.809 (g). Whilst the Canadian TSB<sup>278</sup> study relating to the evacuation of large passenger carrying aircraft did not indicate a need to take "...specific safety action regarding operation of emergency doors or over-wing exits" concern was expressed regarding the delays incurred in evacuations "... because crew could not deploy the airstairs, possibly due to their false

expectations that the airstairs could be deployed without power".

There is evidence that exit jamming during emergency evacuation in the presence of post-crash fires has resulted in fatalities. However, further research is required to ascertain the magnitude of the threats related to exit jamming and the degree to which it might be mitigated by amendments to the airworthiness requirements.

<sup>265</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, Informe Técnico A-048/2001, Accidente ocurrido el día 29 de agosto de 2001 a la aeronave CASA CN-235 matrícula EC-FBC, en las proximidades del Aeropuerto de Málaga (Málaga)

National Transportation Safety Board, NTSB Identification DCA99MA007, Airtran Airways B737-200

registration: EI-CJW, November 1, 1998, William B. Hartsfield International, Dallas, TX <sup>269</sup> Transportation Safety Board of Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005 <sup>270</sup> National Transportation Safety Board, NTSB Identification CHI05MA111A, Northwest Airlines, McDonnell

Douglas DC-9-51 registration: N763NC, May 10, 2005 in Minneapolis, MN

Accident Investigation Division - Civil Aviation Department Hong Kong, Aircraft Accident Report 1/2004, Report on the accident Boeing MD11 B-150 at Hong Kong International Airport on 22 August 1999

National Transportation Safety Board, Aircraft Accident Report, Runway Overrun During Landing - American Airlines Flight 1420, McDonnell-Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999 <sup>273</sup> National Transportation Safety Board (2001) Safety Study – Emergency Evacuation of Commercial Airplanes,

NTSB/SS-00/01. Washington D.C.: NTSB

National Transportation Safety Board, Aircraft Accident Report NTSB/AAR-97/04 Runway Collision United Express Flight 5925 And Beechcraft King Air A90 Quincy Municipal Airport Quincy, Illinois November

19,1996 <sup>275</sup> South African Civil Aviation Authority, *Incident Report – Executive Summary Ref: 0411, Jetstream 41* Registration ZS-NRI, 11 June 2005, Durban International Airport

Aviation Accidents Prevention and Investigation Department Government of Portugal, Accident Investigation Final Report All Engines-out Landing Due to Fuel Exhaustion Air Transat Airbus A330-243 marks C-GITS Lajes, Azores, Portugal 24 August 2001, ref. 22 / ACCID /GPIAA / 2001

National Transportation Safety Board, NTSB Identification NYC05FA026, Commercial Gama Aviation *Gulfstream Aerospace G-IV registration: G-GMAC, December 01, 2004 Teterboro, NJ* <sup>278</sup>Transportation Safety Board of Canada (1995) Report Number SA9501, *A Safety Study of Evacuations of* 

Large, Passenger-Carrying Aircraft. Canada: Author. <sup>279</sup> RGW Cherry & Associates (2002) 0919/R/000129/KK Issue 1, A Study of Factors Influencing the Evacuation

of Occupants in Fire Related Accidents. United Kingdom: Author

 <sup>280</sup> European Aviation Safety Agency, *Notice of Proposed Amendment (NPA) No. 2008/04* <sup>281</sup> RGW Cherry & Associates (2008) 0942/R/000308/KK Issue 2, *Benefit Analysis for the Installation of* Automatic Hatches at Type III Exits, Prepared for Transport Canada

Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, Technical Report A-054/1999, Accident to Boeing 757-200 G-BYAG at Girona Airport on 14 September 1999

Aviation Safety Council Taiwan, Accident Investigation Report ASC-AAR-00-11-001, UIA 873, B-17912, MD-90-30 Cabin explosion and fire during landing roll, Hua-Lien, Taiwan, August 24<sup>th</sup>, 1999

## Cabin Safety Threat:

## 25. Evacuees Ability to Find Available Exit in a Dark/Smoke-Filled Cabin

W03 / Darkness or Smoke inside Cabin during Evacuation

W04 / Failure of Emergency Lighting or Escape Path Marking or Exit Marking System

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 has several requirements to ensure that exits can be found by passengers during emergency conditions. The requirements are as follows:

CS 25.811 Emergency exit marking paragraphs (a), (b), (c), (d), (g)

*CS 25.812 Emergency Lighting* paragraphs (a), (b), (c), (d), (e), (f), (i), (j), (k), (l)

#### Accident Experience and Safety Recommendations

The accident review found 5 accidents where heavy smoke was present during evacuation and likely to have hindered the evacuation process. Extracts from the accident reports describing the events are as follows:

The relentless spread of the fire in the lower section of the fuselage and along the skin of the upper part of the passenger cabins, the high concentration of combustion products, the smoke, darkness and panic that broke out among passengers greatly hindered the evacuation of passengers. (ADB Ref. 20060708A)<sup>282</sup>

The first officer stated that, after he transmitted to the ATCT that they were evacuating the airplane, the smoke was so heavy that he could not see his hand in front of him. (ADB Ref. 20060207A)<sup>283</sup>

The cabin crew ordered an evacuation within seconds of the aircraft stopping because fire was observed out the left side of the aircraft, and smoke was entering the cabin. Smoke entered the cabin through the opened evacuation doors before the evacuation was complete. Black smoke first entered the cabin from the left side of the aircraft, just below the windows in the area of passenger seat rows 29 and 31. When the aircraft came to a stop, smoke continued to enter the cabin, making it difficult to see during the evacuation. (ADB Ref. 20050802A)<sup>284</sup>

During the airplane's exit from the runway onto taxiway B-3, the lead flight attendant opened the cockpit door and announced that there was smoke in the cabin. A short time later, the lead flight attendant again opened the cockpit door and reported that the amount of smoke in the cabin had increased and asked the captain if he wanted to evacuate. He [the captain] reported that the visibility in the first class cabin was about 1 to 2 feet. (ADB Ref. 20001129B)<sup>285</sup>

(also ADB Ref. 20001031B below)

Darkness was mentioned as a factor that hindered evacuation in 3 accidents:

The main comments gathered, apart from the fact that personal items were taken before the evacuation, were that it was very dark both inside and outside the aircraft. As it has been stated above, it is very probable that the emergency lighting system was on and worked correctly, but even in that case a lot of statements mentioned the abnormal darkness. (ADB Ref. 20041128A)<sup>286</sup>

All items inside the aircraft fell down, seats were thrust forward, and all lights went out, making it dark inside the aircraft, except for light streaming in through the broken fuselage. (ADB Ref. 20020415A)<sup>287</sup>

(also ADB Ref. 20001031B below)

In the following accident, the investigation report states that the current system of emergency lights is ineffective when the cabin is filled with smoke and dust:

This passenger [17A] mentioned that when the two upper deck exits were opened. a very bad burning smell and heavy smoke immediately entered the cabin from outside. Cabin visibility was about 1 meter. The whole cabin was dark and he [4R outboard CC] could not see any emergency lights. She [4R CC] could not see the emergency lights in cabin. Based on the interview data, when the accident happened, the escape path lights on the floor and exit lights appeared dim in heavy smoke and dust. During accidents involving post-crash fire, dense smoke and noise adversely affect vision and hearing. It is essential that emergency exits and direction of movement be identified immediately by the survivors. Some survivors located at the tail section of the aircraft, stated that they did not see the emergency lights at the exit door. Other survivors indicated that they could hardly see the very dim emergency lights. The investigation team determined that most of the cabin emergency lights located in the tail section were operating normally during the accident. The ability to see the emergency lights was impaired by dense smoke and dust, making it more difficult for survivors to find their way out of the aircraft. This indicates that the current system of emergency lights is ineffective when dealing with circumstances of this accident. (ADB Ref. 20001031B)<sup>288</sup>

Following the investigation of accident ADB Ref. 20001031B, the following finding was made:

29. The dense smoke made breathing difficult and the emergency lights less visible for the survivors during the evacuation.

The investigation of this accident resulted in the following safety recommendation to the Boeing Company, US FAA, and JAA:

2. Review the effectiveness of cabin emergency lights to ensure that maximum conspicuity is achieved in dense smoke following survivable accidents. ASC-ASR-02-04-36, -54, & -58

The accident review also found that emergency lighting systems have failed in 3 accidents. Extracts from the accident reports describing the events are as follows:

Based on information provided by cabin crew and passengers and from completed passenger safety questionnaires, it appears that, during the impact sequence, the regular lighting system in the cabin went out. The emergency lighting system came on, flickered, went off in some areas of the cabin and remained on in other areas. The floor escape path marking system lights were not on in the passenger aisle leading to the R4 emergency exit door during the evacuation. Photos taken by passengers inside the cabin during the evacuation confirmed that the ceiling exit sign adjacent to the exit L2 was lit. The emergency lighting in the forward cabin likely failed at the same time as the PA system. In the passenger safety questionnaire, passengers were asked to report on visibility after the aircraft came to a stop. In all, 20 per cent of respondents reported that, from their seats, they could see only a "few rows around them"; 14 per cent reported that they could only see "a few seats around them." Respondents did not indicate why their visibility was restricted, although they were asked to do so. Although it was somewhat dark in the cabin, the ability of the passengers to evacuate was not

compromised by insufficient lighting. (ADB Ref. 20050802A)<sup>284</sup>

4L exit sign above and beside door – off; 4K floor light adjacent to attendant seat forward of door - off (ADB Ref. 20001031B)<sup>288</sup>

The overhead emergency lighting system was not observed aft of row 17 due to fuselage destruction and fire damage. (ADB Ref. 19990601A)<sup>289</sup>

Following the investigation of accident ADB Ref. 20001031B, the following safety recommendation was made to IATA, US FAA, and JAA:

Based on the lessons learned from the circumstances of the SQ006 accident, including severe impact forces and breakup of the aircraft, strong winds and heavy rain, and heavy smoke and fire, which rendered many emergency evacuation systems inoperative and procedures ineffective, provide support to an international joint government/industry program to develop possible improvements to emergency evacuation equipment and procedures for the prevention of future injuries and death following an aircraft accident. (3.2-[25]) -ASC-ASR-02-04-48, -52 & -56

In the B737-200 C-GQPW accident in 1984 in Calgary (not part of the accident review in this study) passengers who evacuated from the rear exit reported that "they were unable to see the exit, and were required to follow the person ahead to locate it. By the time most had reached this exit, the smoke had lowered to about knee height. The bottom portion of the door and the slide were all that was visible."<sup>290</sup>

It is vital that passengers are able to distinguish and locate available exits. This was mentioned in the accident report on the DC-9 accident in Cincinnati in 1983<sup>291</sup>, which states "the location of two passengers' bodies indicated that, in their attempt to get out of the aircraft, they had unknowingly passed an available exit."

In a study carried out for Transport Canada<sup>292</sup>, it was found that a system used for locating aircraft emergency exits was considered as having a life-saving benefit potential in 22 accidents (western-world built, turboprop/turbojet, maximum certificated passenger capacity of 30 and above in 1967-2003). These accidents were survivable, fire/smoke-related or water-related, and involved an evacuation.

### Research and Rulemaking Activities

Many research studies have been carried out into methods for improving evacuees' ability to find available exits in low visibility situations. The systems considered in this study are discussed below.

## 1) Installation of light emitting devices in emergency exit doorframes

A study carried out by FAA<sup>293</sup> concluded that the lack of exit illumination might have contributed to the reports of low observer (trial subjects) confidence in the emergency escape path marking system. The study indicated that the use of exit illumination in addition to the escape path marking might improve this confidence.

Another study<sup>294</sup> investigated the installation of a green/yellow/blue electroluminescent light that can be seen and attracts passengers to available exits particularly in the presence of smoke. This system is currently used in helicopters. The study recommends that tests and simulations be carried out on the technology for aeroplanes and its potential effectiveness.

### 2) Installation of audible devices at available exits

A research study commissioned by the European Communities Commission (ECC)<sup>295</sup> found that passenger awareness of exit routes is worthy of future research because "*its life-saving potential is likely to be favourable compared to the difficulty in developing and implementing solutions for both in-service aircraft and new designs.*"

As found in the review of accident experience carried out part as part of this study, the ECC study suggested that "escape-path markings may not be readily visible to passengers in certain accident scenarios, and they do not necessarily lead the passenger to an available exit." The study then suggested the use of audible devices at the exits activated on door opening to solve those problems.

A safety study carried out by the Transportation Safety Board of Canada<sup>290</sup> states that where the cabin was filled with smoke and visibility was obscured, a loud voice can act as a beacon guiding passengers to the nearest exit. Although the report was referring to additional commands/instructions given by cabin crew (such as "Come this way"), this indicates that aural guidance could help considerably in evacuation during low visibility conditions.

Evacuation trials carried out at Cranfield University found that there was an improvement in door usage when using directional sound<sup>296</sup>. The directional sound was able to direct passengers from forward of the monument to the available exits at the rear, which the cabin crew alone are unable to do. The directional sound would be even more advantageous in a situation where the cabin crew were incapacitated and unable to give verbal commands. The evacuation trial<sup>297</sup> found that 60% of the passengers said that the sound did provide them with assistance to evacuate. It should be noted that the cabin crew in the evacuation trials did feel disturbed by the sound and that in some cases it prevented them from communicating with each other.

A study on localizable sound<sup>298</sup> recommended further tests to assess the extent to which different sounds can be localized within the more realistic environment of an aircraft cabin, and to determine the influence that cabin fixtures and fittings may have on the perceived direction of sound.

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat. JAA has included 'Sounds Above Exits' as one of the proposed new initiatives in "An inventory of work to assist the transition to EASA Issue 3" dated 16 January 2004, stating "Sounds above exits could serve as a guidance for evacuating persons in conditions of dense smoke and/or absence of cabin crew at available exits."

### 3) Installation of an exit monitoring system for cabin crew

A study carried out by Sofreavia<sup>294</sup> evaluated various systems for identifying usable exits and guiding passengers toward the exits. One of the systems is called CHECK (Check Exit and Communicate Knowledge).

The system consists of displays situated at each main exit, showing a layout of all exits. The display provides information to cabin crew on availability and manning of exits. This system will help passenger flow management during evacuation but will still place reliance on cabin crew.

Evacuation trials utilising this system have shown that it enriched cabin crew's situational awareness during the evacuation and improved their ability to work as a team<sup>297</sup>. However, the impact on passenger behaviour has not been demonstrated.

This system will provide little or no benefit in the event of cabin crew incapacitation during evacuation.

### 4) The use of headsets for cabin crew

The use of headsets is also discussed in Threat IB03 'Inability for Cabin Crew to Communicate with Each Other During Emergency Situations'. Headsets will enable cabin crew to communicate with one another and inform the status of their exits. The Sofreavia study<sup>294</sup> recommended studies to be carried out with the cooperation of operators and cabin crew in order to determine whether the introduction of such a device and its integration into aircraft operations is feasible.

This system will provide little or no benefit in the event of cabin crew incapacitation during evacuation.

### Discussion

Accident experience has shown that current systems and evacuation procedures may not be adequate to assist passengers in identifying available exits, as discussed below:

### (i) Escape path markings

Electrically powered escape path markings are vulnerable to a variety of problems, including battery and wiring failures, burned-out light bulbs, and physical disruption caused by vibration, passenger traffic, galley-cart strikes and hull breakage in accidents<sup>293</sup>.

Photoluminescent escape-path marking can be more reliable – however, the light emitted from these materials is not as bright as the light from electrically operated systems. Additionally, some photoluminescent materials are not as effective when they have not been exposed to light for an extended period of time – although current generation systems may only need a minimum amount of charging<sup>299</sup>. A thick smoke may obscure photoluminescent escape path markings.

Additionally, some responses from observers (trial subjects) in a study carried out by FAA<sup>293</sup> indicated that escape path markings did not necessarily "guide" them:

"Confused as to which direction to go. Red & Green lights would have been much better"

"Told me where the aisle was - didn't necessarily help me move down the aisle"

(ii) Cabin crew commands

There have been many accidents where cabin crew members were incapacitated, injured or killed leaving passengers without any guidance to available exits. Furthermore, cabin crew from different sections of the cabin would not necessarily have information on the status of the other exits or the ability to communicate with each other.

(iii) Exit markings

Exit markings help passengers to locate where the exits are but not with regard to their availability. Their location at a height makes them prone to obscuration by smoke. Additionally these markings can be easily obscured or detached if there is cabin disruption.

It is evident that there needs to be a system that can assist passengers in finding available exits in low visibility conditions. Low visibility conditions are often related to the presence of smoke in the cabin, which is associated with post-crash fire, which makes this issue even more crucial.

### Proposed Potential Solutions

Based on the literature review, the following methods are considered to have the potential to improve passengers' ability to find available exits:

- (i) Installation of light emitting devices in emergency exit doorframes
- (ii) Installation of audible devices at available exits
- (iii) Installation of an exit monitoring system for cabin crew
- (iv) The use of headsets for cabin crew

Each system will have different advantages/disadvantages and cost-benefit considerations. It should be noted that none of the potential solutions above has a mature technology and proven benefits.

### **Conclusions and Recommendations**

It is evident that there needs to be a system that can assist passengers in finding available exits in low visibility conditions. Low visibility conditions are often related to the presence of smoke in the cabin that is usually associated with post-crash fire, which makes this issue even more crucial. Various systems that can mitigate this threat have been identified. It is recommended that consideration be given by EASA to carry out further research on the technologies that can be used to locate available exits, with or without cabin crew involvement, and their feasibility for emergency evacuation in low visibility conditions.

France Airbus A340-313 F-GLZQ, Toronto/Lester B. Person International Airport, Ontario, 02 August 2005 <sup>285</sup> National Transportation Safety Board, NTSB Identification DCA01MA005, Airtran Airways Douglas DC-9,

registration: Nacional Carlos Doald, NY 36 Identifi 286 Comparison: November 29, 2000, Atlanta, GA

Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, Technical Report A-070/2004, Accident of Aircraft Boeing B737, registration PH-BTC, at Barcelona Airport (Spain), on 28 November 2004 Korea Ministry Of Construction and Transportation Korea Aviation - Accident Investigation Board. Controlled Flight Into Terrain, Air China International Flight 129 B767-200ER, B2552, Mountain Dotdae, Gimhae, April 15,

2002 <sup>288</sup> Aviation Safety Council Taiwan, Crashed on a partially closed runway during takeoff, Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, Chiang Kai Sek Airport, Taoyuan, Taiwan, October 31, 2000

National Transportation Safety Board, Aircraft Accident Report, Runway Overrun During Landing – American Airlines Flight 1420, McDonnell-Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999 <sup>290</sup> Transportation Safety Board of Canada (1993) A Safety Study of Evacuations of Large, Passenger-Carrying

Aircraft, Report Number SA9501. Retrieved from http://www.bst.gc.ca/eng/rapports-reports/aviation/etudesstudies/sa9501/sa9501.asp, November 2008

National Transportation Safety Board (1986) Aircraft Accident Report, Air Canada Flight 797 McDonnell-Douglas DC-9-32, C-FTLU, Greater Cincinnati International Airport, Covington, Kentucky, June 2, 1983, NTSB/AAR-86/02. Washington D.C.: NTSB

<sup>292</sup> R.G.W. Cherry & Associates Limited (2006) A Benefit Assessment for a System Used for Locating Aircraft Emergency Exits using Directional Sound, 0935/R000310/KK <sup>293</sup> McLean, G. A. & Chittum, C. B. (1998) Performance Demonstration of Zinc Sulfide and Strontium Aluminate

Photoluminescent Floor Proximity Escape Path Marking Systems, DOT/FAA/AM-98/2. Washington D.C.: Federal Aviation Administration

<sup>4</sup> Société Francaise d'Études et Réalisations d'Équipements Aéronautiques (2002) *Identification of Usable* Exits in the Event of a Survivable Crash, IISU Project, Final Report. <sup>295</sup> R.G.W Cherry & Associates Limited (1993) Analysis of Factors Influencing the Survivability of Passengers in

Aircraft Accident. <sup>296</sup> Whittington, D. The Use of Directional Sound to Aid Aircraft Evacuation.

<sup>297</sup> Société Française d'Études et Réalisations d'Équipements Aéronautiques (2003) *Identification of Usable* Exits – Analysis of the Results and Recommendations.

<sup>298</sup> Lower, M., Kay, A. M., Thomas, L. J., & Muir, H. C. *Localizable sound and its application in guiding* passengers towards exits during aircraft evacuations, presented at The Fourth Triennial International Aircraft Fire and Cabin Safety Research Conference, Lisbon, Portugal, 15-18 November 2004 <sup>299</sup> Photoluminescent Escape-Path Marking Alters Few Duties of Flight Attendants, Flight Safety Foundation –

Cabin Crew Safety, Vol. 39 No. 1, January - February 2004

<sup>&</sup>lt;sup>282</sup> Interstate Aviation Committee, Final Report on the Results of the Investigation of the Accident A-310-324 F-OGYP OAO Aviakompania Sibir 8 July 2006 <sup>283</sup> National Transportation Safety Board, NTSB/AAR-07/07 PB2007-910408, Inflight Cargo Fire United Parcel

Service Company Flight 1307 McDonnell Douglas DC-8-71F, N748UP, Philadelphia, Pennsylvania, USA, February 7, 2006 <sup>284</sup> Transportation Safety Board Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air

## Cabin Safety Threat:

## 26. Cabin Crew Station Location

U01 / Cabin Crew Unable to Monitor Passenger Cabin

U04 / Cabin Crew Station Location Not Appropriate for Evacuation

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to this threat group are as follows:

*CS* 25.785(*h*) Each seat located in the passenger compartment and designated for use during take-off and landing by a cabin crewmember required by the Operating Rules must be –

(1) Near a required floor level emergency exit, except that another location is acceptable if the emergency egress of passengers would be enhanced with that location. A cabin crewmember seat must be located adjacent to each Type A emergency exit. Other cabin crewmember seats must be evenly distributed among the required floor level emergency exits to the extent feasible.

(2) To the extent possible, without compromising proximity to a required floor level emergency exit, located to provide a direct view of the cabin area for which the cabin crewmember is responsible.

FAA Advisory Circular 25.785-1A defined "Direct View" as follows:

... "direct view" means direct (line of sight) visual contact with cabin area/main aisle(s), which enables the flight attendant to be made aware of passenger needs relative to safety when the flight attendant is seated with torso restraint (safety belt and shoulder harness) fastened. Mirrors or other such devices are not acceptable equivalents to direct view, except in those cases where flight attendant proximity to the floor level emergency exit takes precedence over direct view. Video systems may be an acceptable means of direct view, if the level of conspicuity is equivalent to that provided by line of sight visibility.

There is no definition of "direct view" in CS-25.

Cabin crew location is also addressed in EU-OPS1.730 - Seats, seat safety belts, harnesses and child restraint devices:-

(a) An operator shall not operate an aeroplane unless it is equipped with:

(6). seats for cabin crew members located near required floor level emergency exits except that, if the emergency evacuation of passengers would be enhanced by seating cabin crew members elsewhere, other locations are acceptable. Such seats shall be forward or rearward facing within 15° of the longitudinal axis of the aeroplane.

### Accident Experience and Safety Recommendations

### 1) Direct View

The accident review found 2 accidents where the inability of cabin crew to have a direct view of the cabin has presented risk to the safety of the occupants. Extracts from the accident reports describing the events are as follows:

In some areas of the cabin, the placement of galleys and bulkheads prevented cabin crew and passengers from observing one another. One cabin crewmember did not call brace because his seating position faced a wall and he could not see passengers. (ADB

## Ref. 19990923A)<sup>300</sup>

The cabin crew's lack of visual information concerning the cabin was also identified in accident ref. 20050802A, although it was not directly related to cabin crew's seat location.

He [the chief purser] was not aware of the smoke/fire from where he was standing, nor did he know that many passengers were already in the aisles making their way to the emergency exits. (ADB Ref. 20050802A)<sup>301</sup>

In the Manchester 1985 accident, the view of the forward cabin crew towards the passenger cabin was restricted by a galley bulkhead, which precluded them from monitoring the conditions in the cabin<sup>302</sup>.

No recommendations on this particular issue were made.

### 2) Cabin Crew Location for Evacuation

The accident review found 2 accidents where the location of the cabin crew station was an impediment to cabin crew's management of the evacuation. Extracts from the accident reports describing the events are as follows:

Both cabin attendants located at the aft emergency exit (tail cone) stated that they had difficulties reaching the overwing area due to the crowd. (ADB Ref. 20030617A)<sup>303</sup>

The cabin crew reported that one of the rear cabin crew members had tried to make her way up the cabin towards the overwing exit location, but by that time most of the passengers were standing in the aisle and further progress was not possible. She attempted to call to the passengers by the overwing exits to open them, but they did not do so, preferring to join the flow of passengers to the main door slides. The passengers seemed reluctant to open the over-wing exit hatches, preferring to use the main cabin doors and slides. The congestion in the aisle precluded the rear cabin crew member reaching these exits to direct their opening. This could have lost valuable time had any fire been present after the aircraft stopped. (ADB Ref. 19980521A)<sup>304</sup>

No recommendations on this particular issue were made.

### Research and Rulemaking Activities

### 1) Direct View

A paper presented at the 4<sup>th</sup> Triennial International Aircraft Fire and Cabin Safety Research Conference<sup>305</sup> states that safety and security considerations, especially post 9/11, have highlighted the need for the cabin crew members to be able to supervise passengers and monitor their behaviour. The study carried out interviews with cabin crew members from a number of airlines. The conclusion of the study is as follows:

In summary, during the interviews, all participants reported that they never had a problem with direct view. However, they then proceeded to list the parts of the cabin and the situations in which they had limited or no view. Mirrors would appear to be the most feasible and cost effective way to enhance direct view. This would make it easier for cabin crew to monitor passengers during the critical phases of flight. However, mirrors are not always installed, and where they are, they are not always effective. Commonly reported problems in this study included mirrors that were too small, that were in the wrong places or not angled correctly, or not cleaned. However, this research was qualitative, and therefore gives little indication of the true extent of the problem because the results are not necessarily representative of crew flying with different operators on different aircraft types. Nevertheless, one simple solution would be to check, with crew members, that mirrors are provided where required, and that they are

located in suitable positions. A requirement to check mirrors pre-flight could also be introduced. Further, future very large transport aircraft and new generation aircraft types may include novel cabin interiors such as multiple cabins, multiple decks and internal staircases, and will carry larger numbers of passengers. Given these developments, it is perhaps even more important that cabin crew are able to monitor the actions and behaviour of passengers. Hence, the maintenance of direct view in flight operations on these aircraft types will need to be carefully considered at the design stage.

According to the paper, showing compliance to the direct view requirement is usually done by using a cabin configuration diagram and various anthropometric measurements of the cabin crew.

In late 1992, the FAA tasked the Aviation Rulemaking Advisory Committee (ARAC) to review the guidance material in AC 25.785-1 for finding compliance with the cabin attendant direct view requirements of 25.785 and make a recommendation for new or revised guidance. Draft AC 25-785-1B has been issued and incorporates the direct view guidance recommended to the FAA by ARAC. The Draft AC 25-785-1B contains the following:

- Criteria of areas that should be visible to the flight attendant
- Cabin crew seating position of which the criteria should be satisfied
- Guidance in determining whether aisles, exits or seats are within direct view
- Anthropometry of the persons used to determine acceptability of the arrangement

The Draft AC further states that "While the regulation gives proximity to floor level exits higher priority, every effort should be made to accommodate both requirements. It is possible though, that not all flight attendants will have a direct view of the cabin. It is the intention of the requirements, however, that no less than a majority of the required flight attendants contribute to direct view, even considering that some seat locations may be dictated by proximity to floor level exits."

### 2) Cabin Crew Location for Evacuation

A safety study carried out by the NTSB<sup>306</sup> found that positioning a cabin crew member in the rear of aeroplanes with a certain exit configuration (i.e. no assigned emergency exit at the rear) can limit the crewmember's usefulness, as found in an evacuation of a Fokker F100 in Charlotte, North Carolina. It stated that:

The Safety Board concludes that on some Fokker airplanes, the aft flight attendant is seated too far from the overwing exits, the assigned primary exits, to provide immediate assistance to passengers who attempt to evacuate through the exits. Therefore, the Safety Board believes that the FAA should require the flight attendants on Fokker 28 and Fokker 100 airplanes to be seated adjacent to the overwing exits, their assigned primary exits. In requiring the aft flight attendants on Fokker 100 airplanes to be seated adjacent to the overwing exits, their assigned primary exits. In requiring the aft flight attendants on Fokker 28 and Fokker 100 airplanes to be seated adjacent to the overwing exits, their assigned primary exits, consideration should be given to the flight attendants' view of the cabin and other safety duties.

As an outcome of the safety study, the NTSB issued the following safety recommendation:

Require the aft flight attendants on Fokker 28 and Fokker 100 airplanes to be seated adjacent to the overwing exits, their assigned primary exits. (A-00-78)

It is understood that some national authorities require a cabin crew member to be stationed in the area of the overwing exits on F100/F70 aircraft via operational rules.

The same concern is raised on other types of aeroplanes, as cited below:

In Airplanes H [EMB 145] and I [Dash 8], the flight attendants are seated at the forward and aft of the cabin, both facing the passengers. [When available, or required,] the aft flight attendant would be responsible for the RH and LH middle emergency exits, but

his/her position in the very last seat row does not fully support this duty.<sup>307</sup>

The NTSB safety study<sup>306</sup> also cited a research study conducted by CAMI on the effects of cabin crew location on aircraft evacuation<sup>308</sup>, which concluded that there are significant differences in evacuation times based on cabin crews' initial position:

Evacuations with flight attendants 24 feet aft of their primary emergency exits proceeded significantly slower than evacuations with a flight attendant next to the exit. Delays resulting from passenger inability to open the exit or indecisiveness can be reduced if flight attendants are available to assist.

The CAMI study concluded that crewmembers located one row forward of the exit provide the fastest evacuation.

The Very Large Transport Aircraft Emergency Requirements Research Evacuation Study (VERRES)<sup>309</sup> recommended experimentation on the impact of cabin crew location, with special attention to panic mitigation and passenger flow redirection.

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to cabin crew station location. The JAA, in their document 'An inventory of work to assist the transition to EASA Issue 3' dated 16 January 2004, state that a cost/benefit analysis is needed before further research can be initiated on "Cabin Crew at Type III exits (CSSG #2)".

SAE Standard ARP583 (Flight Attendant Stations) provides guidance for the design and location of flight attendant stations, including emergency equipment installations at or near such stations, so as to enable the flight attendant to function effectively in emergency situations, including emergency evacuations. Recommendations regarding design of flight attendant stations apply to all such stations; recommendations regarding location apply to those stations located near or adjacent to floor level exits. However, this document is not referred to by CS-25 Requirements or Acceptable Means of Compliance.

### **Conclusions and Recommendations**

### 1) Direct View

The requirement regarding direct view for cabin crew of the cabin area, was incorporated for the first time into airworthiness requirements in FAR 25.785 Amendment 25-32 (effective date 03/06/1980). However, since other considerations often take precedence, which to some extent is allowed by the requirements, cabin crew do not always have direct view of the cabin area. The use of the phrase "to the extent possible" is considered vague and weakens the requirement for direct view.

As evident in the Toronto A340 accident (ADB Ref. 20050802A), managing a high number of passengers in an emergency situation without visual information can be detrimental to the safety of the occupants. It is understood that cabin crew's ability to monitor cabin areas will be even more important in larger aircraft with multiple cabins, multiple decks, and internal staircases. Real time information plays a significant role in managing the cabin, not only during an emergency situation but also during normal operations. It will improve safety as well as security.

There is evidence that the current applicable CS-25 requirements may need to be reviewed to take into account the escalating need for improvements in monitoring the cabin area by the cabin crew. Therefore, it is recommended that consideration be given to carrying out further research, which encompasses the following:

- A survey of current commercial transport aeroplanes may need to be conducted to ascertain how, if applicable, the requirement of CS 25.785(h)(2) has been complied with.
- A review of incidents associated with the effectiveness of cabin crew's ability to monitor cabin areas.
- A survey involving cabin crew of very large transport aeroplanes.

## 2) Cabin Crew Location for Evacuation

Accident experience and studies have shown that cabin crew located remotely from their assigned emergency exits could adversely affect evacuation time. This threat is particularly relevant to some aircraft designs, for example the Fokker 28 and Fokker 100. The NTSB concluded that on these aircraft the aft flight attendant is seated too far from the over-wing exits, the assigned primary exits, to provide immediate assistance to passengers attempting to evacuate through the exits. This situation is not addressed by CS 25.785(h)(1). It is therefore concluded that this threat may need to be addressed by amendments to CS-25 requirements. However, further research may be required to confirm the magnitude of the threat and ascertain how the threat is best mitigated.

<sup>309</sup> Joint Aviation Authorities (2003) Very Large Transport Aircraft (VLTA) Emergency Requirements Research Evacuation Study (VERRES) – A Project Summary, JAA Paper 2003/x

<sup>&</sup>lt;sup>300</sup> Australian Transport Safety Bureau (2001) *Investigation Report 199904538, Boeing 747-438, VH-OJH, Bangkok, Thailand, 23 September 1999.* Canberra: ATSB

 <sup>&</sup>lt;sup>301</sup> Transportation Safety Board of Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005
<sup>302</sup> UK Air Accidents Investigation Branch (1989) Aircraft Accident Report 8/88, Boeing 737-236 G-BGJL at

Manchester International Airport on 22 August 1985

<sup>&</sup>lt;sup>303</sup> Dutch Safety Board, Runway overrun after rejected take-off of the Onur Air MD-88, registration TC-ONP, at Groningen Airport Eelde on 17 June 2003

<sup>&</sup>lt;sup>304</sup> Comisión de Investigación de Accidentes e Incidentes de Aviación Civil, *Technical Report, Accident occurred* on 21 May 1998 to Aircraft Airbus A-320-212 Registration G-UKLL at Ibiza Airport, Balearic Islands

<sup>&</sup>lt;sup>305</sup> Thomas, L. J., Wilson, R, & Kelleher, I. (2004) Direct view for cabin crew members, presented at the 4<sup>th</sup> Triennial International Aircraft Fire and Cabin Safety Research Conference, Lisbon, Portugal, 15-18 November 2004

<sup>2004</sup> <sup>306</sup> National Transportation Safety Board (2001) *Safety Study – Emergency Evacuation of Commercial Airplanes, NTSB/SS-00/01.* Washington D.C.: NTSB

 <sup>&</sup>lt;sup>307</sup> RGW Cherry & Associates Limited (2006) A Research Study into the More Pertinent Features of Small Transport Airplanes Affecting Emergency Evacuation, Prepared for Transport Canada, 0944/R/000311/KK
<sup>308</sup> George, M. & Corbett, C. (1999) Effects of Cabin Crew Location and Passenger Motivation on Aircraft Evacuations, Proceedings, 1998 International Aircraft Fire and Cabin Safety Research Conference, November 16–20, 1998, Atlantic City, NJ, DOT/FAA/AR-99/68
<sup>309</sup> Joint Avietics Aviets (2020) Variable Conference, November Technology, 1000 (2020)

## Cabin Safety Threat:

## 27. Issues Related to Exits for Cargo Aeroplanes

Z01 / Insufficient External Marking on Cargo Aeroplanes for Rescue Efforts

W08 / Insufficient Number of Floor Level Emergency Exits for Cargo Aeroplanes

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to this threat group are as follows:

*CS* 25.811(*f*) Each emergency exit that is required to be openable from the outside, and its means of opening, must be marked on the outside of the aeroplane. In addition, the following apply:

(1) The outside marking for each passenger emergency exit in the side of the fuselage must include a 51 mm (2 inch) coloured band outlining the exit.

(2) Each outside marking including the band must have colour contrast to be readily distinguishable from the surrounding fuselage surface. The contrast must be such that if the reflectance of the darker colour is 15% or less, the reflectance of the lighter colour must be at least 45%. 'Reflectance' is the ratio of the luminous flux reflected by a body to the luminous flux it receives. When the reflectance of the darker colour is greater than 15%, at least a 30% difference between its reflectance and the reflectance of the lighter colour must be provided.

(3) In the case of exits other than those in the side of the fuselage, such as ventral or tail cone exits, the external means of opening, including instructions if applicable, must be conspicuously marked in red, or bright chrome yellow if the background colour is such that red is inconspicuous. When the opening means is located on only one side of the fuselage, a conspicuous marking to that effect must be provided on the other side.

## Accident Experience and Safety Recommendations

These issues were found in one accident (ADB Ref. 20060207A). Extracts from the accident report describing the issues are as follows:

A floor level emergency exit, including one equipped (when appropriate) with an evacuation slide, would enable more efficient emergency egress for airplane occupants than cockpit window exits, and the associated, instructional placarding of such an exit would assist emergency responders with locating and operating the exit door and accessing the interior of the airplane.

CAR 4b also stated, "all emergency exits and their means of opening shall be marked on the outside of the airplane for guidance of rescue personnel. Passenger airplanes certified after June 7, 1965, are required under 14 CFR 25.811(f) to have a 2-inch contrasting colored band outlining emergency exits in addition to exterior markings providing instructions on their operation. Cargo airplanes are not required to have such bands around the emergency exits. The L1 door, which was the entry and exit door for crewmembers during normal operations, was also designated as an "emergency exit" in the UPS DC-8 AOM and on the emergency briefing card. Although the interior of the L1 door included instructions for emergency door operation, the door did not have exterior operational placards. [Findings:] 17. A floor level emergency exit, including one equipped (when appropriate) with an evacuation slide, would enable more efficient

emergency egress for airplane occupants than cockpit window exits, and the associated, instructional placarding of such an exit would assist emergency responders with locating and operating the exit door and accessing the interior of the airplane. (ADB Ref. 20060207A)<sup>310</sup>

The accident aeroplane (DC8-71F) was configured to carry up to 7 occupants. The aeroplane's two side cockpit windows had been designated as the emergency exits. The left forward (L1) door, a floor level exit used as the primary means of entry and exit for the aeroplane, was also identified as an emergency exit in the UPS DC-8 AOM and on the emergency briefing card. As stated in the NTSB recommendation letter<sup>311</sup>, the FAA acknowledged that, although a forward floor level emergency exit is not required on cargo aeroplanes, operators often designate the L1 door as an alternate emergency exit. In this accident (and the FedEx DC10-10 accident<sup>312</sup> - not within the accident review period), the floor level exit was the preferred emergency exit even if the cockpit window exits were accessible. The NTSB is concerned that the L1 door is not required to be designated as an "emergency exit" despite this evidence and the fact that the floor level exit provides a faster and more efficient means for the occupants to evacuate.

Following the investigation of accident ADB Ref. 20060207A, the following safety recommendation was made:

Require cargo operators to designate at least one floor level door as a required emergency exit and equip the door with an evacuation slide, when appropriate. (A-07-102)

Require all emergency exits on cargo aircraft that are operable from the outside to have a 2-inch contrasting colored band outlining the exit. (A-07-103)

The FAA replied that it is evaluating what regulatory changes and guidance materials are needed to implement these safety recommendations for both newly produced aircraft and the existing fleet. Pending the FAA's taking the recommended actions, Safety Recommendations A-07-102 and -103 are classified Open Acceptable Response.

### Research and Rulemaking Activities

The review carried out in this study did not identify any current/past EASA rulemaking activities pertinent to this cabin safety threat. As mentioned in the FAA's reply to the NTSB recommendation, the FAA are evaluating what regulatory changes and guidance materials would be needed to implement these safety recommendations for both newly produced aircraft and the existing fleet. The results of their evaluation are not yet available at the time that this study was carried out.

### Conclusions and Recommendations

Cargo operators are allowed to carry additional personnel, which can range from one or two to up to 27 occupants<sup>313</sup>. As stated by the NTSB<sup>311</sup>, while the two cockpit windows provide a means for the flight crew to evacuate the airplane, a floor level emergency exit with an evacuation slide would provide a more efficient and expedient way for all occupants to exit a cargo airplane in the event of an emergency.

A floor level emergency exit would also allow rescue and firefighting personnel to enter an aeroplane to conduct rescue and firefighting efforts, which would be difficult to do via a cockpit window. Additionally, access through the L1 door may be required to manually operate the main cargo door, as seen in the UPS and the FedEx accidents. The designated floor level exit would be required to have instructional placards to locate and operate the exit door and the 2-inch contrasting colored band outlining the exit for rescue and firefighting personnel to identify it.

Dependent on and bearing in mind the results of FAA deliberations, it is recommended that consideration be given by EASA to require cargo operators to designate at least one floor level door as a required emergency exit and equip the door with an evacuation slide and external marking, when appropriate.

<sup>310</sup> National Transportation Safety Board, In-Flight Cargo Fire, United Parcel Service Company Flight 1307, McDonnell Douglas DC-8-71F, N748UP, Philadelphia, Pennsylvania, February 7, 2006, Aircraft Accident Report NTSB/AAR-07/07. <sup>311</sup> National Transportation Safety Board, Safety Recommendation A-07-97 through -103, December 17, 2007

 <sup>312</sup> National Transportation Safety Board, *In-Flight Fire/Emergency Landing, Newburgh, New York, Federal Express Flight 1406, Douglas DC-10-10, N68055, September 5, 1996, Aircraft Accident Report NTSB/AAR-*98/03 <sup>313</sup> FAA CertAlert dated January 21, 2004

## Cabin Safety Threat:

## 28. Evacuation Issues Related to Internal Doors

V18 / Occupants Unaware of Exit(s) Beyond Internal Doors

V20 / Obstruction of Evacuation Route by Internal Doors

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to internal doors are as follows:

CS 25.813 Emergency Exit Access

(d) If it is necessary to pass through a passageway between passenger compartments to reach any required emergency exit from any seat in the passenger cabin, the passageway must be unobstructed. However, curtains may be used if they allow free entry through the passageway.

(e) No door may be installed in any partition between passenger compartments.

(f) If it is necessary to pass through a doorway separating the passenger cabin from other areas to reach any required emergency exit from any passenger seat, the door must have a means to latch it in open position. The latching means must be able to withstand the loads imposed upon it when the door is subjected to the ultimate inertia forces, relative to the surrounding structure, listed in CS 25.561 (b).

#### Accident Experience and Safety Recommendations

The accident review carried out in this study did not identify events associated with these cabin safety threats.

### Research and Rulemaking Activities

#### 1) General

CS 25.813(f) implies that the installation of an internal door separating an emergency exit and any passenger seat (including those that are occupiable during takeoff and landing) is allowed:

If it is necessary to pass through a doorway separating the passenger cabin from other areas to reach any required emergency exit from any passenger seat, the door must have a means to latch it in open position. The latching means must be able to withstand the loads imposed upon it when the door is subjected to the ultimate inertia forces, relative to the surrounding structure, listed in CS 25.561 (b).

Additionally, because CS 25.813(e) only states that "*No door may be installed in any partition between passenger compartments*", a door can still be installed between an emergency exit located in the aft galley, for example, and the passenger compartment, since an argument can be made that a galley is not considered a passenger compartment.

Even though CS 25.813(f) requires those internal doors to have a means to latch in an open position that can withstand the loads listed in CS 25.561(b), allowing the installation of doors between any passenger seat and any required emergency exit does not reflect an acceptable level of safety.

As a comparison. FAR 25.813(e) and (f) at Amdt. 25-116 state:

[(e) No door may be installed between any passenger seat that is occupiable for takeoff and landing and any passenger emergency exit, such that the door crosses any egress path (including aisles, cross aisles and passageways).

(f) If it is necessary to pass through a doorway separating any crewmember seat (except those seats on the flightdeck), occupiable for takeoff and landing, from any emergency exit, the door must have a means to latch it in the open position. The latching means must be able to withstand the loads imposed upon it when the door is subjected to the ultimate inertia forces, relative to the surrounding structure, listed in Sec. 25.561(b).]

At the time this evaluation was conducted, EASA has commenced a rulemaking task (Task No. 25.039) addressing the harmonisation of several Cabin Safety requirements with FAR 25, which includes the issue discussed above.

## 2) Internal Doors in Private Use Aeroplanes

The evaluation of FAA exemptions carried out in this study found 38 petitions for exemption from FAR 25.813(e) for the installation of internal doors, primarily in executive interior configuration. This has led the FAA to include "interior" doors in SFAR No. 109 'Special Requirements for Private Use Transport Category Airplanes', issued 8 May 2009. The FAA considers that in private use aeroplanes "the number of passengers involved is much smaller and there has been no demonstrated unsafe condition", hence Paragraph 10 of the SFAR allows installation of otherwise prohibited interior doors, provided a number of conditions are met. The requirement reads as follows:

10. Interior doors. In lieu of the requirements of Sec. 25.813(e), interior doors may be installed between passenger seats and exits, provided the following requirements are met.

- (a) Each door between any passenger seat, occupiable for taxi, takeoff, and landing, and any emergency exit must have a means to signal to the flightcrew, at the flightdeck, that the door is in the open position for taxi, takeoff and landing.
- (b) Appropriate procedures/limitations must be established to ensure that any such door is in the open configuration for takeoff and landing.
- (c) Each door between any passenger seat and any exit must have dual means to retain it in the open position, each of which is capable of reacting the inertia loads specified in Sec. 25.561.
- (d) Doors installed across a longitudinal aisle must translate laterally to open and close, e.g., pocket doors.
- (e) Each door between any passenger seat and any exit must be frangible in either direction.
- (f) Each door between any passenger seat and any exit must be operable from either side, and if a locking mechanism is installed, it must be capable of being unlocked from either side without the use of special tools.

### Conclusions and Recommendations

Amending CS 25.813(e) and (f) as per FAR 25.813(e) and (f) at Amendment 25-116 would ensure harmonisation and also improve the level of safety. It is understood that this has been addressed by an ongoing rulemaking task (Task No. 25.039)

FAA SFAR 109 addresses the installation of internal doors on private use aeroplanes. Since EASA has no equivalent of an FAA SFAR, consideration should be given to developing a means for adopting the contents of SFAR 109 into the airworthiness requirements to reduce certification costs for private use aeroplanes incorporating internal doors.

## Cabin Safety Threat:

## 29. Minimum Exit Height for Requiring Assist Means

Y11 / Absence of Assist Means on Non-Over-Wing Exits (Not Required)

Y31 / Injuries Related to Jumping Off the Wing when Evacuating Through Overwing Exit

Y08 / Flaps Not Extended as Required for Evacuation via Overwing Exit

## Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to this threat group are as follows:

CS 25.810 (a) Each non-over-wing landplane emergency exit more than 1.8 m (6 feet) from the ground with the aeroplane on the ground and the landing gear extended and each non-over-wing Type A exit must have an approved means to assist the occupants in descending to the ground.

CS 25.810 (d) If the place on the aeroplane structure at which the escape route required in sub-paragraph (c) of this paragraph terminates, is more than 1.8 m (6 feet) from the ground with the aeroplane on the ground and the landing gear extended, means to reach the ground must be provided to assist evacuees who have used the escape route. If the escape route is over a flap, the height of the terminal edge must be measured with the flap in the take-off or landing position, whichever is higher from the ground. The assisting means must be usable and self-supporting with one or more landing gear legs collapsed and under a 46 km/hr (25-knot) wind directed from the most critical angle. The assisting means provided for each escape route leading from a Type A emergency exit must be capable of carrying simultaneously two parallel lines of evacuees. For other than Type A exits, the assist means must be capable of carrying simultaneously as many parallel lines of evacuees as there are required escape routes.

### Accident Experience and Safety Recommendations

The accident review found 4 accidents where having no assist means on floor level exits had the potential to pose a risk to the safety of the occupants. Extracts from the accident reports describing the events are as follows:

After the commander's order, the two flight attendants immediately initiated an emergency evacuation. The passengers left the aircraft through the front main door and the rear service door. As they did so, they had to jump onto the runway from a height of 1.62 m in the case of the front door and 1.78 m in the case of the rear door. The overwing emergency exits were not opened. One passenger slightly injured his foot jumping from the aircraft onto the runway. (ADB Ref. 20051117A)<sup>314</sup>

The DHC-8-402 is not equipped with slides at the doors. The distance from the door sills down to the ground is 1.55 metres at the rear door and 1.24 metres at the front. During evacuation, passengers thus have to jump down to the ground. According to Widerøe all passengers were in good physical condition and no one sustained any physical injury during the evacuation. (ADB Ref. 20040519A)<sup>315</sup>

With the aircraft leaning to the left, it was quite high from the emergency exit to the ground and so the fireman jumped down and helped the passengers from outside while the senior cabin attendant and her supernumerary crew member assisted the evacuation from inside. (ADB Ref. 19980209B)<sup>316</sup>

In one accident, an exit was not used due to a slight sloping ground making the exit height to the ground much higher:

The forward flight attendant stated that she looked out the forward left emergency exit window and saw a lot of "crash debris" on the ground and that she then looked out the right emergency exit window and thought that the exit looked as if it were too far above the ground to use; therefore, she decided not to open either forward exit. This flight attendant stated that most of the passengers were seated near the rear of the airplane. (ADB Ref. 20040509A)<sup>317</sup>

No recommendations on this particular issue were made. Additional accident experience on this issue was identified during the review of research activities described below.

The accident review found 2 accidents where some passengers were injured as they descended from the wing to the ground during evacuation. Extracts from the accident reports describing the events are as follows:

One of these passengers suffered a whiplash. She evacuated through an overwing exit and fell on her back when jumping off the wing. (ADB Ref. 20041128A)<sup>318</sup>

The serious injuries were three fractured ankles sustained while sliding off the wing flap trailing edge to the ground. The announcement makes no mention of the escape path direction once the evacuee steps through the overwing exit and out onto the wing. (ADB Ref. 19980330B)<sup>319</sup>

No recommendations on this particular issue were made.

In 4 accidents (ADB Ref. 20060912A<sup>320</sup>, 20050415A<sup>321</sup>, 20020227B<sup>322</sup>, 19981203A<sup>323</sup>), the flaps were not set to the position required for evacuation via the overwing exit. This has resulted in the overwing exit being blocked or not used. In one of those accidents, the flight crew decided to shut down the left engine with the flaps at about 2 degrees to expedite evacuation because the flaps were travelling really slowly. In a recent incident<sup>324</sup> (not part of the accident review), the flaps were also not lowered because using the electrical system to do so would have either meant delaying the use of the overwing exits whilst the flaps were lowered, or having the flaps travelling as passengers were on or possibly under them. Both options posed risk of injuries to evacuees. As in the previous accident, the hydraulic system was not available since the engines were shut down.

### Research and Rulemaking Activities

Research carried out by the NTSB<sup>325</sup> concluded that:

Although the number of serious injuries was small in the evacuations investigated for the study, the most serious evacuation-associated injuries were the result of jumping out of exits or off of wings, with the exception of the injuries sustained in the Little Rock accident. Four of the six serious injuries, excluding Little Rock, were sustained by passengers who jumped from the wings: a 10-year-old, two elderly people, and a female of short stature weighing 200 pounds. One injury occurred when a passenger jumped from an exit door.

The incidence of injury was likely reduced because passengers were unwilling to jump and returned to the airplane cabin or because passengers received assistance from ground personnel. In the 727 evacuation in Chicago following an APU torching (case 16), passengers waited on the wings because they were afraid to jump from the wings; they reentered the cabin to exit via the aft stairs. Passengers that used an overwing exit in a 737 evacuation in Eugene, Oregon (case 5) also reentered the cabin because they were afraid to jump from the wings. In an evacuation of a DC-9 in Indianapolis (case 19), a resourceful ground crewmember brought a luggage cart to the wing to enable the passenger to more easily get off the wing. In a 727 evacuation in Fort Lauderdale,

Florida (case 13), a flight crewmember who exited after all the passengers had exited noticed a dozen passengers standing on the wing moving toward the wingtips. In this case, the crewmember ran to the passengers and redirected them to the rear of the wing near the cabin to slide down.

As previously mentioned, current Federal regulations require an approved means to assist passengers in descending to the ground from an exit that is higher than 6 feet from the ground. For overwing exits, this height can be measured with the flaps in either a takeoff or landing condition, whichever is higher. There are many airplanes whose wings are less than 6 feet from the ground, such as the 727, 737, and CRJ. The Safety Board questions the wisdom of this rule and believes there is a need to revisit the rationale for the 6-foot designation. An above-ground exit without a means of assistance to the ground can alter the flow of an evacuation; some passengers in the study cases exited onto a wing and then stayed on the wing, thus interfering with the smooth evacuation of passengers onto and then off the wing. Passengers exiting via a door without a slide also hesitated before jumping to the ground. Flight crewmembers in both a DC-9 evacuation in Indianapolis (case 19) and a 737 evacuation in Eugene, Oregon (case 5) indicated in statements that they did not want passengers to use overwing exits because of the likelihood for injury. The Safety Board's study cases (5, 13, 16, 19) suggest that exit assist means are needed for some exits that are less than 6 feet from the ground. The Safety Board concludes that the majority of serious evacuation-related injuries in the study cases, excluding the Little Rock, Arkansas, accident of June 1, 1999, occurred at airplane door and overwing exits without slides. Therefore, the Safety Board believes that the FAA should review the 6-foot height requirement for exit assist means to determine if 6 feet continues to be the appropriate height below which an assist means is not needed. The review should include, at a minimum, an examination of injuries sustained during evacuations.

A study carried out for Transport Canada<sup>326</sup> discussed the issue of exit height from the ground:

All of the exits on the inspected airplanes have an exit height of less than 6 ft, which means no assist means are required on any of these airplanes. However, it was observed that some of the floor level/non-overwing exits are quite high, to the extent that injuries to evacuees may occur if they have to jump from the exits of an airplane in an adverse attitude (e.g. one main landing gear collapsed or nose wheel collapsed).

The non-overwing/non-airstair emergency exit on Airplane H could be as high as 1.595 m (5.23 ft) from the ground on empty load. On Airplane G, the height of the non-overwing exits on empty load is approximately 1.7 m (5.58 ft).

The non-overwing/non-airstair exit on Airplane F is approximately 5.4 ft high (Figure [Y11-1]). With its location at the aft section of the aircraft, this exit could become very high from the ground in an airplane with a collapsed nose wheel.

It is considered that exiting through the Type III/IV non-overwing emergency exit may be more difficult because there is no step down to the wing surface (Figure 31, Figure 32, and Figure 33). The height of this type of exit is therefore of particular concern.



[Figure Y11-1 Aft emergency exit on Airplane F]

Past Accident Evacuation Issues:

Three smaller airplane accident reports addressed the issue of exit height. In one accident, the passengers were injured jumping out from the rear exit (about 3.5 – 4 meters high) because the nose wheel had collapsed (accident reference 19700506A). In another, several passengers received minor injuries when they dropped about 5.5 ft to the icy taxiway (accident reference 19880202A). A third accident report noted that the exit was quite high from the ground, because the aircraft was leaning to one side (accident reference 19980209B).

As reported in accident reference 19971207A, evacuees did have difficulty in exiting from underwing Type IV exits (the Flight Attendant had to shout the instruction "Leg first then body"). Instructions on how to get out from the smaller exits in the safety card may help considerably.

The research conducted to date suggests that further research may be beneficial in determining the adequacy of the 6 feet rule.

Since 24/10/1967 FAR 25.807 (a) (4) required, by definition, that Type IV exits are located over the wing. Thus Part 25 aircraft without a step down foothold at Type IV exits are limited to types certificated prior to this date, such as the Fokker F-27. However, CS-25 still permits non-overwing Type III exits without step down footholds. Research may therefore be beneficial to establish whether Type III exits not having step down footholds allow safe and expedient egress.

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

### **Conclusions and Recommendations**

### 1) The Acceptability of 1.8m (6ft) Height with no Assist Means

The evidence available from accidents and research studies suggests that the requirement to jump to the ground from a height of up to 1.8m (6 feet) during evacuation, without assist means, may potentially cause serious injury or may delay the progress of an evacuation due to hesitation or unwillingness to jump. It is therefore recommended that further research should be carried out to establish whether the current height is appropriate or whether a lesser height should be specified within CS 25.810(a) and CS 25.810(d).

Since setting the flap position for evacuation is greatly dependent on flight crew action and the availability or speediness of the systems for lowering the flaps, further consideration should be given to re-assessing the adequacy of CS 25.810(d) on the subject of the measurement of the height of the terminal edge with the flap in the take-off or landing position.

## 2) Type III Exits with No Step Down Foothold

The evidence available shows that small openings such as Type III exits, when located in positions that do not have a foothold such as a wing to step down on to, can be very difficult to exit through. It may therefore be beneficial to carry out research to establish whether this type of exit feature allows safe and expedient egress.

For aircraft with no step down foot hold for the emergency exits it may be beneficial for safety cards and passenger briefings to include specific instructions on how to exit.

<sup>318</sup> Comision de Investigacion de Accidentes e Incidentes de Aviacion Civil, Technical Report A-070/2004, Accident of aircraft Boeing B-737, registration PH-BTC, at Barcelona Airport (Spain), on 28 November 2004 National Transportation Safety Board, MIA98FA112, Accident occurred Monday, March 30, 1998 in Fort

Lauderdale, FL, Aircraft: Boeing 727-212, registration: C-FRYS <sup>320</sup> The Transport Accident Investigation Commission New Zealand, Report 06-003 Boeing 737-319 ZK-NGJ electrical malfunction and subsequent ground evacuation Auckland International Airport 12 September 2006 <sup>321</sup> Comision de Investigacion de Accidentes e Incidentes de Aviacion Civil, Addenda Bulletin 5/2007, Report IN-

011/2005, Ryanair Boeing 737-800, EI-DAC, 15 April 2005, Murcia San Javier Airport <sup>322</sup> UK Air Accidents Investigation Branch, AAIB Bulletin No: 7/2004 Ref: EW/C2002/02/07, Boeing 737-8AS, EI-

<sup>&</sup>lt;sup>314</sup> Aircraft Accident Investigation Bureau, Investigation Report No. u1956 by the Aircraft Accident Investigation Bureau concerning the serious incident to the SAAB 2000 aircraft, HB-IZZ operated by Darwin Airline under flight number DWT 018 on 17 November 2005 at Lugano Airport, municipality of Agno/TIm, Switzerland. <sup>315</sup> Accident Investigation Board Norway, SL Report 2007/33, Report On Serious Aviation Incident, 19 May 2004

Approx. 20 Nm West-Northwest Of Sandefjord Airport Torp, Norway, Involving Bombardier DHC-8-402, LN-WDA, Operated By Widerøes Flyveselskap ASA <sup>316</sup> UK Air Accidents Investigation Branch, Accident to SD3-60 Variant 100, G-BLGB, AAIB Bulletin No 7/98 Ref

EW/C98/2/1

National Transportation Safety Board, Aircraft Accident Report NTSB/AAR-05/02, Crash During Landing, Executive Airlines Flight 5401, ATR 72-212 N438AT, San Juan, Puerto Rico, May 9, 2004.

CSA, 27 February 2002, London Stansted Airport, Essex

<sup>&</sup>lt;sup>323</sup> Transportation Safety Board of Canada, Aviation Investigation Report, Rejected Take-off / Runway Overrun, First Air / Bradley Air Services Limited. Hawker Siddeley HS-748-2A C-FBNW. Igaluit, Nunavut, 03 December 1998, Report Number A98Q0192 <sup>324</sup> UK Air Accidents Investigation Branch, *Serious Incident to Fokker F.28 Mark 0070, PH-KZB, Manchester* 

Airport, 29 September 2008, AAIB Bulletin 5/2009 Ref. EW/C2008/09/01

National Transportation Safety Board. (2000). PB2000-917002 NTSB/SS-00/01, Safety Study: Emergency

Evacuation of Commercial Airplanes. Washington, D.C.: Author. <sup>326</sup> RGW Cherry & Associates Limited. (2006). 0944/R/000311/KK Issue 1, A Research Study into the More Pertinent Features of Small Transport Airplanes Affecting Emergency Evacuation. United Kingdom: Author.

## Cabin Safety Threat:

## 30. Emergency Exit Marking and Locator Signs

W10 / Exit Marking/Locator Sign Not Visible Enough (Size/Colour/Luminosity)

W11 / Exit Marking/Locator Sign Not in Appropriate Location

### Current Applicable CS-25 Requirements and Associated Regulatory Material

CS-25 Cabin Safety requirements related to location and legibility of emergency exit marking and locator signs are as follows:

CS 25.811 Emergency exit marking

(b) The identity and location of each passenger emergency exit must be recognisable from a distance equal to the width of the cabin.

(d) The location of each passenger emergency exit must be indicated by a sign visible to occupants approaching along the main passenger aisle (or aisles). There must be –

(1) A passenger emergency exit locator sign above the aisle (or aisles) near each passenger emergency exit, or at another overhead location if it is more practical because of low headroom, except that one sign may serve more than one exit if each exit can be seen readily from the sign;

(2) A passenger emergency exit marking sign next to each passenger emergency exit, except that one sign may serve two such exits if they both can be seen readily from the sign; and

(3) A sign on each bulkhead or divider that prevents fore and aft vision along the passenger cabin to indicate emergency exits beyond and obscured by the bulkhead or divider, except that if this is not possible the sign may be placed at another appropriate location.

(g) Each sign required by sub-paragraph (d) of this paragraph may use the word 'exit' in its legend in place of the term 'emergency exit' or a universal symbolic exit sign (See AMC 25.812(b)(1), AMC 25.812(b)(2) and AMC 25.812(e)(2)). The design of exit signs must be chosen to provide a consistent set throughout the cabin.

CS 25.812 Emergency lighting

(b) Emergency exit signs -

(1) For aeroplanes that have a passenger-seating configuration, excluding pilot seats, of 10 seats or more must meet the following requirements:

(i) Each passenger emergency exit locator sign required by CS 25.811 (d)(1) and each passenger emergency exit marking sign required by CS 25.811(d)(2) must have red letters on an illuminated white background or a universal symbol, of adequate size (See AMC 25.812(b)(1)). These signs must be internally electrically illuminated with a background brightness of at least 86 candela/m2 (25 foot lamberts) and a high-to-low background contrast no greater than 3:1.

(ii) Each passenger emergency exit sign required by CS 25.811(d)(3) must have red letters on a white background or a universal symbol, of adequate

size (See AMC 25.812(b)(1)). These signs must be internally electrically illuminated or selfilluminated by other than electrical means and must have an initial brightness of at least 1.27 candela/m2 (400 microlamberts). The colours may be reversed in the case of a sign that is self-illuminated by other than electrical means.

(2) For aeroplanes that have a passenger seating configuration, excluding pilot seats, of 9 seats or less, each sign required by CS 25.811 (d)(1), (2), and (3) must have red letters on a white background or a universal symbol, of adequate size (See AMC 25.812(b)(2)). These signs may be internally electrically illuminated, or self-illuminated by other than electrical means, with an initial brightness of at least 0.51 candela/m2 (160 microlamberts). The colours may be reversed in the case of a sign that is self illuminated by other than electrical means.

(There are no differences with the equivalent FAR requirements)

### Accident Experience and Safety Recommendations

The accident review carried out in this study did not identify any events associated with this cabin safety threat.

#### Research and Rulemaking Activities

This threat was identified during the review of certification documents. The accident review shows, however, that there have been no threats specifically related to the emergency exit locator or marking not being visible or legible. The issues discussed here are therefore focused on certification/compliance issues.

A review of FAA ELOS and Exemptions for smaller transport category aeroplanes<sup>327</sup> (up to a maximum certificated passenger capacity of 60) in the period 1994-February 2006, found that emergency exit marking and locator signs are the third most frequent subject. These applications were made for 10 different aircraft models consisting of Bombardier BD-100-1A10 (max. 16 passengers), Bombardier BD700-1A10 (max. 19 passengers), Cessna Model 680 (max. 12 passenger), Cessna Model 750 (max. 12 passengers), Dassault Falcon Models 50, 900 and 900EX (max. 19 passengers), Gulfstream Model GV-SP and GIV-X (max. 19 passengers), and a Bombardier CL600-2B16 (max. 20 passengers).

For this category of aeroplanes, the issue was the difficulty in installing an overhead emergency exit locator sign because it would present a head strike hazard due to the low headroom of the cabin. The FAA has issued in a number of ELOS (ST5542NY-T-S-1, SP5109SE-T-C-1, ST3302WI-T-A-1, AT5177AT-T-C-1, ANM-113-04-01, and TC2548WI-T-AG-4) allowing the combining of the exit locator sign with the exit marking sign.

ERJ190 (TC0099IB-T-C-9) and Falcon7X (TC0030IB-T-C-2) have ELOS for combining the emergency exit locator sign and the bulkhead/divider mounted exit sign due to their close proximity.

The size, background area or illumination levels of exit signs have also been the subject of those ELOS as well as several CRIs; however on some occasions, some of those aspects do exceed the requirements and compensate for other factors that do not meet the requirements such as location. It should be noted, however, that CS 25.812(b) does not specify letter sizes and areas as in FAR 25.812(b).

The FAA issued Final Rule on SFAR No. 109 'Special Requirements for Private Use Transport Category Airplanes' on 8 May 2009. Paragraph 8 of the SFAR permits the use of a single exit sign to meet the requirements of 25.811(d)(1) and (2):

8. Emergency Exit Signs. In lieu of the requirements of Sec. 25.811(d)(1) and (2) a single sign at each exit may be installed provided:

(a) The sign can be read from the aisle while directly facing the exit, and

(b) The sign can be read from the aisle adjacent to the passenger seat that is farthest from the exit and that does not have an intervening bulkhead/divider or exit.

#### **Conclusions and Recommendations**

The requirements for emergency exit locator signs have not presented any significant compliance issues for larger transport aeroplanes for commercial use; however, some smaller transport aeroplanes (above 10 passenger seats up to 20 passenger seats) have had difficulty in complying with the requirements in the past.

SFAR No. 109 permits the use of a single exit sign to meet the requirements of 25.811(d)(1) and (2) for private use aeroplanes. It is recommended that consideration be given by EASA to review CS 25.811(d) to take into account its practicability for smaller transport category aeroplanes (regardless of their type of operation). It is recommended that this proposal be considered for evaluation via a Regulatory Impact Assessment.

<sup>&</sup>lt;sup>327</sup> RGW Cherry & Associates Limited (2006) *An Evaluation of Equivalent Levels of Safety Findings and Exemptions Relating to Cabin Safety Regulations for Smaller Transport Aeroplanes, Prepared for Transport Canada, 0945/R/000343/KK Issue 1* 

## Cabin Safety Threat:

## 31. The Use of Internal Stairways during Evacuation (V10)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

There are no airworthiness requirements specifically addressing the use of stairways during evacuation. CS 25.813 ensures that each required emergency exit must be accessible to the passengers and located where it will afford an effective means of evacuation.

#### Accident Experience and Safety Recommendations

The accident review found 2 accidents where the occupants had to go through internal stairways to reach the available exits. Extracts from the accident reports describing the events are as follows:

*He [pax 17A] also noticed that the UDR cabin crewmember directed the passenger to the main deck via stairs.* (ADB Ref. 20001031B)<sup>328</sup>

Respondents from the upper deck reported that the aisles were crowded and that having to go down the stairs slowed their exit. (ADB Ref. 19990923A)<sup>329</sup>

No recommendations on this particular issue were made.

#### Research and Rulemaking Activities

The VLTA conference<sup>330</sup> concluded as follows:

In operation, whatever the configuration of the proposed VLTA, for evacuation purposes, it should be treated as a single vessel. However, for certification purposes, it may be necessary to consider multiple decks as either independent or interrelated in demonstrating compliance with requirements on evacuation, dependent on the scenario to be considered.

If a VLTA is to be certificated (for evacuation requirements) by considering the multiple decks as independent decks, this would assume that during a real evacuation, cabin crew will have a complete control of the flow of passengers so that they only evacuate from the deck where they are seated. This may not be the case; for example when there are psychological issues with passengers in using upper deck slides, or post-crash conditions that may render some exits unavailable on either or both decks. This concern was raised by the Association of Flight Attendants Aircraft Technical Committee<sup>331</sup>. Additionally, in the Special Condition on stairways between decks on the A380-800<sup>332</sup>, the FAA states that "although compliance with the evacuation demonstration requirements of Sec. 25.803 does not depend on the use of stairs, there must be a way for passengers on one deck to move to the other deck during emergency evacuation". This does not seem consistent with the certification process that considers multiple decks as independent.

JAA issued Interpretative Material for the A380-800 emergency evacuation<sup>333</sup> (compliance with 25.803). In this IM, Airbus proposed a concept to demonstrate compliance with JAR/FAR 25.803 which was accepted by JAA. The concept is as follows:

The conduction of a full scale evacuation test involving the complete upper deck cabin (max. pax 308, min. crew 8, 25.803-conditions).

The conduction of a partial evacuation test involving the main deck cabin between doors 2 and 4 (max. pax 330, min. crew 7, 25.803-conditions).

Both tests exclude any use of staircases. As the aspects around staircase use (how many persons, coming from where, moving where etc.) are very various and complex, it is Airbus opinion that these issues would most suitably be addressed and evaluated by means of analytical work, e.g. by computer models.

The issue of test versus analysis is addressed in the recommendation OS-6 of the VLTA Conference:

"The group has not identified this issue as a specific issue for VLTA based on conventional design, and therefore, see no reason for the current requirement to be changed for VLTA. However, an opinion expressed by the ITF (and supported by ALPA US) was that full scale evacuation demonstrations provide valuable information on passenger management and crew procedures, and that such demonstrations do give a basic indication of evacuation capability in the absence of more sophisticated regulatory requirements. There was therefore not a consensus on this question within the workshop."

With regard to the use of stairs between decks in evacuation, Galea et. al<sup>334</sup> concluded:

- Passenger behaviour in utilising stairs for egress is both rich and complex and warrants further investigation.
- Stair performance can be influenced by both crew procedures and cabin layout.
- For crew to consistently make appropriate or optimal redirection command decisions that include the possibility of using the stairs, they must have sufficient situational awareness.

The study recommended further fundamental research in the following areas:

- Performance of passengers on stairs, with and without hand rails
- Preference of upper deck passengers to utilise stairs in emergency situations
- Impact of orientation on passenger stair performance

The report for the VERRES work package<sup>335</sup> states that "it must also be considered if the staircases should be treated as an exit in the respect that that they are manned by cabin crew during an evacuation. If this is deemed to be the case, the number, location and procedures adopted by the cabin crew will need to be carefully researched." This has been addressed in a Special Condition issued by the FAA<sup>336</sup> and JAA<sup>337</sup>.

'Internal Stairs' is one of the "Proposed New Initiatives - Evacuation Related" in 'An inventory of work to assist the transition to EASA Issue 3' dated 16 January 2004 issued by the JAA.

### **Conclusions and Recommendations**

Since multiple stairways between decks are currently only installed on one aircraft type, amendment to CS-25 requirements to address this feature may not be currently necessary and the use of a Special Condition is probably more effective. However, the subject still requires further investigation to identify all potential evacuation issues on aeroplanes with multiple stairways and to ensure that the current certification process is adequate.

<sup>&</sup>lt;sup>328</sup> Aviation Safety Council Taiwan, Crashed on a partially closed runway during takeoff, Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, Chiang Kai Sek Airport, Taoyuan, Taiwan, October 31, 2000

Australian Transport Safety Bureau, Investigation Report 199904538, Boeing 747-438, VH-OJH, Bangkok, Thailand

<sup>&</sup>lt;sup>330</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16 October 1998 <sup>331</sup> "Fire on a Double-Deck Airliner May Affect Evacuation of Upper Cabin". Air Safety Week. FindArticles.com.

<sup>22</sup> January, 2009. http://findarticles.com/p/articles/mi\_m0UBT/is\_26\_15/ai\_75890806/

Joint Aviation Authorities, A380 Certification Review Item; Use of the stairs between desk - Special Condition

<sup>&</sup>lt;sup>332</sup> Federal Aviation Administration, Final Special Conditions No. 25-326-SC; Airbus Model A380-800; Stairways Between Decks <sup>333</sup> Joint Aviation Authorities, A380 Certification Review Item; Emergency Evacuation – Interpretative Material,

*Ref. D-11* <sup>334</sup> Galea, E.R., Blake, S.J., & Dixon, A. (2004) An analysis of passenger performance on stairs and upper deck slides during evacuation trials: A Report from the VERRES project, presented at the 4<sup>th</sup> Aircraft Fire and Cabin

Safety Research Conference, Lisbon, Portugal 15-18 November 2004 <sup>335</sup> Wilson, R., & Muir, H. (2003) VERRES VLTA Emergency Requirements Research Evacuation Study, Work

Package 1, Task 1.1. report <sup>336</sup> Federal Aviation Administration, Final Special Condition Airbus Model A380-800 Airplane; Stairways Between Decks, Ref. D-6

## Cabin Safety Threat:

## 32. Cabin Crew Unable to Assess External Hazards Prior to Opening Exit (Y14)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

There is no CS-25 requirement addressing the outside viewing means.

#### Accident Experience and Safety Recommendations

The accident review found one accident where the viewing window installed could not be used to assess external conditions for safe evacuation:

In this occurrence, the L3 cabin attendant did not use the viewing window to assess the exterior conditions because it was too small for her to clearly observe the conditions outside. She left the attendant station, went into the passenger seating area, looked out a cabin window, and saw the fire outside. The only thing visible to the L1 cabin crew through the viewing window was light. When the emergency exit was opened, it was usable. The R3 cabin attendant assessed the exterior conditions using the viewing window but did not see the fire below the exit or the wreckage in the slide deployment path. When the emergency exit door was opened, black smoke entered the cabin and the slide deflated when it contacted sharp pieces of wreckage. The R1 cabin attendant assessed the exterior conditions using the viewing window, but did not see that there was a creek outside until the exit was opened. When the slide deployed, the foot of it was very near the water. The cabin crew blocked the exit and redirected passengers. (ADB Ref. 20050802A)<sup>338</sup>

The accident investigation report discussed the issue of viewing windows, citing a 1992 NTSB accident investigation. In that accident, it was suspected that the outside pane of the viewing window might be badly scratched, which prevented a clear view of the conditions outside the aeroplane.

In a 1992 investigation, the NTSB identified the risk to passenger safety created by cabin crew when they leave their emergency exit and enter the passenger seating area to assess exterior conditions. On 30 July 1992, during daylight hours, a Lockheed L-1011 was destroyed by fire after the crew executed a take-off followed by an immediate emergency landing at JFK. The cabin attendant responsible for exit L2 was unable to clearly see the conditions outside through the viewing window, and left her exit and moved to a passenger window to see the conditions outside. After assessing the conditions through the passenger window, she found it impossible to return to her exit because passengers blocked the aisle leading to it. Another cabin attendant assumed her position at the exit and, when told by the L2 cabin attendant that it was clear outside, opened the exit door, allowing passengers to escape from the burning aircraft. The NTSB examined a viewing window on another Lockheed L-1011 operated by the air carrier to determine why the cabin crew had been unable to clearly see the conditions outside through the viewing window. They found that several of the outside window panes were crazed or scratched to the extent that it was difficult to view the ground clearly. Some other window panes also had scratches or crazing that interfered with a clear view, especially when looking aft. Due to extensive fire damage, it could not be determined if the condition of the viewing windows on AFR358 contributed to the cabin attendant's difficulty in assessing the conditions outside the aircraft in this occurrence.

Another problem with the current design of viewing windows is that, due to their locations, some hazards may not be visible from the viewing window position:
The over-wing slide deployment did not directly hamper the ARFFS crew from fighting the fire in the right body landing gear. However, the close proximity of the slide to the wheel well may have presented a problem in the event of a more substantial fire, or if the fire had spread. However, it was not possible to see the landing gear area from the over-wing exits or the adjacent windows. Therefore, during brake fires an accurate assessment of the extent of fire could not be obtained by viewing through the number-three left and right doors or adjacent windows and the potential to evacuate passengers into a fire hazard area existed. (ADB Ref. 20030702B)<sup>339</sup>

Following the investigation of this accident, the following safety recommendations were made:

Safety Recommendation R20050003 The Australian Transport Safety Bureau recommends that Qantas Airways Ltd, review the adequacy of their procedures for the deployment of over-wing slides during known brake fire situations. This review should take into consideration the visual cues used and potential risk to passengers of evacuating within close proximity of a fire zone.

Safety Recommendation R20050004 The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority, review the adequacy of operator procedures for the deployment of over-wing slides during known brake fire situations. This review should take into consideration the visual cues used and potential risk to passengers of evacuating within close proximity of a fire zone.

The inability to assess external hazards, by cabin crew, flight crew, or passengers, presented a danger to occupants during evacuation in the following accident. Fire/rescue personnel attempted to inform the flight crew; however this was not successful:

In accordance with Company Standard Operating Procedures, he [the captain] left the decision as to which exits were to be used to the cabin crew. At that time 'Fire One' called the aircraft saying: "[Operator] FROM FIRE ONE, CAN YOU MAKE SURE YOU EVACUATE PORT SIDE" This was not acknowledged. About 40 passengers evacuated onto the right side of the aircraft, including six onto the right wing. This placed them in the vicinity of the right engine and the area where the fire crews were directing their firefighting efforts. These six passengers were instructed by the fire crew to return inside the aircraft and seek an alternative exit. [Significant factors:] 4. The use of the over-wing slides during the evacuation, presented passengers with the potential hazard of being placed in close proximity to the fire source. (ADB Ref. 20020227B)<sup>340</sup>

The same problem has been identified in the evacuation of a Fokker 100 in Charlotte, North Carolina, 7 November 1997<sup>341</sup>:

...the flight crew asked both a flight attendant and ATC if any fire was present on or around the airplane. After receiving no report of fire, the flight crew ordered an evacuation of the 99 passengers using only the R1 exit. After 15 passengers had evacuated, the first officer exited the airplane using the R1 slide. Upon looking back at the airplane, he noticed a fire around the left main gear. He shouted to the flight attendant to evacuate using all of the right exits.

#### Research and Rulemaking Activities

Viewing windows are already installed on the exits on some aeroplanes in service; however, it has not been required until FAR 25.809 amendment 25-116 was introduced<sup>342</sup>. The FAA issued a Final Rule dated October 27, 2004 ('Miscellaneous Cabin Safety Changes'), which added the requirement for outside viewing means at exits to 25.809. This requirement should be complied with by all type certificate applications made after November 26, 2004. The FAA did not require retrofit due to the technical difficulties and costs of modification.

The amended FAR requirement (amendment 25-116) reads:

Sec. 25.809 Emergency exit arrangement.

(a) Each emergency exit, including each flightcrew emergency exit, must be a moveable door or hatch in the external walls of the fuselage, allowing an unobstructed opening to the outside. In addition, each emergency exit must have means to permit viewing of the conditions outside the exit when the exit is closed. The viewing means may be on or adjacent to the exit provided no obstructions exist between the exit and the viewing means. Means must also be provided to permit viewing of the likely areas of evacuee ground contact. The likely areas of evacuee ground contact must be viewable during all lighting conditions with the landing gear extended as well as in all conditions of landing gear collapse.

Unlike FAR 25, CS-25 does not require emergency exits to have outside viewing means. Current CS 25.809(a) reads:

(a) Each emergency exit, including a flight crew emergency exit, must be a movable door or hatch in the external walls of the fuselage, allowing unobstructed opening to the outside.

It is understood that the FAR 25.809(a) requirement has presented problems in compliance for the certification of a new design aircraft. According to the manufacturer, the requirement "...*The likely areas of evacuee ground contact must be viewable during all lighting conditions with the landing gear extended as well as in all conditions of landing gear collapse*" will result in a large area needing to be illuminated. This will incur high costs due to the required large battery and light unit.

#### **Conclusions and Recommendations**

It is evident that means of assessing the outside conditions to determine whether an exit is safe to use is extremely valuable. FAR 25 has already incorporated such a requirement and many in-service aeroplanes are already equipped with viewing windows.

It is recommended that consideration be given by EASA to amend CS-25 to add the requirement for outside viewing means and its minimum performance standards. However, the required level of illumination implied by FAR 25.809(a) needs further deliberation. Additionally, the requirement should not be limited to viewing windows at, or adjacent to, the exits, but should be open to the possibility of using other technologies such as external cameras. The use of external cameras may also improve flight crew awareness of external conditions for safe evacuation. It is recommended that this proposal be considered for evaluation via a Regulatory Impact Assessment.

 <sup>&</sup>lt;sup>338</sup> Transportation Safety Board Canada, Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005
 <sup>339</sup> Australian Transport Safety Bureau, Boeing 747-738, VH-OJU, Sydney Aerodrome, NSW, 2 July 2003

<sup>&</sup>lt;sup>340</sup> Air Accidents Investigation Branch, *Boeing 737-8AS EI-CSA Incident, London Stansted Airport, Essex, 27 February 2002, AAIB Bulletin No. 7/2004 Ref. EW/C2002/02/07* 

<sup>&</sup>lt;sup>341</sup> National Transportation Safety Board (2001) *Safety Study – Emergency Evacuation of Commercial Airplanes, NTSB/SS-00/01.* Washington D.C.: NTSB

<sup>&</sup>lt;sup>342</sup> Federal Aviation Administration, CFR Final Rule Miscellaneous Cabin Safety Changes, Federal Register: October 27, 2004 (Volume 69, Number 207), Docket No. FAA-2004-19412, Amendment Nos. 25-116 and 121-306

#### Cabin Safety Threat:

#### 33. Issues Related to Ditching Doors (AA02)

Current Applicable CS-25 Requirements and Associated Regulatory Material	
Ditching exit requirements are addressed in CS-25 (Amendment 6) as follows:	
25.801 Ditching	
(a) If certification with ditching provisions is requested, the aeroplane must meet the requirements of this paragraph and CS 25.807(e), 25.1411 and 25.1415(a).	
(b) Each practicable design measure, compatible with the general characteristics of the aeroplane, must be taken to minimise the probability that in an emergency landing on water, the behaviour of the aeroplane would cause immediate injury to the occupants or would make it impossible for them to escape.	
(d) It must be shown that, under reasonably probable water conditions, the flotation time and trim of the aeroplane will allow the occupants to leave the aeroplane and enter the life rafts required by CS 25.1415. If compliance with this provision is shown by buoyancy and trim computations, appropriate allowances must be made for probable structural damage and leakage. If the aeroplane has fuel tanks (with fuel jettisoning provisions) that can reasonably be expected to withstand a ditching without leakage, the jettisonable volume of fuel may be considered as buoyancy volume.	
25.807(e) Ditching emergency exits for passengers. Ditching emergency exits must be provided in accordance with the following requirements whether or not certification with ditching provisions is requested:	
(1) For aeroplanes that have a passenger seating configuration of nine seats or less.	

(1) For aeroplanes that have a passenger seating configuration of nine seats or less, excluding pilots seats, one exit above the waterline in each side of the aeroplane, meeting at least the dimensions of a Type IV exit.

(2) For aeroplanes that have a passenger seating configuration of 10 seats or more, excluding pilots seats, one exit above the waterline in a side of the aeroplane, meeting at least the dimensions of a Type III exit for each unit (or part of a unit) of 35 passenger seats, but no less than two such exits in the passenger cabin, with one on each side of the aeroplane. The passenger seat/exit ratio may be increased through the use of larger exits, or other means, provided it is shown that the evacuation capability during ditching has been improved accordingly.

(3) If it is impractical to locate side exits above the waterline, the side exits must be replaced by an equal number of readily accessible overhead hatches of not less than the dimensions of a Type III exit, except that for aeroplanes with a passenger configuration of 35 seats or less, excluding pilots seats, the two required Type III side exits need be replaced by only one overhead hatch.

Doors are regulated by CS 25.783 (b)(1) and (2):

Opening by persons. There must be a means to safeguard each door against opening during flight due to inadvertent action by persons. In addition, for each door that could be a hazard, design precautions must be taken to minimise the possibility for a person to open the door intentionally during flight. If these precautions include the use of auxiliary devices, those devices and their controlling systems must be designed so that:

1) no single failure will prevent more than one exit from being opened, and

(2) failures that would prevent opening of any exit after landing must not be more probable than remote.

#### Accident Experience and Safety Recommendations

The accident review found one accident where the ditching doors could not be opened. An extract from the accident is as follows:

It is likely that the only escape route available to the crew would have been through the overhead hatch. This would probably have been very difficult to open with the flight deck submerged... It is worth noting that had the hatch been opened prior to hitting the surface this escape route may have been more available, but such an action would have been contrary to the published ditching procedures. (ADB Ref. 20010227A)<sup>343</sup>

The accident investigation organisation could not establish whether the crew escape was precluded by the nature of the impact or by difficulty in operation of the flight deck emergency escape hatch under water. No safety recommendation was made on the subject.

#### Research and Rulemaking Activities

No current research on the subject has been identified.

The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

#### Discussion

The requirements regarding ditching emergency exits in CS 25.807(e) do not explicitly state that the ditching emergency exit doors should be operable during any likely ditching conditions. It was considered that this is implied by 25.801(b) and (d) and CS 25.783(b)(1) and (2).

However, there is a concern with regard to CS 25.807(e)(3) in relation to CS 25.783(b)(1). CS 25.807(e)(3) states that if it is impractical to locate side exits above the waterline, only **one** overhead hatch is required to replace the two required Type III side exits for aeroplanes with a passenger configuration of 35 seats or less. This means that this category of aeroplane may only have one exit that can be used during ditching. The requirements of CS 25.783(b)(1) state that "*no single failure will prevent more than one exit from being opened*", which "allows" the failure of one exit. In this case, there is no requirement to ensure that if there is only one ditching door it should be available.

#### **Conclusions and Recommendations**

Based on the review of the current applicable CS-25 requirements and accident experience, it was concluded that the possible jamming of a sole ditching door on aeroplanes with a passenger configuration of 35 seats or less may need to be addressed by amending CS-25 requirements. It is recommended that further investigation be carried out on this subject to assess the extent of the risk of such a scenario.

<sup>&</sup>lt;sup>343</sup> UK AAIB, Aircraft Accident Report No: 2/2003 (EW/C2001/2/6), Shorts SD3-60, G-BNMT, near Edinburgh Airport on 27 February 2001

#### Cabin Safety Threat:

#### 34. Emergency Exit Door Difficult to Latch Open (X14)

#### Current Applicable CS-25 Requirements and Associated Regulatory Material

Requirement for the latching open of emergency exit doors is not addressed in CS-25. However, it is addressed in FAR Part 25 as follows:

FAR 25.809 (i) Emergency exit arrangement

Each emergency exit must have a means to retain the exit in the open position, once the exit is opened in an emergency. The means must not require separate action to engage when the exit is opened, and must require positive action to disengage.

Related requirements are:

CS 25.809 Emergency exit arrangement

(b) ......Each emergency exit must be capable of being opened, when there is no fuselage deformation –

(1) With the aeroplane in the normal ground attitude and in each of the attitudes corresponding to collapse of one or more legs of the landing gear; and...

#### Accident Experience and Safety Recommendations

The accident review found two accidents where difficulties occurred with the latching open of emergency exits during emergency evacuation:

The forward entry door (1L) opened normally and the slide inflated normally, although the door did not lock in the open position at this first attempt and another movement was needed to bring it to the fully open and locked position. The forward service door (1R) also opened normally and was taken to the fully open position, although it did not lock in that position and swung back again. The slide inflated normally, although it remained folded approximately half way down. The CA2 informed the senior cabin attendant (CAI) that the exit could not be used. In the rear part of the cabin, the entry door (2L) could be opened and latched at the second attempt. CA3 reported that the door was extremely heavy to open, and that it started closing again while she had locked it against the fuselage. The aft service door (2R) could be opened but the slide appeared to be folded and the door swung back hitting the slide. The cabin attendant opening the door concluded that this exit was unusable and both rear cabin attendants directed passengers towards door 2L. (ADB Ref. 20041128A)<sup>344</sup>

Although the attitude of the aircraft after it came to rest is not discussed in the accident investigation report, the post accident photographs were studied during this detailed evaluation and it has been assessed that the aircraft was in a near normal, very slightly nose-up attitude.

*F/A* "*C*" reported that he opened the 2*R* door and the slide deployed and inflated normally. He stated the door functioned easily except that it did not lock against the fuselage as he expected it would. (ADB Ref. 20010317A)<sup>345</sup>

For this accident, it is not possible to accurately assess the attitude of the aircraft during the emergency evacuation since no details are given in the accident investigation report. However, given the absence of any information provided to the contrary, and from the general description of the impact sequence and ensuing evacuation, it is considered likely that the aircraft was in a near normal attitude.

There were no safety recommendations related to the difficulties in latching open the emergency exits, resulting from either of the above accidents.

#### Research and Rulemaking Activities

No current research on the subject has been identified. The review carried out in this study did not identify any current/past EASA or US FAA rulemaking activities pertinent to this cabin safety threat.

However, EASA has commenced a rulemaking task (Task No. 25.039) which addresses harmonisation of CS-25 with FAR 25.809 (i).

#### **Conclusions and Recommendations**

It is evident that difficulties have been experienced with latching open emergency exit doors during evacuations. The precise reasons are unknown, although it is suspected that adverse aircraft attitude may be a contributory factor because greater forces may be necessary to swing open doors compared to when the aeroplane is level. Evidence from one accident suggests that even a slight nose-up attitude may be enough to prevent the doors from being initially swung open with sufficient motion to result in latching against the fuselage.

It is recommended that further research is carried out into the causes of difficulties experienced in latching open emergency exits. This should include sensitivity to aircraft attitude. The research should also identify potential solutions.

<sup>345</sup> NTSB, Docket CHI01FA104, Accident of Airbus A320-200, registration N357NW, March 17, 2001 in Detroit, *MI, USA* 

<sup>&</sup>lt;sup>344</sup> Comision de Investigacion de Accidentes e Incidentes de Aviacion Civil (CIAIAC), *Technical Report A-*070/2004, Accident of aircraft Boeing B-737, registration PH-BTC, at Barcelona Airport (Spain), on 28 November 2004

## Table A9-1 Cabin Safety Threats Resulting in Recommendations for Minor Amendments to CS-25

CS-25 PARAGRAPH	ISSUE	RATIONALE FOR MINOR AMENDMENT	RECOMMENDATION
25.851(a)(6)	The requirement prescribes the use of Halon 1211 as the extinguishing agent for handheld fire extinguishers: At least one of the required fire extinguishers located in the passenger compartment of an aeroplane with a passenger capacity of at least 31 and not more than 60, and at least two of the fire extinguishers located in the passenger compartment of an aeroplane with a passenger capacity of 61 or more <b>must contain Halon</b> <b>1211 (bromochlorodifluoromethane,</b> <b>CBrC1F2)</b> , or equivalent, as the extinguishing agent. The type of extinguishing agent used in any other extinguisher required by this paragraph must be appropriate for the kinds of fires likely to occur where used.	The United Nations Environment Programme's (UNEP) Ozone Secretariat has recommended that ICAO consider a mandate, to be effective in the 2011 time frame, for the replacement of Halon in hand-held extinguishers for aircraft for which a new application for type certification has been submitted <sup>a</sup> . UNEP also recommended that ICAO consider a mandate to be effective in the 2014 timeframe for the replacement of Halon in hand-held extinguishers for new production aircraft <sup>b</sup> .	<ul> <li>Recommendation 4.2.1</li> <li>Given the imminent phasing out of Halon 1211 and the use of new extinguishing agents in civil aviation, it is recommended that EASA give consideration to amending CS 25.851(a)(6) to accommodate this, as follows:</li> <li>At least one of the required fire extinguishers located in the passenger compartment of an aeroplane with a passenger capacity of at least 31 and not more than 60, and at least two of the fire extinguishers located in the passenger compartment of an aeroplane with a passenger capacity of 61 or more must contain agents meeting the Minimum Performance Standards specified in AMC 25.XXX. The type of extinguishing agent used in any other extinguisher required by this paragraph must be appropriate for the kinds of fires likely to occur where used.</li> <li>It is also recommended that an MPS for handheld fire extinguishers, equivalent to the FAA AC 20-42D (Draft), be included in the AMC.</li> </ul>

<sup>&</sup>lt;sup>a</sup> International Civil Aviation Organization – Working Paper, A36-WP/206, TE/63, 17/9/07, Halon Replacement in Civil Aviation Aircraft. Retrieved April 2008, from <a href="http://www.icao.int">http://www.icao.int</a>

CS-25 PARAGRAPH	ISSUE	RATIONALE FOR MINOR AMENDMENT	RECOMMENDATION
25.1360(b)	The paragraph only mentions protection from burns for flight crew, which is inconsistent with AMC 25.1360(b) Burns. The temperature of any part, which has to be handled during normal operation <b>by the</b> <b>flight crew</b> , must not be such as to cause dangerous inadvertent movement, or injury to the crewmember. (See AMC 25.1360 (b).)	AMC 25.1360(b)(1) clearly states: For equipment which has to be handled during normal operation <b>by the flight or cabin crew</b> , a temperature rise of the order of 25 ℃, for metal parts, should not be exceeded. For other equipment, mounted in parts of the aeroplane <b>normally accessible to passengers or crew</b> , or which may come into contact with objects such as clothing or paper, the surface temperature should not exceed 100 ℃, in an ambient temperature of 20 ℃	It is recommended that a minor amendment be made to 25.1360(b) to also address cabin crew and passengers: Burns. The temperature of any part, which has to be handled during normal operation by the flight or cabin crew, or is normally accessible to passengers, must not be such as to cause dangerous inadvertent movement, or injury to the crewmember or passenger. (See AMC 25.1360 (b).)
AMC 25.561(d)	CS 25.785(f)(3) refers to AMC 25.561(c) for the determination of the strength of the local attachments: (3) For the determination of the strength of the local attachments (see AMC 25.561(c)) of	There is no "AMC 25.561(c)" in CS-25 Book 2. AMC 25.561(d) addresses the strength of the local attachments of seats and items of mass. AMC 25.561(d) is referred to by CS 25.561(d)	Minor amendment required to ensure the correct reference.

<sup>b</sup> United Nations Environment Programme. (2006). 2006 Report of the Halon Technical Options Committee – 2006 Assessment. Retrieved April 2008, from http://www.icao.int

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CS-25 PARAGRAPH	ISSUE	RATIONALE FOR MINOR AMENDMENT	RECOMMENDATION
CS 25.853(f)	The requirement reads: (f) Smoking is not to be allowed in lavatories. If smoking is to be allowed in any other compartment occupied by the crew or passengers, an adequate number of self- contained, removable ashtrays must be provided for all seated occupants.	This requirement was equivalent to FAR 25.853(f) up to. Amdt. 25-83. The FAA amended this paragraph in Amendment 25-116, since "removable ashtrays must be provided for all seated occupants" was considered ambiguous.	Amend CS 25.853(f) as per FAR 25.853(f) as follows: (f) Smoking is not allowed in lavatories. If smoking is allowed in any area occupied by the crew or passengers, an adequate number of self-contained, removable ashtrays must be provided in designated smoking sections for all seated occupants. Note: at the time this evaluation was conducted, EASA has commenced a rulemaking task (Task No. 25.039) which addresses this subject.
CS 25.809(x)	FAR 25.809 includes the requirement for provisions of means to retain the exit in the open position (25.809(i)), as follows: [(i) Each emergency exit must have a means to retain the exit in the open position, once the exit is opened in an emergency. The means must not require separate action to engage when the exit is opened, and must require positive action to disengage.] There is no such requirement in CS-25	Harmonisation with FAA on the exit hold-open feature will ensure a common standard and will not have any adverse impact on EASA or industry.	Add the following requirement in CS 25.809(x) Each emergency exit must have a means to retain the exit in the open position, once the exit is opened in an emergency. The means must not require separate action to engage when the exit is opened, and must require positive action to disengage. Note: at the time this evaluation was conducted, EASA has commenced a rulemaking task (Task No. 25.039) which addresses this subject.

CS-25 PARAGRAPH	ISSUE	RATIONALE FOR MINOR AMENDMENT	RECOMMENDATION
CS 25.807(x)	FAR 25.807(a) includes Type B and Type C exit specifications, but CS 25.807(a) does not.	CRIs have been used to allow the installation of Type B or Type C exits. Inclusion of Type B and Type C exits in CS-25 will reduce certification costs.	<ul> <li>Add the following requirements in 25.807(a):</li> <li>(8) Type B. This type is a floor-level exit with a rectangular opening of not less than 32 inches wide by 72 inches high, with corner radii not greater than six inches.</li> <li>(9) Type C. This type is a floor-level exit with a rectangular opening of not less than 30 inches wide by 48 inches high, with corner radii not greater than 10 inches.</li> <li>Note: at the time this evaluation was conducted, EASA has commenced a rulemaking task (Task No. 25.039) which addresses this subject.</li> </ul>

CS-25 PARAGRAPH	ISSUE	RATIONALE FOR MINOR AMENDMENT	RECOMMENDATION
CS 25.855	The requirement reads: For each cargo or baggage compartment not occupied by crew or passengers, the following apply:	<ul> <li>This requirement was equivalent to FAR 25.855 until Amendment 25-93. The FAA amended this introductory phrase in Amendment 25-116, since it has been brought to the attention of FAA that this phrase may cause confusion, i.e.:</li> <li>This phrase may be interpreted in that the requirements do not apply to cargo/baggage compartments that are occupied occasionally by crew or passengers (although it has not been interpreted as such).</li> <li>Crew and passengers are not permitted to be seated or stationed on a full-time basis in cargo or baggage compartments; therefore, this phrase does not have any applicability.</li> <li>Conversely, in special circumstances such as "groom stations" where crew are seated on a full-time basis in a cargo compartment, the requirements in 25.855 should still be applicable for the compartment.</li> </ul>	Amend the introductory phrase of CS 25.855 as per FAR 25.855 as follows: <i>For each cargo or baggage compartment, the</i> <i>following apply:</i> Note: at the time this evaluation was conducted, EASA has commenced a rulemaking task (Task No. 25.039) which addresses this subject.

# Attachment 1

#### EASA REGULATORY IMPACT ASSESSMENT

Power Supplies For Public Address, Interphone and Evacuation Alert Systems

#### SEPTEMBER 2009

Issue 1

## AMENDMENT RECORD

ISSUE NUMBER	DATE	Remarks
1	September 2009	Initial Issue

# CONTENTS

Abbreviations4			
1	Purpose and Intended Effect5		
1.1 1.2 1.3	Issue which the NPA is intended to address       5         Scale of the issue       5         1.2.1       Accident and incident data       5         1.2.2       Discussion       6         1.2.2.1       Public address (PA) system       6         1.2.2.2       Interphone system       7         1.2.2.3       Evacuation alert system       8         1.2.3       Analysis of the requirements       9         Brief statement of the objectives of the NPA       10		
2	Options11		
2.1 2.2	The options identified11 The preferred option selected11		
3	Sectors Concerned13		
4	Impacts13		
4.1	All impacts identified134.1.1Safety134.1.2Economic144.1.3Environmental144.1.4Social144.1.5Other aviation requirements outside EASA scope144.1.6Foreign comparable regulatory requirements15Issues of equity and fairness15		
5	Summary and Final Assessment15		
5.1	.1 Comparison of the positive and negative impacts for each option evaluated		
5.2 5.3	<ul> <li>A summary describing who would be affected by these impacts and analysing issues of equity and fairness</li></ul>		
6	References		

# ABBREVIATIONS

AAIB	Air Accidents Investigation Branch (UK)
EASA	European Aviation Safety Agency
EWIS	Electrical Wiring Interconnection System
NPA	Notice of Proposed Amendment
NTSB	National Transportation Safety Board (USA)
PA	Public Address
TSB	Transportation Safety Board of Canada

# 1 PURPOSE AND INTENDED EFFECT

## 1.1 ISSUE WHICH THE NPA IS INTENDED TO ADDRESS

Public address (PA) and interphone systems, when installed to meet operational requirements, provide capability for crew to passenger and crew to crew communications that are vital in some emergencies. The integrity of the power supplies to these systems is therefore very important.

Aeroplanes are not required by operational rules to be equipped with evacuation alert systems. However, since some aeroplane types are equipped with these systems and the emergency evacuation procedures used by operators of these aeroplanes are dependant on the evacuation alert system being functional, the integrity of power supplies to these systems is very important.

Accident and incident data demonstrate that during some emergencies, PA, interphone and evacuation alert systems have become inoperable or severely degraded as a result of power supply failure or disconnection. There is consequently a need to improve the integrity of power supplies for PA systems, interphone systems and evacuation alert systems. This conclusion is verified by recommendations issued by accident investigation bodies and research studies commissioned by the NTSB, TSB and EASA.

CS-25 partially addresses requirements for PA system power supply but does not address requirements for interphone and evacuation alert system power supplies.

## 1.2 SCALE OF THE ISSUE

#### 1.2.1 Accident and incident data

There is evidence of many survivable accidents and incidents in which power failure or intentional disconnection of the power to PA, interphone or evacuation alert systems occurred during an emergency. A sample of relevant accidents extracted from a study carried out for EASA (Reference 1), involving aeroplanes manufactured in compliance with FAR 25.1423, is shown in Table 1. The accident reports identified in the study for EASA did not include data on the number of injuries or fatalities that resulted from failure of the power supply to the communication systems. It is considered unlikely that such information could be determined during accident investigations.

Accident	Resume
B737-300 ( ZK-NGJ)	In-flight power failure to PA system, interphone and call button
Auckland, New Zealand	following Battery Bus failure. Evacuation after landing due to smoke in cabin. No aircraft impact. Due to the upavailability of
12 September 2006	and cabin crew, amongst cabin crew, and between crew and passengers had to be carried out face-to-face.
B737-700 (N471WN)	Post crash power failure to PA system. Moderate impact after a
Chicago, U.S.A.	landing overrun. The PA system was unavailable for cabin crew direction of the evacuation. One cabin crew member expected the
8 December 2005	PA not to work due to aircraft power failure and therefore did not try. Another tried to use the PA and did not know it was not working until advised by a passenger that no sound was coming through.

#### Table 1 Sample of recent accidents

#### EASA REGULATORY IMPACT ASSESSMENT POWER SUPPLIES FOR PUBLIC ADDRESS, INTERPHONE AND EVACUATION ALERT SYSTEMS Issue 1 September 2009

Accident	Resume
A340 (F-GLZQ) Toronto, Canada 2 August 2005	<b>Post crash power failure to PA system, EVAC COMMAND and EVAC ON alert.</b> Landing overrun followed by moderate impact, fire and evacuation. The PA operated for a short time allowing three announcements including one evacuation announcement, but then failed. The EVAC COMMAND function failed to work when operated by the chief purser to notify the flight crew. The EVAC ON function failed to work when operated by the flight crew in order to activate the evacuation alert to the cabin crew. The accident report cites the vulnerable location of the PA system emergency power in the
	avionics bay as the reason.
MD88 (TC-ONP)	Post crash failure of PA system. Rejected takeoff, overrun,
Groningen, Netherlands 17 June 2003	announcement soon after the aircraft stopped but it was unintelligible. The Purser stated the PA system did not work after
	the crash.

#### 1.2.2 Discussion

#### 1.2.2.1 Public address (PA) system

Aircraft configured with greater than 19 passenger seats are required by OPS.CAT.517 to be equipped with a public address system.

The primary reasons for using the PA system during emergency situations are to initiate an emergency evacuation and for the flight crew to call 'Brace for Impact'. The potential threats resulting from the PA system being un-powered at such times would therefore include:-

- i) delayed commencement of evacuation
- ii) evacuation attempted through unavailable exits (blocked by fire)
- iii) evacuation commenced when not required
- iv) evacuation commenced whilst engines running
- v) occupants not bracing for impact

All of the above threats have the potential to cause fatal or serious injuries. It is therefore logical that CS 25.1423 requires the PA system to be powerable in the event of engines and APU not running, or the loss of generated power. CS 25.1423 originates from FAR 25.1423, which was introduced in 1989 and is effective for aircraft manufactured after 27 November 1990. This requirement caters for an in-flight loss of engines and APU and the possible need to shut down engines after an emergency landing or impact.

However, in the study carried out for EASA (Reference 1), several accidents were identified for the period 1998 to 2007 inclusive, where there was no power available to the PA system immediately after emergency landing or impact when the crew were faced with an evacuation situation. In one accident, (Toronto A340), the PA system received power for only enough time for three messages to be broadcast.

In some accidents, the power supplies to the PA systems failed despite there being relatively low levels of impact damage to the fuselages.

Additionally, it is possible for the power to the communications systems to be switched off by the flight crew and this occurred in at least one accident. The precise reason for loss of power is not available for some accidents and for others where the aircraft was

manufactured prior to FAR 25.1423 becoming effective, the PA system was not required to be powered following engine and APU shutdown.

Several examples of in-flight failure of the battery bus, which removed power supply to the PA system, are evident.

The study carried out for EASA (Reference 1) also states:-

"In 1995, the TSB published a document entitled A Safety Study of Evacuations of Large, Passenger-Carrying Aircraft. Twenty-one occurrences involving emergency evacuations were reviewed. In 8 of the 21 occurrences, the aircraft's PA system was inoperable or inaudible following the accident. As a result, cabin crew and/or passengers did not hear the initial command to evacuate and/or did not hear other emergency instructions. The onset of these evacuations was delayed, placing the safety of passengers and crew at risk. One of the recommendations resulting from this safety study is as follows:

The Department of Transport review the adequacy of power supplies and standard operating procedures for PA systems in an emergency for all Canadian operators of large passenger aircraft. (A95-04)"

#### 1.2.2.2 Interphone system

Aircraft configured with greater than 19 passenger seats or greater than 15,000 kg Maximum Take-off Weight are required by OPS.CAT.516 to be equipped with an interphone system allowing communications between flight deck crew and cabin crew.

OPS.CAT.516 clearly intends the interphone to be operable during emergency situations since AMC OPS.CAT.516 states "The crew member interphone system should have a means for the recipient of a call to determine whether it is a normal call or an emergency call..."

However, CS-25 does not require the interphone system to be powerable when the engines or APU are not running, as it does for the PA system. This means that aircraft compliant with CS-25 could potentially have non-functioning interphone systems as a result of engine shutdown or failure following emergency landing or impact, at a time when two way communications between the flight deck and cabin are most vital to establish the need for an evacuation. It is normal for the aircraft commander to initiate evacuation, but it is often the cabin crew who first recognise the need for evacuation, because either they have sight of an external fire or fire has entered the passenger compartment. Without an interphone system the ability of the cabin crew to notify the captain is severely degraded.

Similarly, following total engine failure in flight, two way communications between the flight deck and passenger compartment could be lost, degrading preparations for ditching or emergency landing. This threat is exacerbated by the requirement for locked cockpit doors.

Unlike the interphone system, CS-25 requires PA systems to be powerable when the engines and APU are off. There appears to be no obvious reason why CS-25 should not require an interphone system to be powerable by a supply that meets a similar standard.

These conclusions are very clearly supported by a UK AAIB investigation into a cabin and flight deck smoke incident near Leeds, UK on 4 August 2005 involving a DHC-8-400. The AAIB incident report (Reference 2) stated:-

"Flight deck and cabin crews work together to ensure the safety of the operation. Interphone systems, historically, have been provided and used as backups to faceto-face communications. With the advent of the locked flight deck door policy, full reliance for operationally necessary communications is placed on the electronic communications systems, and failure of the interphone system is itself considered to be an in-flight emergency. However, these systems were designed before the advent of present-day security policies and do not provide the necessary reliability for use in this role, particularly in emergencies as the busbars which supply them are not the aircraft's essential busbars. As a result, such essential communications will be lost if there is a loss of the associated electrical busbar supplies as, for example, if the aircraft were to be configured into a typical emergency electrical configuration such as might be expected if the flight crew were dealing with an electrical fire. In a recent AAIB investigation, due to such a power shutdown, a large public transport aircraft was evacuated on the stand without the knowledge or authority of the Commander (AAIB Bulletin 1/2007, Avro RJ 146-100 G-CFAE on 11 Jan 2006). In those situations where the training and resources of the flight and cabin crews are required to minimise injuries or loss of life, the necessary communications may be impeded, and may not be available at all. Therefore the AAIB makes the following Safety Recommendation:

Safety Recommendation 2007-004: It is recommended that for all large aeroplanes operating for the purposes of commercial air transport, the UK CAA and the EASA should take such steps, procedural or technical, as are necessary to improve the reliability and availability of communications between flight and cabin crews, including the reliability of communications equipment and associated power supplies in both normal and emergency configurations."

#### 1.2.2.3 Evacuation alert system

Evacuation alert systems are not currently required by operational requirements or CS-25. However, it is evident from accident data, that on some aircraft types these systems have been introduced and airline operating procedures specify their use for initiating evacuations. In the Toronto A340 accident, the evacuation alert system failed to function when required.

If an aeroplane is equipped with an evacuation alert system and the system is to be used in an emergency procedure it is essential that the power supply to the system is available when required. It is therefore considered that the status and availability of the power supply to an evacuation alert system should be same as that for a PA system.

The study carried out for EASA (Reference 1) cites an NTSB recommendation to the FAA:-

Require all newly manufactured transport-category airplanes operating under Title 14 Code of Federal Regulations Part 121 to be equipped with independently powered evacuation alarm systems operable from each crewmember station, and establish procedures and provide training to flight crews and flight attendants regarding the use of such systems. (A-00-90)

In response to this recommendation, the FAA considered that crew interphone and public address systems perform the function of an evacuation alarm and it is therefore not necessary to mandate the requirement for an evacuation alarm system. The NTSB disagreed, and argued that it continues to investigate accidents and incidents in which the PA and interphone systems did not work at critical periods in an evacuation and in which an

evacuation alarm was needed. The status of this recommendation is "Closed – Unacceptable action".

The regulatory action considered in this RIA is intended to improve the integrity of the power supplies to the PA and interphone systems on newly designed aeroplanes and may lessen the justification for evacuation alert systems on these aeroplanes. However, regulatory action resulting from the NPA would have no effect on the justification for mandating evacuation alert systems on newly built aeroplanes with existing type certificates.

#### **1.2.3** Analysis of the requirements

In relation to the PA system power supply, CS-25 states:-

#### CS 25.1423 Public address system

A public address system required by operational rules must –

(a) Be powerable when the aircraft is in flight or stopped on the ground, after the shutdown or failure of all engines and auxiliary power units, or the disconnection or failure of all power sources dependent on their continued operation, for –

(1) A time duration of at least 10 minutes, including an aggregate time duration of at least 5 minutes of announcements made by flight and cabin crew members, considering all other loads which may remain powered by the same source when all other power sources are inoperative; and

(2) An additional time duration in its standby state appropriate or required for any other loads that are powered by the same source and that are essential to safety of flight or required during emergency conditions

In practice, 25.1423 part (a), shown above, may be interpreted as follows -

The PA system must be powerable after loss or disconnection of aeroplane generated electrical power. It must therefore be powered or have the capability to be powerable from a battery. To achieve this, it may be permanently connected to a battery bus, or may be connected to a bus that is selectable from generator to battery power, or may have its own independent battery. If the power source is selectable it may be manual or automatic.

CS-25 has no equivalent electrical power requirements applicable to interphone or evacuation alert systems.

#### EASA REGULATORY IMPACT ASSESSMENT POWER SUPPLIES FOR PUBLIC ADDRESS, INTERPHONE AND EVACUATION ALERT SYSTEMS Issue 1 September 2009

From accident and incident experience, it is evident that there are several power interruption

- (1) The system may be connected to a battery bus that fails due to an electrical fault.<sup>1</sup>
- (2) The system may be connected to a battery bus that fails due to inertia forces in an emergency landing.<sup>2</sup>
- (3) The system may be connected to a battery bus that fails due to deformation or rupture of the fuselage in a minor crash landing.<sup>2</sup>
- (4) Failure of the pilot, due to injury, or by not following procedures, to manually select battery power to replace generator power when the engines have failed or been shut down in an emergency evacuation. (This is a hypothetical scenario that could occur on some aeroplane designs requiring manual selection).<sup>3</sup>
- (5) Intentional in-flight disconnection of the bus supplying the system when carrying out an 'Electrical System Fire or Smoke' procedure.<sup>4</sup>

CS-25 should therefore be amended. It should retain the existing power supply requirements for the PA system with the addition of:-

- (1) Similar power supply requirements for the interphone system and evacuation alert system (if fitted)
- (2) A requirement for the power supplies to be maintained automatically
- (3) A requirement that addresses inertia forces encountered during emergency landing
- (4) A requirement that addresses a reasonable level of tolerance to fuselage damage resulting from emergency landing impact

#### **1.3 BRIEF STATEMENT OF THE OBJECTIVES OF THE NPA**

scenarios that are not addressed by CS 25.1423 part (a):

The NPA is intended to improve the integrity of power supplies to the PA, interphone and evacuation alert systems to enable these systems to remain functional for sufficient time for the crew to carry out emergency procedures that are dependent on crew to crew and crew to passenger communications.

The intention is to provide the aircraft manufacturer with a performance based and nonprescriptive requirement, providing flexibility as to the manner in which this goal is achieved.

<sup>&</sup>lt;sup>1</sup> In flight failure of the battery bus occurred in the Auckland B737-300. See Table 1.

<sup>&</sup>lt;sup>2</sup> Crash landing inertia forces or fuselage damage were the causes of the battery buses to fail in the Chicago B737-700, Toronto A340 and Groningen MD88 accidents. See Table 1.

<sup>&</sup>lt;sup>3</sup> A comparable emergency scenario exists on the Boeing 737, whereby when conducting an emergency evacuation procedure, the pilot is required to manually select the standby bus to 'BAT' in order to maintain power to the VHF 1 radio to preserve communication capability with the tower.

<sup>&</sup>lt;sup>4</sup> Intentional disconnection of the electrical bus occurred in an EMB-190 in-flight smoke incident overhead Edinburgh in January 2009. Subsequently, during the remainder of the flight when the aircraft was operating on battery and ram-air turbine emergency power, the functioning of the interphone system was severely degraded. (Reference 3)

# 2 OPTIONS

## 2.1 THE OPTIONS IDENTIFIED

Two regulatory options are considered in this Regulatory Impact Assessment:

#### Option 1 – Do Nothing

The "Do nothing" option means to make no improvements to CS-25 in relation to the power supply requirements for PA, interphone and evacuation alert systems.

**Option 2 – Amend CS-25** to provide power supplies for PA, interphone and evacuation alert systems, required by operational rules or otherwise, with the capability to maintain the functioning of these systems for sufficient time to allow completion of emergency procedures dependent on crew to crew and crew to passenger communications.

(Note: For the PA system only, CS 25.1423 already includes requirements that partially satisfy this intention).

Three potential solutions have been identified, but alternative means may be used. The PA, interphone and evacuation alert systems may –

(1) Be powerable from the emergency bus, or could be automatically selectable to the emergency bus upon power supply interruption, or –

(2) Be powerable from a dedicated power source, rechargeable from the aircraft normal electrical supply, or -

(3) Be powerable from an aeroplane generator or battery bus, but have an automatically activated dedicated standby power supply.

and –

for all solutions, the power source and any required controller and EWIS, including their supports and fixing to the aeroplane, must be capable of normal operation after having been subjected to the inertia forces listed in CS25.561(b), and all practicable measures must be taken to minimise the probability of failure caused by lower fuselage deformation or rupture following an emergency landing.

#### 2.2 THE PREFERRED OPTION SELECTED

After due consideration the Agency believes that Option 2 - Amend CS-25 to provide power supplies for PA, interphone and evacuation alert systems, required by operational rules or otherwise, with the capability to maintain the functioning of these systems for sufficient time to allow completion of emergency procedures dependant on crew to crew and crew to passenger communications is to be preferred.

This rule would apply to aircraft equipped with these systems whether or not required by operational rules.

The existing CS 25.1423 includes requirements specific to the PA system that are not related to power supply. Therefore, the power supply requirements for the PA system would need to be deleted from CS 25.1423 and be incorporated, suitably modified, into a new CS-

#### EASA REGULATORY IMPACT ASSESSMENT POWER SUPPLIES FOR PUBLIC ADDRESS, INTERPHONE AND EVACUATION ALERT SYSTEMS Issue 1 September 2009

25 requirement that includes the power supply requirements for interphone and evacuation alert systems. The following would be deleted from CS 25.1423:-

- (a) Be powerable when the aircraft is in flight or stopped on the ground, after the shutdown or failure of all engines and auxiliary power units, or the disconnection or failure of all power sources dependent on their continued operation, for –
  - (1) A time duration of at least 10 minutes, including an aggregate time duration of at least 5 minutes of announcements made by flight and cabin crew members, considering all other loads which may remain powered by the same source when all other power sources are inoperative; and
  - (2) An additional time duration in its standby state appropriate or required for any other loads that are powered by the same source and that are essential to safety of flight or required during emergency conditions

A new rule would be added to CS-25 to include the electrical power requirements for the PA, interphone and evacuation alert systems:-

# CS 25.xxx Power supplies for public address, interphone and evacuation alert systems

- (a) When required by operational rules or installed for other purposes, a public address system, interphone system and evacuation alert system must be powerable when the aircraft is in flight or stopped on the ground.
- (b) The power supplies must be automatically maintained following the shutdown, disconnection or failure of any generated powered source, or the disconnection or failure of any non-emergency battery powered bus except following normal termination of aeroplane operation by the flight crew, for-
  - (1) A time duration of at least 10 minutes, including -
    - (i) an aggregate time duration of at least 5 minutes of public address system announcements made by flight and cabin crew members considering all other loads which may remain powered by the same source when all other power sources are inoperative; and
    - (ii) an aggregate time duration of at least 10 minutes of interphone communications made by flight and cabin crew members considering all other loads which may remain powered by the same source when all other power sources are inoperative; and
    - (iii) a aggregate time duration of at least 5 minutes of evacuation alert system operation considering all other loads which may remain powered by the same source when all other power sources are inoperative; and

- (2) An additional time duration in their standby states appropriate or required for any other loads that are essential to safety of flight or required during emergency conditions.
- (c) The power source and any required controller and EWIS, must be capable of normal operation after being subjected to the inertia forces specified in CS 25.561(b)(3)
- (d) All practicable measures must be taken to minimise the probability of failure of the power supplies to the public address, interphone and evacuation alert systems resulting from deformation or rupture of the lower fuselage lobe in a minor crash landing.

# 3 SECTORS CONCERNED

The proposed regulatory change is to CS-25 and hence the aeroplanes affected will be those for which the application for a type certificate is made after the regulatory change considered in this Regulatory Impact Assessment. All such CS-25 aeroplanes equipped with interphone, PA or evacuation alert systems will need to comply.

The primary cost of the regulatory change will be borne by the operator due to increased fuel costs associated with increased weight. There will be marginal costs to manufacturers due to engineering and material costs, marginal cost to EASA in their oversight of the manufacturer in showing compliance with the regulatory change and marginal cost to operators due to increased maintenance.

## 4 IMPACTS

## 4.1 ALL IMPACTS IDENTIFIED

## 4.1.1 Safety

## Option 1 – Do Nothing

This option would have no impact on safety.

It would not change the current level of safety required by CS-25 for the power supplies to PA, interphone and evacuation alert systems on some aeroplane types. This is considered unsatisfactory. There would be continued occurrences of crew to crew and crew to passenger communications capability becoming partially or totally degraded during the execution of emergency procedures that are dependent on communication.

#### Option 2 – Amend CS-25

This option would improve the current level of safety by ensuring the power supplies to the PA, interphone and evacuation alert systems, for which some emergency procedures are dependant, are maintained for sufficient time for the emergency procedures to be completed. This applies in particular to the execution of Electrical System Fire or Smoke, Ditching, Emergency Landing and Emergency Evacuation procedures.

## 4.1.2 Economic

#### **Option 1 – Do Nothing**

No economic impacts have been identified.

#### Option 2 – Amend CS-25

It is expected that to comply with Option 2, aeroplanes will need to be equipped with new and additional parts. Some existing parts may be redundant. This will add the following costs:-

(a) Engineering cost: Parts will be required to be designed and tested. This is likely to be carried out by specialist suppliers and airframe manufacturers. The engineering cost of some parts may be amortised across more than one aeroplane type (e.g. an integral amplifier, standby power source and controller). The costs will be borne by the aircraft manufacturers and are expected to be minimal once amortised across many aeroplanes. Operators will incur marginal additional engineering costs associated with increased maintenance due to additional parts.

(b) Material cost: It is expected that some existing parts may be redundant and will offset the cost of new and additional parts. Material cost per aeroplane is expected to be minimal.

(c) Added fuel cost: The new and additional parts are expected to weigh more and thus there will be a fuel-weight penalty over existing designs. It is estimated that additional weight will be around 5kg per aeroplane. This induces additional fuel consumption which equates to approximately 1.7 million Euros of additional fuel costs per year to the industry worldwide, (once all aeroplanes in the world fleet are in compliance).

#### 4.1.3 Environmental

#### **Option 1 – Do Nothing**

No significant environmental impacts have been identified.

#### Option 2 – Amend CS-25

It is expected that to comply with Option 2, aeroplanes will need to be equipped with additional parts. Carbon dioxide emissions to the atmosphere will consequently increase, resulting from parts manufacture and increased fuel burn associated with increased aeroplane weight. However, the increase in carbon dioxide emissions will be minimal.

No other environmental impacts have been identified.

#### 4.1.4 Social

No social impacts have been identified.

#### 4.1.5 Other aviation requirements outside EASA scope

There would be no impact on other aviation requirements outside EASA scope.

## 4.1.6 Foreign comparable regulatory requirements

ICAO Annex 6 and Annex 8 were reviewed and no text was found in conflict with the content or overall objectives of the NPA.

Since there are no current rulemaking activities within the FAA or Transport Canada regarding this subject, a rule change will introduce differences in the standards.

#### 4.2 **ISSUES OF EQUITY AND FAIRNESS**

There are no issues of equity and fairness associated with any of the regulatory options considered in this Regulatory Impact Assessment.

## 5 SUMMARY AND FINAL ASSESSMENT

# 5.1 COMPARISON OF THE POSITIVE AND NEGATIVE IMPACTS FOR EACH OPTION EVALUATED

**Option 1:** This is the "Do Nothing" option. It would have no impacts and would make no changes to the current level of safety required by CS-25 for the power supplies to PA, interphone and evacuation alert systems. Events would continue, in which crew to crew and crew to passenger communication capability is partially or totally degraded during the execution of emergency procedures that are dependent on communication. The consequences are likely to result in serious or fatal injuries to occupants.

**Option 2:** This option would bring the highest safety benefits with related economic consequences that are considered acceptable.

# 5.2 A SUMMARY DESCRIBING WHO WOULD BE AFFECTED BY THESE IMPACTS AND ANALYSING ISSUES OF EQUITY AND FAIRNESS

**Option 1** would have no impact on the aeroplane manufacturers, operators, or EASA.

**Option 2** would require the aeroplane manufacturer to incur increased engineering and material costs related to the provision of new and additional parts. These costs would be minimal. For operators, this option would increase fuel costs due to the increased weight of the aeroplane and would marginally increase maintenance costs due to additional parts. There will be marginal costs incurred by EASA in their oversight of the manufacturer in showing compliance with the regulatory change.

#### **5.3 FINAL ASSESSMENT AND RECOMMENDATION OF A PREFERRED OPTION**

After due consideration Option 2 (Amend CS-25) is to be preferred. It provides an increased level of safety over Option 1 (Do Nothing).

Option 2 will ensure the PA, interphone and evacuation alert systems are:-

i) powerable for sufficient time for the crew to carry out emergency procedures that are dependent on crew to crew and crew to passenger communications

ii) automatically powerable when all other power supplies have failed or been disconnected

iii) powerable by a supply that will operate normally after being subjected to inertia forces and deformation or rupture of the lower fuselage lobe that may occur during an emergency landing impact.

The engineering and material costs of introducing Option 2 on new type designs are minimal. However, aeroplane operating costs will be increased due to additional fuel burn associated with weight increase. These costs are considered to be outweighed by the potential safety benefits provided.

## 6 **REFERENCES**

 RGW Cherry and Associates (2009). Study on CS-25 Cabin Safety Requirements 4208/R/000454/KK, prepared for the European Aviation Safety Agency.
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# Attachment 2

## EASA REGULATORY IMPACT ASSESSMENT

OCCUPANT PROTECTION FROM POST CRASH FIRE AND SMOKE

DECEMBER 2009

Issue 2

Issue 2 December 2009

# AMENDMENT RECORD

ISSUE NUMBER	DATE	Remarks
1	September 2009	Initial Issue
2	December 2009	Minor Amendment - Section 1.2 paragraphs 3 and 4

# CONTENTS

Abbre	bbreviations5					
Definition of Terms5						
1	Purpose and Intended Effect					
1.1 1.2 1.3	Issue which the NPA is intended to address					
2	Options9					
2.1 2.2 2.3	Scope of options92.1.1 Enhanced Fuselage Burnthrough Protection92.1.2 Cabin Water Mist Systems102.1.3 Passenger Smoke Hoods10The options identified10The preferred option selected11					
3	Sectors Concerned11					
4	Impacts12					
4.1	Option 4.1.1 \$ 4.1.2 E 4.1.3 E 4.1.4 \$ 4.1.5 \$ 4.1.6 F 4.1.7 \$	1 - Do Nothing       12         Safety       12         Conomic       12         Invironmental       12         Social       12         Other aviation requirements outside EASA scope       12         Foreign comparable regulatory requirements       12         Conclusions       12	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2			
4.2	Option means 4.2.1 \$ 4.2.2 \$ 4.2.3 \$ 4.2.3 \$ 4.2.4 \$ 4.2.5 \$ 4.2.6 \$ 4.2.7 \$ 0 \$ 4.2.7 \$ 0	2 - Improved Occupant Protection from Fire & Smoke by         of Cabin Water Mist Systems       13         Safety       13         2.2.1.1       Disbenefits       13         2.2.1.2       Life Saving Potential       14         2.2.1.3       Recommendations from Accident Investigating Authorities       16         Sconomic       16         Social       17         Other aviation requirements outside EASA scope       17         Social       17         Other aviation scope       17         Social       17         Other aviation requirements outside EASA scope       17         Social       17         Social <t< td=""><td>33356677777</td></t<>	33356677777			
4.3	Option Passen 4.3.1 \$ 4 4.3.2 \$ 4.3.3 \$ 4.3.4 \$	3 - Improved Occupant Fire & Smoke Protection by means of ger Smoke Hoods       18         Safety       18         Social       20	3 8 9 9 0			

4.4	4.3.5 4.3.6 4.3.7 Option Crash 4.4.1 4.4.2 4.4.3 4.4.4 4.4.5 4.4.6	Other aviation requirements outside EASA scope Foreign comparable regulatory requirements Conclusions n 4 - Carry out further research into feasible, cost beneficial is that might provide Improved Occupant Protection from Post Fire and Smoke Safety Economic	20 20 20 21 21 21 21 22 22 22 22 22 22		
	4.4.7	Conclusions	23		
5	Summ	nary and Final Assessment	23		
5.1	Comp. evalua 5.1.1 5.1.2 5.1.3 5.1.4	arison of the positive and negative impacts for each option ated Option 1 - Do Nothing Option 2 – Improved Occupant Protection from Fire & Smoke by mean of Cabin Water Mist systems Option 3 - Improved Occupant Protection from Fire & Smoke by mean of Passenger Smoke Hoods Option 4 - Carry out further research into feasible, cost beneficial options that might provide Improved Occupant Protection from Post Crash Fire and Smoke	23 23 1s 23 s 24		
5.2	A sum analys 5.2.1 5.2.2 5.2.3 5.2.4 Final a	The aircraft manufacturers EASA Issues of equity and fairness The operators EASA Issues of equity and fairness assessment and recommendation of a preferred option	25 25 25 25 26 26		
6	Refere	ences	26		
Appendix 1 – The Disadvantages of Passenger Smoke Hoods as cited in the UK CAA Document CAP 586 - Improving Passenger Survivability In Aircraft Fires: A Review					

Issue 2 December 2009

## ABBREVIATIONS

AC	Advisory Circular
AMC	Acceptable Means of Compliance
CAA	Civil Aviation Authority (U.K.)
CS	Certification Specification
CSRTG	Cabin Safety Research Technical Group
CWM	Cabin Water Mist
EASA	European Aviation Safety Agency
EPA	Environmental Protection Agency
ETSC	European Transport Safety Council
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
JAA	Joint Aviation Authorities
MPS	Minimum Performance Standards
NPA	Notice of Proposed Amendment
NTSB	National Transportation Safety Board (United States of America)
PPBE	Passenger Protective Breathing Equipment (Smoke Hoods)
RIA	Regulatory Impact Assessment

# **DEFINITION OF TERMS**

**Occupant Protection Time** is the time in the accident sequence, from the aircraft coming to rest, to the point at which occupants within the cabin cease to be protected from the fire penetrating into the fuselage.

Issue 2 December 2009

# 1 PURPOSE AND INTENDED EFFECT

#### 1.1 ISSUE WHICH THE NPA IS INTENDED TO ADDRESS

A study carried out for the EASA (Reference 1) involved a review of the current cabin safety threats and the degree to which they were addressed by CS-25 requirements. This study identified "Occupant protection from Post Crash Fire and Smoke" as a significant threat to occupant survival.

The issue of occupant protection in post crash fires has been addressed in part by the regulatory action taken by the EASA in amending CS-25 at Amendment 6, by the addition of 25.856(b). This new regulation requires that Thermal Acoustic Insulation fitted to the lower half of the fuselage provides a fire barrier to protect the cabin from fire entry following a post impact pool fire.

Whilst this regulatory action reflects that taken by the FAA in their Final Rule (Reference 2), the EASA considered that an updated review of the potential risks posed to occupant survival from ground pool fires was required. To this end they commissioned a study (Reference 3) to carry out this review and to identify potential regulatory means for mitigating these risks. The study proposed that CS 25.856(b) be replaced by a more objective rule that had the potential to provide a more cost beneficial means of providing Enhanced Fuselage Burnthrough Protection from post impact pool fires. However, the study also concluded that:

"Fire entry into the cabin through fuselage breaks, ruptures, and opened doors constitutes a major threat to occupants in approximately three-quarters of pool fire accidents and this cannot be mitigated by enhanced fuselage burnthrough protection."

Therefore if this residual threat to occupants from ground pool fires is to be mitigated a means other than Enhanced Fuselage Burnthrough Protection must be found.

The EASA study (Reference 1) suggested three potential means of mitigating the post crash fire threat:

- 1. Cabin Water Mist Systems<sup>1</sup>
- 2. Enhanced Fuselage Burnthrough Protection
- 3. Passenger Smoke Hoods

Enhanced Fuselage Burnthrough Protection has been subjected to a Regulatory Impact Assessment as part of the EASA study (Reference 3), and as such is not considered in detail in this RIA. However, the protection afforded by Enhanced Fuselage Burnthrough Protection is considered in the assessment of the residual ground pool fire threat when considering the safety impact of Cabin Water Mist Systems.

<sup>&</sup>lt;sup>1</sup> The term Cabin Water Mist should be considered as being synonymous with Cabin Water Spray within this RIA. Water Mist is now used in preference to Water Spray in order to reflect more precisely the characteristics of the system.

## **1.2 SCALE OF THE ISSUE**

Various estimates have been made of the lives lost from ground pool fires.

A review of the in-service threats experienced in recent accidents carried out as part of the EASA study (Reference 1) suggested that:

"Based on the accident review, smoke/toxic gas inhalation during postcrash fires has caused many injuries and fatalities. It was assessed that over the review period 1998 to 2007, smoke/toxic gas inhalation has resulted in at least 135 and possibly 147 fatalities in three fatal accidents."

Of the estimated number of 135 deaths, 124 were attributed to one accident - the accident to the A310 in Irkutsk in July 2006. The 135 ground pool fire fatalities approximates to an average of 13.5 deaths per year over the period 1998 to 2007 for the western world fleet.

A study carried out by the NTSB (Reference 4) found that 306 (66 percent) of the 465 fatalities in partially survivable U.S. aviation accidents from 1983 through to 2000 died from impact forces, 131 (28 percent) died from fire and smoke, and 28 (6 percent) died from other causes. The 131 fire and smoke fatalities approximates to 7 deaths per year in the United States. The US fleet accumulates approximately 36% of the number of flights worldwide. If the US accident rate was assumed to be typical of the world fleet then the 7 deaths would equate to approximately 19 on a worldwide basis – which is not too dissimilar from the experience suggested by the EASA study.

A Benefit Analysis carried out for the FAA relating to Enhanced Burnthrough Protection and Cabin Water Spray (Reference 5), was based on accidents occurring over the period 1967 to 1996. This analysis suggested that 46 lives might be saved per year worldwide by the introduction both of these improvements. For aircraft with Enhanced Fuselage Burnthrough Protection it was assessed that Cabin Water Spray systems could save a further 34 lives per year. The apparent anomaly between this prediction and the assessed number of lives lost per year to ground pool fires suggested by the EASA and NTSB studies is likely to be attributable to the following factors:

- 1. Variations in the fatal accident rate due to improvements in the safety levels exhibited by the world fleet of aircraft over recent years.
- 2. The variation that might be expected from estimating from small sample sizes [the assessment carried out in the EASA study (Reference 1) was limited to a small study period and the majority of the fatalities resulted from one accident].
- 3. Variations in the number of flights per year accumulated by the world fleet.
- 4. Changes in the average number of occupants on-board aircraft (due to increases in the capacity of aircraft and economic drivers that change the passenger load factor)
- 5. Progressive changes in occupant survivability

However, perhaps the biggest of these factors is the change in the number of fatal accidents per year, and in particular those involving ground pool fires, since the FAA study (Reference 5) was completed. A study carried out for Transport Canada (Reference 6) assessed the likely trend in the number of fatal accidents from all causes to the world fleet of aircraft. These predicted trends and the data generated for the EASA study on Enhanced Fuselage Burnthrough Protection (Reference 3) may be used to assess the likely number of pool fire accidents per year. Data from the EASA study suggested that the ratio of pool fire accidents to all fatal accidents was approximately 0.13. If it is assumed that this proportion

remains largely constant then the trend in pool fire accidents may be derived as shown in Figure 1. The actual number of pool fire accidents per year is also shown in Figure 1 for comparison.



## Figure 1 Actual and Predicted number of Pool Fire Accidents

It may be seen that from the period 1967 to 1996, the period of the FAA Benefit Analysis (Reference 5), there were on average approximately 2 accidents per year involving ground pool fires. A review of the pool fire accidents over this period suggests that the average number of fire fatalities in this type of accident is in the region of 20. Therefore it might be expected that over the period 1967 to 2000 the average number of fire fatalities resulting from ground pool fires might be in the region of around 40 per year.

However, the Transport Canada study suggests that the accident rate for the world fleet has diminished markedly since 2000. This is also reflected in Figure 1, where the predicted number of pool fire accidents appears to be reducing to one per year. This may be symptomatic of the improved accident rate being experienced by current production aircraft. The Transport Canada study (Reference 6) suggested that current production aircraft were exhibiting an accident rate that is in the order of four times better than the current world fleet.

A reduction from two pool fire accidents per year to one would result in the assessed number of fire fatalities reducing to approximately 20 per year, which is comparable with what might be concluded from the EASA and NTSB studies (Reference 1 and Reference 4 respectively).

Furthermore, a reduction in the number of pool fire accidents from two, over the period studied for the FAA Benefit Analysis, to one, would suggest that the prediction of benefit for Cabin Water Mist systems might reduce from 34 to 17.

Issue 2 December 2009

Due to the uncertainties associated with the in-service record regarding this issue, the FAA and Transport Canada are currently commissioning a study to evaluate the proportion of fire fatalities in aircraft accidents over the period 1967 to 2006.

#### **1.3 BRIEF STATEMENT OF THE OBJECTIVES OF THE NPA**

The objectives of the proposed NPA are to ensure that the requirements contained in CS-25 afford an adequate level of protection for occupants in post-impact pool fire accidents commensurate with the costs incurred.

# 2 OPTIONS

## 2.1 SCOPE OF OPTIONS

Three means are considered for occupant protection from post crash fire and smoke -Enhanced Fuselage Burnthrough Protection, Cabin Water Mist Systems, and Passenger Smoke Hoods. It is proposed in all three options that any regulatory action that is taken is limited to aeroplanes with seating configurations of 20 seats or more. This will exclude the smaller transport category and cargo aeroplanes. The primary reason for this is that aeroplanes with small passenger capacities are less likely to realise a significant benefit from any of the protection means proposed due to their high exit-to passenger ratio. Since the protection means considered will impose additional cost, there must be a commensurate benefit to justify the regulatory change. It is considered that such benefits are unlikely to be sufficient to justify regulatory action for aeroplanes with low passenger capacities. Furthermore the 20-passenger threshold is consistent with other occupant safety regulations, such as those for interior materials and cabin aisle width. The protection means considered will increase the evacuation capability of airplanes, with 20 or more passengers, regardless of the exit arrangement.

#### 2.1.1 Enhanced Fuselage Burnthrough Protection

A previous study carried out for the EASA (Reference 3) resulted in the generation of a Regulatory Impact Assessment. This RIA proposed that the current CS 25.856(b) relating to the provision of burnthrough protection from Thermal Acoustic Insulation materials be deleted and replaced by a more objective rule:

#### CS 25.xxx Fuselage burnthrough fire protection

"For aeroplanes with a passenger seating configuration of 20 seats or more, means must be provided to minimise the risk to occupants from the effects of fire penetration into the cabin following a post-impact ground pool fire. All practicable measures must be taken to protect the occupants from fire and smoke for a minimum of five minutes. (See AMC 25.xxx)"

The EASA study (Reference 3) also concluded:

"Fire entry into the cabin through fuselage breaks, ruptures, and opened doors constitutes a major threat to occupants in approximately three-quarters of pool fire accidents and this cannot be mitigated by enhanced fuselage burnthrough protection."
Hence, if the fire fatalities resulting from pool fire accidents that are not prevented by Enhanced Fuselage Burnthrough Protection are to be addressed, an alternate means must be found.

The proposed regulatory change regarding Enhanced Fuselage Burnthrough Protection is currently under review by the EASA. If the Agency decide not to proceed with implementing *CS 25.xxx Fuselage burnthrough fire protection* into the requirements, then the life saving potential of the means, proposed in this RIA for providing occupant protection from post crash fire and smoke, are likely to increase.

### 2.1.2 Cabin Water Mist Systems

Much of the previous research, and proposed regulatory action considered by the Airworthiness Authorities, has related to a Cabin Water Mist system for use in post-crash fire scenarios only. More recently it has been suggested that they might also be beneficial in combating intentional and unintentional in-flight fires in the cabin. Therefore, this Regulatory Impact Assessment considers their use for providing improved protection for occupants from both in-flight fires and post impact pool fires.

### 2.1.3 Passenger Smoke Hoods

In 1987 the major Airworthiness Authorities of North America and Europe concluded that a mandatory requirement for the carriage of Passenger Smoke Hoods "could not be justified at that time". However, following an accident to an A310 aircraft in July 2006 the accident investigating authority recommended that further consideration be given to the use of Passenger Smoke Hoods on large transport aeroplanes. Therefore, this Regulatory Impact Assessment considers their use for providing improved protection for occupants from the effects of smoke.

### 2.2 THE OPTIONS IDENTIFIED

### 1. Do Nothing

• The "Do Nothing" option means to make no improvements to CS-25 in relation to Occupant protection from Post Crash Fire and Smoke beyond those proposed by the deletion of CS 25.856(b) and the addition of *CS.25.xxx Fuselage burnthrough fire protection* 

#### 2. Amend CS-25 to provide Improved Occupant Protection from Post Crash Fire and Smoke by means of Cabin Water Mist Systems

- As with the proposed regulatory change to CS-25, regarding Enhanced Fuselage Burnthrough Protection, five minutes of *Occupant Protection Time* is required. This will entail:
  - The addition of a new CS-25 requirement:

#### CS 25.yyy Occupant Protection from Post Crash Fire and Smoke

"For aeroplanes with a passenger seating configuration of 20 seats or more, means must be provided to protect occupants from the effects of fire penetration into the cabin following a post-impact ground pool fire. These means must include the provision of a Cabin Water Mist system which must be operable both in-flight and following ground impact that could result in fuselage breaks or ruptures. All practicable measures must be taken to protect the occupants from fire and smoke for a minimum of five minutes. (See AMC 25.yyy)"

- Provision of guidance material to define the Minimum Performance Standard for a Cabin Water Mist system and an Acceptable Means of Compliance relating to issues such as the crash impact conditions and levels of reliability required of a system.

# 3. Amend CS-25 to provide Improved Occupant Protection from Post Crash Smoke by means of Passenger Smoke Hoods

- This proposed option will entail:
  - The introduction of a new CS-25 requirement:

### CS 25.zzz Passenger Smoke Hoods

"For aeroplanes with a passenger seating configuration of 20 seats or more, smoke hoods must be provided at each passenger seat meeting the standards specified in ETSO-xxx, (See AMC 25.zzz)"

- Provision of guidance material to define the location and accessibility required of Passenger Smoke Hoods
- The introduction of a new ETSO-xxx defining the standards to which a passenger smoke hood should be designed and manufactured.

# 4. Carry out further research into feasible, cost beneficial options that might provide Improved Occupant Protection from Post Crash Fire and Smoke

### 2.3 THE PREFERRED OPTION SELECTED

After due consideration the Agency believes that **Option 4 - Carry out further** research into feasible, cost beneficial options that might provide Improved **Occupant Protection from Post Crash Fire and Smoke** is to be preferred.

### **3 SECTORS CONCERNED**

The proposed regulatory changes are to CS-25 and hence the aircraft affected will be those for which the application for a type certificate is made after the regulatory changes considered in this RIA. All newly designed CS-25 aircraft, with twenty or more seats, will need to comply. The primary cost of the regulatory change will be borne by the aircraft manufacturer. These costs will result from increases associated with the design, testing and manufacture of the required occupant protection means. Aircraft operators will also be affected since the design solutions will result in weight increases and additional maintenance. There will be a marginal cost to the EASA in their oversight of the manufacturer in showing compliance with the regulatory change and costs may also be incurred by the Agency if further research is carried out.

### 4 IMPACTS

Each option is considered separately in relation to regulatory change against the following impacts:

- Safety
- Economic
- Environmental
- Social
- Other aviation requirements outside of EASA scope
- Foreign comparable regulatory requirements

Equity and fairness issues are also addressed for each of the regulatory options.

### 4.1 OPTION 1 - DO NOTHING

### 4.1.1 Safety

The number of lives lost to post impact fires is likely to reduce due to the apparent reduction in the number of fatal accidents per year and the corresponding reduction in the number of fire related accidents. The precise number of fire fatalities likely to be incurred worldwide is therefore difficult to assess. However, the continual increase in air traffic and the number of passengers carried by the larger aircraft being introduced into service will tend to compensate to some extent for the reduction in the annual number of accidents. The Do Nothing option will therefore mean that there will be no further reduction in the number of fire fatalities due to improvements in occupant survival beyond those that are afforded by the current airworthiness requirements.

### 4.1.2 Economic

The Do Nothing option will result in the Manufacturers and Aircraft Operators not bearing the costs associated with Options 2 and 3 and the EASA not bearing the costs that might be associated with Option 4.

### 4.1.3 Environmental

There are no environmental issues associated with the Do Nothing option.

### 4.1.4 Social

There are no social impacts associated with the Do Nothing option.

### 4.1.5 Other aviation requirements outside EASA scope

There are no aviation requirements outside the EASA scope associated with this option.

### 4.1.6 Foreign comparable regulatory requirements

There are no current foreign regulatory activities associated with occupant survival in post crash fires.

### 4.1.7 Conclusions

Based on the rationales contained in Sections 4.2, 4.3 and 4.4 regarding the alternative options, and the continuation of a significant number of fatalities resulting from post crash fires of adopting Option 1 it is concluded that this is not the preferred option.

### 4.2 OPTION 2 - IMPROVED OCCUPANT PROTECTION FROM FIRE & SMOKE BY MEANS OF CABIN WATER MIST SYSTEMS

### 4.2.1 Safety

Research on Cabin Water Mist or Cabin Water Spray systems was initiated from a Recommendation issued by the UK AAIB following the accident at Manchester Airport on 22 August 1985 (Reference 7):

4.27 A research program should be undertaken to establish the effect of water mist-spray extinguishing systems on the toxic/irritant constituents of fire atmospheres.

Tests carried out by the FAA and UK CAA showed that in a post-crash cabin fire event, water mist is effective in cooling the cabin, wetting the materials, and slowing the progress of fire (Reference 8). The system was shown to result in significant delays in the onset of cabin flashover, providing a more survivable cabin atmosphere and additional escape time.

The JAA issued a Draft Notice of Proposed Amendment (NPA) for Cabin Water Spray Systems in May 1992 (Reference 9). Due to the adverse assessment of benefit no further regulatory work has been carried out since this date. However, Transport Canada, supported by the US FAA and UK CAA, has been funding a research project to investigate the feasibility of a Cabin Water Mist system as part of an aircraft integrated fire protection system (Reference 10). One of the outcomes of this research project is a technical specification for a Cabin Water Mist system (Reference 11).

### 4.2.1.1 Disbenefits

A Disbenefit analysis was commissioned by the FAA in 1993 (Reference 12) which raised several concerns regarding Cabin Water Mist systems. Perhaps the most significant concerns from this study and from other sources were:

- 1. The effects of **inadvertent operation** on electrical and electronic systems
- 2. **Reduced visibility** due to water mist and/or smoke dispersion in the cabin during evacuation and possible interference from **noise** generated by the CWM system with evacuation commands.

### 3. Physiological hazards

Each of these potential disbenefits is considered in turn:

### 1. Inadvertent operation

A study carried out by the State Key Laboratory of Fire Science, University of Science and Technology of China (Reference 13) into Water Mist Systems

"Recently, extensive full-scale fire tests have been conducted to evaluate the feasibility of using water mist systems for the protection of electrical and electronic equipment. Studies showed that fine water mist was effective in extinguishing in-cabinet electronic fires, as well as fires in a computer room, without causing short circuits or other damages to electrical and electronic components. Water mist has also demonstrated some advantages in suppressing fires in electrical and electronic equipment, in comparison to gaseous agents. For example, water mist appears to be the most effective extinguishant for a hot cable fire due to its efficient cooling. In addition, evacuation of the compartment may not be necessary and the electronic equipment can be continuously operated during discharge of the water mist system, especially if a zoned water mist system is used. On the contrary, when halocarbon gaseous agents are used, the compartment has to be evacuated completely due to high concentrations of corrosive gases generated by the agent in fire suppression, which disables the operation of the room."

Whilst further research may be required to assess whether this benign effect on electrical and electronic equipment is reflected in an aircraft environment the Chinese study does suggest that the use of the system in flight in the presence of a cabin fire may not present a greater hazard to the aircraft than the fire itself.

Although inadvertent operation of the system in the absence of a threat may not constitute a hazard to the aircraft, the primary concern is the inconvenience caused to passengers and aircraft operators by nuisance operation. In order to ensure that inadvertent operation of the system occurs at an acceptably low frequency it may need to be designed and manufactured to a level of reliability commensurate with the Extremely Remote<sup>2</sup> classification - equivalent to a numerical target of 10<sup>-7</sup> per aircraft hour or less.

### 2. Reduced visibility and noise

Results of evacuation trials carried out at Cranfield University suggested that, for the specific scenarios investigated (in the test programme), the use of "cabin water spray" systems would not be likely to cause any significant adverse consequences for emergency evacuation of the aircraft (Reference 14). The test programme however, did not address the effect on evacuation of wetting of the cabin interior and escape slides or the effect of water on floor proximity lighting.

The effects of wetting of escape routes and floor proximity lightning may require further research.

### 3. Physiological hazards

A number of potential physiological hazards were identified and examined by the International Cabin Water Spray Research Management Group (Reference 8), as follows:

- Inhalation of Hot Moist Air

"Measurements taken during the wide body optimisation tests showed that the increase in water vapour content with time was similar for sprayed and unsprayed tests and was well below saturation at the higher temperatures. There is, consequently, no increase in hazard from this source."

- Inhalation of Particulate and Water Droplets

"The use of water spray was found to decrease greatly the amount of solid particles and liquid droplets capable of penetrating into the lungs, and also the

<sup>&</sup>lt;sup>2</sup> as defined in the Advisory Material to 25.1309

irritants attached to them, thereby reducing the risk of lung damage. "Although a small amount of larger, non-respirable droplets in the smoke may have been due to the water spray, these had a low dissolved acid gas content and were considered unlikely to present any additional hazard."

- Hypothermia in Evacuees

"... medical advice is that the water spray will not increase the risk of hypothermia unless the victim is wet through to the skin, and the likelihood of this is considerably reduced in the case of a zoned system..."

The Eurofeu Position Paper on Water Mist for Fire Fighting Application (Reference 15) states the following:

"Human safety relating to the deployment of water mist in manned areas has been addressed by the US Environmental Protection Agency (E.P.A). A Medical Health Panel evaluated the water mist under the Significant New Alternatives Policy (SNAP) and the results were published in August 1995<sup>3</sup>.

The overall conclusion was that water mist using potable water is benign to nature and does not present a toxicological or physiological hazard to human beings and is thus safe for use in occupied areas."

### 4.2.1.2 Life Saving Potential

In the conclusions of the research programme on cabin water spray (Reference 8), the International Cabin Water Spray Research Management Group stated that the system was likely to be effective and presented no insurmountable problem areas. It was estimated that cabin water spray systems would save an average of 14 lives per year world-wide, or 6 lives in the US, Canada and European countries of the JAA (at the time) combined. However the cost per life saved was assessed to be in the order of \$22m to \$32m. The European Transport Safety Council review (Reference 16) stated that "the figures underestimated the number of lives that could be saved, and with costs minimised if features are introduced at the design stage, future aircraft should be equipped accordingly."

A more recent study (Reference 5) carried out for the FAA based on improved accident data suggested that the life saving potential of Cabin Water Mist systems in post crash fires was likely to be in the region of 34 lives per year world-wide. However, as discussed in Section 1.2 of this RIA this assessment was based on typically 2 pool fire accidents per year occurring over the study period from 1967 to 1996 compared with one accident per year which is what appears to be the current rate of occurrence.

Therefore the prediction of the number of lives saved per year from Cabin Water Mist systems of 34 per year for the world fleet would reduce to approximately 17.

Whilst it would seem evident that fatalities resulting from pool fire accidents are likely to continue, the life saving potential of Cabin Water Mist systems cannot be predicted

<sup>&</sup>lt;sup>3</sup> Protection of Stratospheric Ozone; Acceptable Substitutes for the Significant New Alternatives Policy (SNAP) Program - [Federal Register: July 28, 1995 (Volume 60, Number 145)][Rules and Regulations]

accurately due to the significant improvements in accident rates that appear to have been achieved over recent years.

### 4.2.1.3 Recommendations from Accident Investigating Authorities

Other than the recommendation made by the UK AAIB following the accident at Manchester Airport on 22 August 1985 (Reference 7) no further Accident Investigating Authority recommendations have been found that are directly pertinent to Cabin Water Mist systems.

### 4.2.2 Economic

A study conducted by AIM Aviation under contract to the UK CAA (Reference 17) was directed toward analysing the "... possible costs of a reduced weight Cabin Water Spray System Installation". This study carried out a detailed analysis of costs, including those for newly designed aircraft. The costs included Direct Operating Costs, the costs of procurement and installation, etc. The derived costs on an aircraft per year basis are dependent on many factors including system weight, cost of fuel, aircraft fleet size, etc. These factors have changed since the time of the AIM Aviation study as has the technology associated with Cabin Water Mist systems.

However, by way of comparison, the AIM Aviation system weight assessment for a narrow bodied aircraft was in the region of 530 lb. If the life saving potential of a Cabin Water Mist system were 34 lives per year, as suggested by the FAA study (Reference 5), then based on a fuel cost of US\$ 2 per gallon, an average flight time of 1.5 hours and an incremental cost per flight hour per pound weight of US\$ 0.0049 then the cost per life saved would be in the region of US\$ 7.5m. However, if the life saving potential of a Cabin Water Mist system reduced to 17 per annum then the cost per life saved would increase to US\$ 15m<sup>4</sup>.

These cost estimates would, at first, seem to be prohibitively high, especially since they do not take into account the costs associated with the design and manufacture of a Cabin Water Mist system or the operating costs of such a system that would be borne by the aircraft operator. However, there are several factors that need to be taken into account when making a more precise estimate of the cost per life saved of a Cabin Water Mist system, including the following:

The life saving potential derived in the FAA study for Cabin Water Mist systems was based on their being used solely for occupant protection in post crash fires. Their use for in-flight occupant protection would increase the assessment of benefit. Furthermore, Water Mist systems have been considered for combating fires in inaccessible areas. If this application of a Water Mist system was found to be practicable it would further increase the assessment of benefit.

The weight estimates made in the AIM study (Reference 17) are likely to be pessimistic since advances in technology are likely to have resulted in more efficient Water Mist systems of lower weight and perhaps cost.

Water Mist systems are being considered as a fire extinguishant for Class C cargo compartments. For aircraft so configured it may be feasible that the stored water used for

<sup>&</sup>lt;sup>4</sup> This cost may be compared with the FAA's current value of life, used in cost benefit analyses of US\$ 5.8m.

this application could be shared with the Cabin Water Mist system with a resultant reduction in system weight.

### 4.2.3 Environmental

It is likely that there are limited environmental impacts associated with the introduction of Cabin Water Mist systems proposed by this regulatory action. However, it will be necessary for the manufacturer to give consideration to the materials used in a Cabin Water Mist system, their manufacturing process, and their performance in post impact pool fires to ascertain that there are no unacceptable environmental impacts. The additional fuel burn associated with the increase in aircraft weight is expected to be small.

Additionally it may be feasible that a Cabin Water Mist system could reduce the quantity of toxic gases and particles released into the atmosphere following a post impact pool fire. This may be of particular significance in the case of accidents to carbon composite aircraft where the release of fibres from the disintegration and burning of the aircraft structure might have a detrimental effect on the environment.

### 4.2.4 Social

There are no social impacts associated with the introduction of Cabin Water Mist systems proposed by this regulatory action other than those associated with the safety, economic and environmental impacts discussed in Sections 4.2.1, 4.2.2 and 4.2.3 of this RIA.

### 4.2.5 Other aviation requirements outside EASA scope

There are no aviation requirements outside the EASA scope associated with the introduction of Cabin Water Mist systems proposed by this regulatory action.

### 4.2.6 Foreign comparable regulatory requirements

There are no current foreign regulatory activities associated with this option.

### 4.2.7 Conclusions

It is evident that there are safety improvements that could result from the introduction of Cabin Water Mist systems. It is also likely that the potential disbenefits might not be as prohibitive as was thought in the 1990s. The rough order of magnitude assessment of the potential life saving and costs incurred do not account for the safety potential that might exist for the in-flight use of CWM systems. Furthermore, research has been carried out in the United States regarding the use of water mist systems in aircraft hidden areas and electrical/avionic equipment bays. Although the results of this research are not currently available it would seem that there is potential for the use of Water Mist systems in hidden areas. Whilst, for the most part, the threat from hidden area fires has been mitigated by the requirements for improved flammability standards of Thermal Acoustic Insulation (TAI) materials, there is still concern regarding the flammability of contaminated or aged TAI materials and other materials in hidden areas. If the use of the system in flight could result in positive enhancements to safety these might be achieved with minimal cost and weight increases beyond those incurred by accommodating the post-impact fire threat. The extended application of Water Mist systems requires further research in order to establish the protection that they might afford in combating in-flight fires.

### 4.3 OPTION 3 - IMPROVED OCCUPANT FIRE & SMOKE PROTECTION BY MEANS OF PASSENGER SMOKE HOODS

### 4.3.1 Safety

### 4.3.1.1 Past Research and Assessments of Life Saving Potential

Following the accident at Manchester Airport, on 22 August 1985, the AAIB recommended to the UK CAA the formulation of a requirement for the provision of Passenger Smoke Hoods to afford passengers an effective level of protection during fires which produce a toxic environment within the aircraft cabin (Reference 7).

As stated in CAP 593 (Reference 18), the UK CAA accepted this Recommendation and gave urgent consideration to the formulation of requirements for the design and provision of Passenger Smoke Hoods for passengers.

However, subsequent considerations by the FAA and CAA raised concerns that the use of Passenger Smoke Hoods might result in a delay in the evacuation due, primarily, to the time taken to don the mask. In a report published by the UK CAA (Reference 19)<sup>5</sup> it was concluded that:

"In the past, the CAA and the FAA have emphasised the probable loss of life resulting from the likely delay in an emergency evacuation due to the extra time needed to don smoke hoods. Tests by Linacre College and the FAA's Civil Aeromedical Institute (CAMI) have suggested donning time delay is small and evacuation rate is little reduced so long as floor level exits of sufficient size are provided. However, no laboratory test can get anywhere near to simulating the real ground fire accident."

"The Authority is concerned that in a crash situation, with passengers experiencing shock and perhaps panicking, any delay in putting on a smoke hood, particularly by parents of young children or partners helping each other, would reduce the benefit (of smoke hoods). It would only require one or two people to get into difficulty with their smoke hoods, for the whole evacuation to be in jeopardy. This, the Authority feels, is an unacceptable safety risk and it is for this reason that it has decided not to require the provision of passenger smoke hoods in Britishregistered aircraft."

However, a CAA paper (Reference 20) suggested that there were a potential 9<sup>6</sup> lives to be saved per year worldwide from the use of "...effective passenger smoke hoods". The final CAA position was formulated in collaboration with other Airworthiness Authorities. In December 1987 in the light of major collaborative research carried out in the UK, USA, Canada and France a decision was made by these countries that a mandatory requirement for the carriage of Passenger Smoke Hoods could not be justified at that time.

<sup>&</sup>lt;sup>5</sup> Salient parts of CAP 586 pertinent to the disadvantages of Smoke Hoods are reproduced in Appendix 1 for reference.

<sup>&</sup>lt;sup>6</sup> It should be noted that this assessment of the lives to be saved from Smoke Hoods was made in 1987. Since that time many factors have changed that would affect the benefit likely to be achieved. Many of these factors are discussed in Sections 1.2 and 4.2.1.2 in relation to Cabin Water Mist systems.

Nevertheless, the UK CAA continued with completion of its specification for a smoke hood defining both the equipment performance and installation requirements (Reference 21).

In a report produced by the European Transport Safety Council in 1996 (Reference 16) it was stated that the delay in evacuation time due to the use of Passenger Smoke Hoods may only have detrimental effects in the event of flashover and that flashover was considered *"a relatively rare event"*. The review recommended the use of Passenger Smoke Hoods to increase fire survivability.

### 4.3.1.2 Recommendations from Accident Investigating Authorities

The Irkutsk A310 accident in July 2006 resulted in the Accident Investigating Authority making a recommendation regarding Passenger Smoke Hoods. The reported injuries to occupants resulting from the accident were as follows:

"Thirteen individuals suffered carbon monoxide poisoning and eight received heat burns. 23 individuals [of the 60 who were hospitalized] who had suffered mechanical traumas were subjected to the effect of high temperatures and carbon monoxide poisoning. Of the 120 passengers who died, 119 died as a result of acute carbon monoxide poisoning in conjunction with oxygen insufficiency in the inhaled air (in one case, the poisoning was accompanied by trauma to the skull and brain) and one female passenger died from severe trauma combined with burns to the body. Forensic medical experts concluded that one [flight attendant] died from acute carbon monoxide poisoning. The concentration of carboxyhemoglobin in her blood was 85%. The three unidentified flight attendants, died as a result of acute carbon monoxide poisoning... Another flight attendant, while helping passengers inside the cabin, died from acute carbon monoxide poisoning".

The safety recommendations, pertinent to Passenger Smoke Hoods, issued by the Accident Investigating Authority were as follows:

5.4. To EASA and other Certifying Authorities together with the Manufacturers of Large Transport Aircraft:

5.4.3. To evaluate the usefulness of cabin crew smoke hood devices in assisting the evacuation of airplanes; to evaluate the possibility of equipping large transport airplanes with devices for passengers and/or flight attendants to be used in case of an emergency evacuation without suffering from the effects of smoke and toxic fumes.

### 4.3.2 Economic

In a study carried out by the United States General Accounting Office in 2003 (Reference 22) the following statements were made regarding the costs of Passenger Smoke Hoods for aircraft passengers.

"Smoke hoods are currently available and produced by several manufacturers; however, not all smoke hoods filter carbon monoxide. They are in use on many military and private aircraft, as well as in buildings. An individually-purchased filter smoke hood costs about \$70 or more, but according to one manufacturer bulk order costs have declined to about \$40 per hood. In addition, they estimated that hoods cost about \$2 a year to install and \$5 a year to maintain. They weigh about a pound or less and have to be replaced about every 5 years. Furthermore, airlines could incur additional replacement costs due to theft if smoke hoods were placed near passenger seats in commercial aircraft."

It must be stressed that the costs of the smoke hoods referred to above are unlikely to comply with the UK CAA Specification for Passenger Smoke Hoods (Reference 21). Costs related to smoke hoods meeting this standard are not currently available. However, it is evident that the costs of the Smoke Hoods referred to in the report from the United States General Accounting Office are exceptionally low.

### 4.3.3 Environmental

It is likely that there are limited environmental impacts associated with the introduction of Passenger Smoke Hoods proposed by this regulatory action. However, it will be necessary for the manufacturer to give consideration to the materials used in the manufacturing process to ascertain that there are no unacceptable environmental impacts.

### 4.3.4 Social

There are no social impacts associated with the introduction of Passenger Smoke Hoods proposed by this regulatory action other than those associated with the safety, economic and environmental impacts discussed in Sections 4.3.1, 4.3.2 and 4.3.3 of this RIA.

### 4.3.5 Other aviation requirements outside EASA scope

There are no aviation requirements outside the EASA scope associated with the introduction of Passenger Smoke Hoods proposed by this regulatory action.

### 4.3.6 Foreign comparable regulatory requirements

There are no current foreign regulatory activities associated with this option.

### 4.3.7 Conclusions

It is evident that there may be safety improvements that could result from the introduction of Passenger Smoke Hoods. However, there are also many unknowns associated with their use and potential disbenefits. Perhaps the most controversial issue is the question as to whether Passenger Smoke Hoods are likely to present an impediment to evacuation, and if so to what degree, and how often, do the conditions resulting in an evacuation impediment, occur. The cost of Passenger Smoke Hoods meeting the CAA Specification is unknown. However, the costs of smoke hoods that are currently commercially available are extremely low. Whether commercially available smoke hoods could be shown to be cost beneficial is also unknown and cannot be determined unless there is a greater understanding of the potential disbenefits that might be associated with them, regarding their potential adverse effects on evacuation.

### 4.4 OPTION 4 - CARRY OUT FURTHER RESEARCH INTO FEASIBLE, COST BENEFICIAL OPTIONS THAT MIGHT PROVIDE IMPROVED OCCUPANT PROTECTION FROM POST CRASH FIRE AND SMOKE

### 4.4.1 Safety

The adoption of Option 4 will delay any benefits to safety that might accrue from implementing the regulatory action proposed by Options 2 and 3.

### 4.4.2 Economic

Since, it is unlikely that research will be undertaken by organisations other than the world's primary Airworthiness Authorities – EASA, FAA and Transport Canada - there will be an economic burden on these Authorities associated with the adoption of this Option.

The research topics suggested in Sections 4.4.2.1 and 4.4.2.2 are those considered necessary to undertake prior to regulatory action being undertaken in relation to Cabin Water Mist systems and Passenger Smoke Hoods.

### 4.4.2.1 Cabin Water Mist Systems

A study carried out for Transport Canada (Reference 23) identified issues requiring further research before Cabin Water Mist systems can be considered as feasible:

- 1. A Minimum Performance Standard needs to be established in order to qualify a Cabin Water Mist system against on-ground and in-flight fire threats.
- 2. Further consideration needs to be given to the required duration that a Cabin Water Mist System needs to operate to provide adequate protection for both on-ground and in-flight fire threats.
- 3. The target performance that may be required for a Cabin Water Mist System intended for in-flight use needs to be defined. This should take into account the influence of varying cabin configurations and the effects of extreme temperature conditions affecting the activation and operation of the system.
- 4. An evaluation needs to be carried out to determine whether the volume of water required for the Cargo Compartment Water Mist/Inerting System is likely to be sufficient for the effective operation of a Cabin Water Mist System.
- 5. Further consideration needs to be given to the integrity of the power supplies needed for the Cabin Water Mist System.
- 6. The weight of a complete Cabin Water Mist System needs to be assessed.
- 7. Consideration needs to be given to the crashworthiness standards appropriate to the Cabin Water Mist System since it is required to operate in a post-crash scenario.
- 8. Further consideration needs to be given as to the effects of both intentional and inadvertent operation of the Cabin Water Mist System in flight and the consequential levels of integrity required of the system.
- 9. The implications of meeting the proposed reliability levels for the Cabin Water Mist System need to be investigated.

- 10. Further consideration needs to be given to the fire standards of the component parts of the Cabin Water Mist System and their effects on cost and weight.
- 11. A more detailed system architecture, meeting the target reliability levels for a Cabin Water Mist activation system, needs to be developed and investigated.
- 12. Further consideration needs to be given to combining the use of the onboard potable water system and dedicated water tanks for enhancing the protection afforded by the Cabin Water Mist System.

As a result of this Regulatory Impact Assessment it would also appear that

- 13. The effects of wetting of escape routes and floor proximity lightning need to be assessed.
- 14. The safety benefits and disbenefits likely to accrue from Cabin Water Mist systems need to be reassessed in particular in relation to their potential for combating in-flight fires in inaccessible areas

### 4.4.2.2 Passenger Smoke Hoods

The research that is required prior to Passenger Smoke Hoods being considered as a cost beneficial solution to post impact fires (and in-flight fires) includes the following:

- 1. Further consideration of the effects of Passenger Smoke Hoods on evacuation in relation to various accident scenarios that might occur.
- 2. A determination of the benefits that might be afforded by commercially available Smoke Hoods

### 4.4.3 Environmental

Any research carried out into Cabin Water Mist systems must take into account the environmental issues that might be associated with the introduction of these systems and equipment into future aircraft designs. There are no environmental issues associated with the research other than those that might relate to any testing that might be carried out (e.g. fire testing). It is expected that these will be accommodated by the procedures that will be put in place by the test facilities.

### 4.4.4 Social

There are no social issues associated with the research other than those that might relate to any testing that might be carried out (e.g. evacuation testing). It is expected that these will be accommodated by the procedures that will be put in place by the test facilities.

### 4.4.5 Other aviation requirements outside EASA scope

This is not applicable to this research activity.

### 4.4.6 Foreign comparable regulatory requirements

There are no current foreign regulatory activities associated with this option. However, FAA and Transport Canada have been carrying out research into Cabin Water Mist Systems as part of an Integrated Fire Protection system concept (see References 10 and 11).

### 4.4.7 Conclusions

It is evident that there are potential benefits likely to accrue from the introduction of Cabin Water Mist systems. Their use in combating the adverse effects of post impact pool fires has been the subject of much research and it has been shown that positive benefit is likely to be realised by their introduction. However, due to the improvements that have been realised over recent years in the fatal accident rate to the world fleet, the precise magnitude of the life saving potential that they are likely to afford is uncertain. Furthermore, the use of Cabin Water Mist systems for protection to occupants from in-flight fires both within the cabin and in inaccessible areas has not been the subject of research on civil aircraft and the potential life saving that might accrue from their use in this role has not been determined.

The use of "...effective Passenger Smoke Hoods" was assessed in a study carried out by the CAA and FAA (Reference 20) to have the potential to save 9 lives per year worldwide. However, the magnitude of the life saving potential of Passenger Smoke Hoods today may be somewhat different due to the improvements that have been made in both fatal accident rates and occupant survivability. Furthermore, the issue regarding the disbenefits that may be associated with Passenger Smoke Hoods, in terms of adverse effects on evacuation, have still to be resolved. Additionally, the potential benefit that might accrue from Passenger Smoke Hoods, of the type that are currently commercially available, has not been evaluated.

Resolution of the issues that require further research into Water Mist systems could result in their being required by regulation. If this were the case, there may no longer be a need for further consideration of Passenger Smoke Hoods since CWM might afford the level of protection to occupants that is sought.

### 5 SUMMARY AND FINAL ASSESSMENT

# 5.1 COMPARISON OF THE POSITIVE AND NEGATIVE IMPACTS FOR EACH OPTION EVALUATED

### 5.1.1 Option 1 - Do Nothing

This option will result in there being no change to CS-25 and hence there will be no economic impact on the manufacturers, aircraft operators or the EASA. However there will be no further improvement in occupant protection from post-crash fires beyond that afforded by the CS-25 amendments associated with Enhanced Fuselage Burnthrough Protection. Whilst this change to the regulations is likely to result in an improvement in safety it will not address the fire fatalities resulting from the majority of pool fire accidents. Furthermore it will not capitalise on the opportunities that might exist for combating in-flight fires from Water Mist systems.

# 5.1.2 Option 2 – Improved Occupant Protection from Fire & Smoke by means of Cabin Water Mist systems

It is evident that there are safety improvements that could result from the introduction of Cabin Water Mist systems. It is also likely that the potential disbenefits might not be as prohibitive as was thought in the 1990s. The rough order of magnitude assessment of the potential life saving and costs incurred do not account for the safety potential that might exist for the in-flight use of CWM systems. Research has been carried out in the United States regarding the use of water mist systems in aircraft hidden areas and electrical/avionic equipment bays. Although the results of this research are not currently

Issue 2 December 2009

available it would seem that there is potential for the use of water mist systems in hidden areas. Furthermore, research carried out in China suggests that water mist systems used in ground applications may be more effective in extinguishing electrical fires than gaseous extinguishants and that they have a benign effect on the functioning of electrical and electronic equipment without adverse effects on humans.

For the most part the threat from hidden area fires has been mitigated by the requirements for improved flammability standards of Thermal Acoustic Insulation (TAI) materials. However, there is still concern regarding the flammability of contaminated or aged TAI materials and other materials in hidden areas. If the use of the system in flight could result in positive enhancements to safety these might be achieved with minimal cost and weight increases beyond those incurred by accommodating the post-impact fire threat. The extended application of Water Mist systems requires further research in order to establish the protection that they might afford in combating in-flight fires.

# 5.1.3 Option 3 - Improved Occupant Protection from Fire & Smoke by means of Passenger Smoke Hoods

It is evident that there may be safety improvements that could result from the introduction of Passenger Smoke Hoods. However, there are also many unknowns associated with their use and potential disbenefits. Perhaps the most controversial issue is the question as to whether Passenger Smoke Hoods are likely to present an impediment to evacuation, and if so to what degree, and how often, do the conditions resulting in an evacuation impediment occur. The cost of Passenger Smoke Hoods meeting the CAA Specification is unknown. However, the costs of Smoke Hoods that are currently commercially available are extremely low. Whether commercially available Smoke Hoods could be shown to be cost beneficial is also unknown and cannot be determined unless there is a greater understanding of the potential disbenefits that might be associated with them regarding their potential adverse effects on evacuation.

# 5.1.4 Option 4 - Carry out further research into feasible, cost beneficial options that might provide Improved Occupant Protection from Post Crash Fire and Smoke

It is evident that there are potential benefits likely to accrue from the introduction of Cabin Water Mist systems. Their use in combating the adverse effects of post impact pool fires has been the subject of much research and it has been shown that positive benefit is likely to be realised by their introduction. However, due to the improvements that have been achieved over recent years in the fatal accident rate to the world fleet the precise magnitude of the life saving potential that they are likely to afford is uncertain. Furthermore, the use of Cabin Water Mist systems for protection to occupants from in-flight fires both within the cabin and in inaccessible areas has not been the subject of research on civil aircraft and the potential life saving that might accrue from their use in this role has not been determined.

Resolution of the issues that require further research into Water Mist systems could result in their being required by regulation. This could result in there no longer being a need for further consideration of Passenger Smoke Hoods since CWM might afford the level of protection to occupants that is sought. For this reason the preferred option is Option 4 with the initial research being directed toward Water Mist systems.

# 5.2 A SUMMARY DESCRIBING WHO WOULD BE AFFECTED BY THESE IMPACTS AND ANALYSING ISSUES OF EQUITY AND FAIRNESS

### 5.2.1 The aircraft manufacturers

### **Option 1 Do Nothing**

This option will have no impact on aircraft manufacturers.

# Option 2 Improved Occupant Protection from Fire & Smoke by means of Cabin Water Mist Systems

This option will result in a significant economic impact on aircraft manufacturers due to the design development and installation of Cabin Water Mist systems for future aircraft designs. It is therefore imperative that solutions are developed that are cost beneficial.

# Option 3 Improved Occupant Protection from Fire & Smoke by means of Passenger Smoke Hoods

This option will result in a small economic impact on aircraft manufacturers.

Option 4 Carry out further research into feasible, cost beneficial options that might provide Improved Occupant Protection from Post Crash Fire and Smoke This option will have no impact on aircraft manufacturers.

### 5.2.2 The operators

### **Option 1 Do Nothing**

This option will have no impact on aircraft operators.

# Option 2 Improved Occupant Protection from Fire & Smoke by means of Cabin Water Mist Systems

This option will result in a moderate economic impact on aircraft operators due to the additional fuel burn associated with the system weight and the maintenance required of the system.

# Option 3 Improved Occupant Protection from Fire & Smoke by means of Passenger Smoke Hoods

This option will result in a small economic impact on aircraft operators resulting from any additional maintenance and weight increases that might be associated with Passenger Smoke Hoods.

# Option 4 Carry out further research into feasible, cost beneficial options that might provide Improved Occupant Protection from Post Crash Fire and Smoke

This option will have no impact on aircraft operators.

### 5.2.3 EASA

### Option 1 Do Nothing

This option will have no impact on the EASA.

# Option 2 Improved Occupant Protection from Fire & Smoke by means of Cabin Water Mist Systems

This option will result in a moderate economic impact on the EASA due to the rulemaking activity required and the subsequent oversight of the industry to ensure compliance with the proposed regulatory change.

Issue 2 December 2009

# Option 3 Improved Occupant Protection from Fire & Smoke by means of Passenger Smoke Hoods

This option will result in a moderate economic impact on the EASA due to the rulemaking activity required and the subsequent oversight of the industry to ensure compliance with the proposed regulatory change.

# Option 4 Carry out further research into feasible, cost beneficial options that might provide Improved Occupant Protection from Post Crash Fire and Smoke

This option could have a small economic impact on the EASA in contributing to the funding required for research. However, the level of commitment from the EASA may be reduced by combining the research with any that may be undertaken by the FAA and Transport Canada.

### 5.2.4 Issues of equity and fairness

There are no issues of equity and fairness associated with any of the regulatory options considered in this Regulatory Impact Assessment.

### 5.3 FINAL ASSESSMENT AND RECOMMENDATION OF A PREFERRED OPTION

Based on the assessments made in this Regulatory Impact Assessment the preferred Option is **Option 4 - Carry out further research into feasible, cost beneficial options that might provide Improved Occupant Protection from Post Crash Fire and Smoke** 

It is further considered that the focus of the initial research should be on Water Mist systems since it is feasible that a successful outcome of the research into these systems might afford the level of protection required by occupants from the fire threat without the need to regulate for Passenger Smoke Hoods.

Co-ordination of the research activity by means of the Cabin Safety Research Technical Group (CSRTG) may result in the FAA and Transport Canada sharing the economic burden of the research activity with the EASA.

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Issue 2 December 2009

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#### EASA REGULATORY IMPACT ASSESSMENT Occupant Protection from Post Crash Fire and Smoke

Issue 2 December 2009

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### Appendix 1 – The Disadvantages of Passenger Smoke Hoods as cited in the UK CAA Document CAP 586 - Improving Passenger Survivability In Aircraft Fires: A Review

Opposition to the mandatory provision of passenger smoke hoods has been expressed by fire safety specialists in other aviation authorities, fire services, research organisations, the airline industry and various representative bodies.

The major concern of these specialists is <u>not</u> with the technical design of passenger smoke hoods so long as they comply with the recognised aviation specification. It is mainly the unpredictable response of untrained passengers to a strange piece of equipment in rapidly changing conditions that causes professionals to argue against the value of smoke hoods on transport aircraft. It is unlikely that smoke hoods will be less complicated to don than the flotation life jackets required for over-water flights. Although data is difficult to come by, it is not thought that high levels of life jacket use have been attained in unpremeditated ditchings. In this respect it should be noted that in a recent fire accident, one of the few fatalities is attributed to the inability of the passenger, even though uninjured, to do something as simple as undoing his seat belt.

In the past, the CAA and the FAA have emphasised the probable loss of life resulting from the likely delay in an emergency evacuation due to the extra time needed to don smoke hoods. Tests by Linacre College and the FAA's Civil Aeromedical Institute (CAMI) have suggested donning time delay is small and evacuation rate is little reduced so long as floor level exits of sufficient size are provided. However, no laboratory test can get anywhere near to simulating the real ground fire accident. Even the Cranfield Applied Psychology Unit's competitive behaviour evacuation tests in smoke are far removed from simulating actual human response to the rapidly changing conditions of some post crash ground fires with the associated shock, disorientation and possible injury.

For smoke hoods to have any potential to save life, they must be readily available to passengers in their seats, easy to don by the old, the infirm and the very young, capable of providing adequate means to see and hear, and reliable in respect of fire and toxic gas protection. The deaths by suffocation of four Israelis reported earlier this year, due to their inexperience in donning gas masks, illustrates the hazard of using unfamiliar equipment.

Furthermore, it is important to understand how smoke hoods might affect the ground fire evacuation. Where passengers have survived a crash, are mobile but shocked, and threatened by a developing fuel-fed fire, they will immediately evaluate and respond to:

- The need to get out of their seat and evacuate the aircraft quickly;
- The safety of others, particularly children and partners;
- The instinct to take personal belongings;

and were smoke hoods available,

- The need to protect themselves by donning the smoke hood.

Each passenger has to develop a strategy for his own survival. This strategy must not be unduly complicated, otherwise precious seconds will be lost. When threatened by fire passengers would be faced with the dilemma - "Do I put on a smoke hood or do I just get out as quickly as possible?" It would only take a few passengers to hesitate over the question before a disciplined and orderly evacuation becomes disorganised and chaotic. Worse still, if some passengers had donned their hoods and others not, some of the latter may try to get back to their seats to fetch theirs, effectively blocking the aisle and stopping evacuation.

Other issues cited by professional safety specialists are:

(a) Passengers could easily be lulled into a false sense of security once smoke hoods are donned. Generally, once protected, people will tend to stand up rather than get down as low as possible. This usually means they are more exposed to the effects of high temperatures and more likely to be within the fire/smoke layer.

(b) Smoke hoods could increase the evacuation time due to impaired vision and communication.

(c) Some passengers, such as parents or spouses, may delay evacuating in order to ensure that their children or their partners have correctly donned their hoods. This might cause blocking of aisles.

(d) The importance of training in the use of smoke hoods should not be underestimated. Trials have shown that untrained people do the most improbable things.

(e) It is probable that passengers will, due to trauma in an emergency, forget about smoke hoods. In cases where aircraft have ditched only 50% of life-jackets have been used.

# Attachment 3

### EASA REGULATORY IMPACT ASSESSMENT

### REQUIREMENTS FOR FIRE PROTECTION IN REMOTE/ISOLATED COMPARTMENTS NOT PERMANENTLY OCCUPIED DURING FLIGHT

### **OCTOBER 2009**

Issue 2

#### EASA REGULATORY IMPACT ASSESSMENT REQUIREMENTS FOR FIRE PROTECTION IN REMOTE/ISOLATED COMPARTMENTS NOT PERMANENTLY OCCUPIED DURING FLIGHT

Issue 2 October 2009

## AMENDMENT RECORD

ISSUE NUMBER	DATE	Remarks
1	September 2009	Initial Issue
2	October 2009	Incorporation of Comments

# CONTENTS

Abb	reviations4		
1	Purpose and Intended Effect5		
1.1 1.2	Issue which the NPA is intended to address		
1.3	Brief Statement of the Objectives of the NPA7		
2	Options8		
2.1 2.2	<ol> <li>The Options Identified</li></ol>		
3	Sectors Concerned11		
4	Impacts11		
4.1	All identified impacts		
	4.1.1 Safety		
	4.1.2 ECONOMIC		
	4.1.5 Environmental 11		
	4.1.5 Other Aviation Requirements outside EASA scope		
	4.1.6 Foreign Comparable Regulatory Requirements		
4.2	Equity and fairness issues identified		
5	Summary and Final Assessment13		
5.1	Comparison of the positive and negative impacts for each option evaluated		
5.2	A summary describing who would be affected by these impacts and		
E 0	analysing issues of equity and fairness		
ე.ა	rinal assessment and recommendation of a preferred option		
6	References14		

### ABBREVIATIONS

CAR	Canadian Aviation Regulations
CRI	Certification Review Item
CS	Certification Specifications
EASA	European Aviation Safety Agency
ETSO	European Technical Standard Order
FAA	Federal Aviation Administration (United States)
MPS	Minimum Performance Standards
NPA	Notice of Proposed Amendment
PBE	Protective Breathing Equipment
RIA	Regulatory Impact Assessment
SFAR	Special Federal Aviation Regulations
VIP	Very Important Person
VLTA	Very Large Transport Aeroplane

# 1 PURPOSE AND INTENDED EFFECT

### 1.1 ISSUE WHICH THE NPA IS INTENDED TO ADDRESS

The current requirements of CS-25 do not address fire protection in passenger or crew compartments that are not permanently occupied during flight other than lavatories. However, aircraft are often configured with compartments that are isolated physically from the main passenger cabin by doors, curtains or partitions. In other instances compartments are located in remote areas of the aircraft. Examples of such compartments include bedrooms, offices, praying rooms, recreational areas, and crew rest compartments. In the past, the fire protection standards required of isolated compartments have been addressed by Special Conditions. The intention of this proposed regulatory action is to amend CS-25 to accommodate the fire protection requirements appropriate to isolated and remotely located compartments with the intention of reducing the need for Special Conditions and standardising the required fire protection means.

### **1.2 SCALE OF THE ISSUE**

The accident review carried out as part of a study commissioned by EASA (Reference 1) did not identify any accidents associated with in-flight fires in remote or isolated compartments that are not permanently occupied during flight. However, there are indications that the installation of such compartments is becoming more frequent, particularly in large transport aeroplanes and VIP configuration aeroplanes.

This Regulatory Impact Assessment addresses the threats associated with in-flight fires in isolated compartments. Other safety issues associated with these compartments, including emergency evacuation, communication and supplemental oxygen systems are currently addressed by Special Conditions. However, since fire in an unoccupied compartment can pose a significant threat to aircraft safety, by spreading into the passenger compartment or affecting critical aircraft systems, it is considered that this issue should be addressed by CS-25. In a Special Conditions document (Reference 2), the FAA considers a failure of the crew rest compartment fire protection system (i.e., smoke or fire detection and fire suppression systems) in combination with a crew rest area fire to be a catastrophic occurrence.

### **1.2.1** Special Areas on Very Large Transport Aeroplanes

There will inevitably be areas in Very Large Transport Aeroplanes (VLTA) that are unoccupied and unsupervised for long periods of time. Therefore, reliable fire protection systems providing timely notification will be required. This issue was discussed at the Very Large Transport Aeroplane (VLTA) Conference in 1998 (Reference 3) which resulted in the following conference recommendations:

"In view of fire protection aspects which may be compounded, altered or have unique benefit due to the size, shape and configuration of VLTA aircraft, there was general agreement that the following issues need to be studied during VLTA design development and certification:

4 - Smart systems for the crew to detect smoke and fire in hidden or unoccupied areas.

7 - Detection and suppression in large compartments used for carry-on baggage and electrical equipment.

6 - The amount and location of fire emergency and survival equipment for use by the crew."

### 1.2.2 Isolated Compartments in Aeroplanes with VIP Configurations

Isolated compartments in aeroplanes with VIP configurations have been the subject of Special Conditions. Perhaps the most significant concern raised by isolated compartments is related to timely fire detection. Special Conditions have included the following fire protection requirements:

- Each isolated compartment must incorporate a smoke detection system that meets the requirements of 25.858. A visual and audible indication of a smoke detection, that identifies in which compartment the smoke has been detected, must be provided to the flight crew or to the cabin crew.

Whilst this requirement is appropriate to many isolated compartments it is inappropriate to those where smoking is allowed or cooking equipment is installed without additional measures being introduced to prevent nuisance warnings.

- In addition to what is prescribed by 25.851, at least one hand fire extinguisher appropriate to the kinds of fires likely to occur and associated protective breathing equipment must be provided in close proximity of the doors that lead from each emergency exit area to each isolated compartment.
- It must be demonstrated that there is sufficient access in flight to enable a crew member to effectively reach any part of the isolated compartment with the content of a hand fire extinguisher.

This requirement is applicable to small compartments and other means for fire suppression need to be considered in larger compartments such as crew rest areas.

- It must be demonstrated that no hazardous quantities of smoke, flames or extinguishing agents will enter any compartment that could be occupied by the crew members or passengers.
- If a waste container is installed, it must meet the relevant requirements of 25.853[h].
- Smoking is not permitted in isolated compartments. Appropriate placards must be installed to indicate these restrictions.

This requirement is applicable to compartments, such as crew rest areas, on passenger transport aircraft. However, it is probably inappropriate to ban smoking in all "isolated compartments" on all aircraft. On some VIP aircraft the "isolated compartment" could be occupied for the majority of the flight and the area assigned to be the main cabin (i.e. that compartment used for take-off and landing) unoccupied. In this instance, it would seem illogical to ban smoking in the compartment that is occupied for the majority of the time but allow it in the area that is least occupied. It would also seem inappropriate to prohibit smoking in an isolated compartment but allow the use of galley equipment which might be left unattended.

The FAA has issued SFAR No. 109 'Special Requirements for Private Use Transport Category Airplanes Regulatory Information (Reference 4), which contained fire protection requirements as follows:

12. Materials for Compartment Interiors. Compliance is required with the applicable provisions of Sec. 25.853, except that compliance with appendix F, parts IV and V, to part 25, need not be demonstrated if it can be shown by test or a combination of test and analysis that the maximum time for evacuation of all occupants does not exceed 45 seconds under the conditions specified in appendix J to part 25.

13. Fire Detection. For airplanes with a type certificated passenger capacity of 20 or more, there must be means that meet the requirements of Sec. 25.858(a) through (d) to signal the flightcrew in the event of a fire in any isolated room not occupiable for taxi, takeoff and landing, which can be closed off from the rest of the cabin by a door. The indication must identify the compartment where the fire is located. This does not apply to lavatories, which continue to be governed by Sec. 25.854.

15. Hand-Held Fire Extinguishers.

(a) For airplanes that were originally type certificated with more than 60 passengers, the number of hand-held fire extinguishers must be the greater of--

(1) That provided in accordance with the requirements of Sec. 25.851, or

(2) A number equal to the number of originally type certificated exit pairs, regardless of whether the exits are deactivated for the proposed configuration.

(b) Extinguishers must be evenly distributed throughout the cabin. These extinguishers are in addition to those required by paragraph 14 of this SFAR, unless it can be shown that the cooktop was installed in the immediate vicinity of the original exits.

### Crew Rest Compartments

The fire protection provisions for isolated areas in aeroplanes for private use discussed above are generally similar to the fire protection provisions for crew rest compartments. Some of the Special Conditions for crew rest compartments also mention additional provisions for the use of built-in fire extinguishing systems and fire protection for stowage compartments. The texts of the Special Conditions have been considered in the formulation of the proposed regulatory change to CS-25 addressed in this RIA.

### **1.3 BRIEF STATEMENT OF THE OBJECTIVES OF THE NPA**

The purpose of the NPA is to amend CS-25 to include requirements for fire protection in compartments that are not permanently occupied during flight and are isolated from the main passenger cabin. The requirements would ensure that the fire protection measures for these compartments are standardised and would also reduce time and costs for the certification of such compartments.

The proposed amendment consists of the requirements for flammability of compartment material, fire/smoke detection systems, fire extinguishing systems or firefighting equipment (and its associated provisions), and means to exclude smoke or extinguishing agents from entering other occupiable compartments.

### 2 OPTIONS

### 2.1 THE OPTIONS IDENTIFIED

Two regulatory options for Agency action are considered in this Regulatory Impact Assessment:

### Option 1 – Do Nothing

The "Do Nothing" option means no amendments to CS-25 in relation to fire protection in compartments not permanently occupied during flight that are isolated or located in remote areas will be made. Installation of such compartments will continue to be addressed by means of Special Conditions.

### Option 2 – Rulemaking Action

This option means new requirements and associated guidance material will be added to CS-25 to incorporate the provisions of Special Conditions related to fire protection in compartments not permanently occupied during flight that are isolated or located in remote areas. The proposed requirements are as follows:

### CS 25.xxx Fire protection in isolated compartments (see AMC 25.xxx)

An isolated compartment is one which is not permanently occupied during flight and which is separated from other areas of the cabin. Isolated compartments must comply with the following:

- (a) There must be at least one ashtray on the inside and outside of any entrance to the compartment.
- (b) Each disposal receptacle for towels, paper, or waste, located within the compartment must be equipped with a built-in fire extinguisher. The extinguisher must be designed to discharge automatically into each disposal receptacle upon occurrence of a fire in that receptacle.
- (c) The interiors need not meet the meet the test requirements of parts IV and V of appendix F, provided such compartments are isolated from the main passenger cabin by doors or equivalent means that would normally be closed during an emergency landing condition and the compartment is not occupied for take-off and landing,
- (d) Enclosed stowage compartments within an isolated compartment must be at least fire resistant.
- (e) There is readily available safety equipment appropriate to the size of the compartment and the likely nature of the fire threat.
- (f) In compartments that do not contain equipment that is a potential fire source and where smoking is not permitted:
  - (1) There must be appropriate placards, inside and outside each entrance to the compartment, and in each section of the compartment created by the installation of a curtain, in accord with 25.791(a).
  - (2) A smoke or fire detection system (or systems) meeting CS 25.858(b), (c), and (d) must be provided that monitors each occupiable area within the

compartment, including those areas partitioned by curtains. Each system (or systems) must provide:

- (i.) Within one minute after the start of a fire, a visual warning in the cockpit, or a visual or audible indication in the passenger cabin that would be readily detected by persons in the cabin, taking into consideration their positioning throughout the cabin during various phases of flight, and
- *(ii.)* An aural warning in the compartment that would be certain to wake a sleeping occupant.
- b. A means to fight and suppress a fire in the compartment must be provided. This means can either be a built-in extinguishing system or a manual hand fire extinguisher as specified in sub-paragraph (e) of this paragraph.
  - (i.) If a built-in fire extinguishing system is used it must have adequate capacity to suppress any fire occurring in the compartment, considering the fire threat, volume of the compartment, the ventilation rate and the minimum performance standards (MPS) that have been established for the agent being used. In addition it must be shown that a fire will be contained within a controlled volume meeting the requirements of Appendix F, Part III. There must be a means provided to exclude hazardous quantities of smoke or extinguishing agent originating in the compartment from entering any other occupiable compartment.
  - (ii.) If manual hand held extinguishers are used it must be demonstrated that any fire within the compartment can be controlled without entering the compartment or the access provisions must allow crewmembers equipped for fire fighting to have unrestricted access to the compartment. There must be at least one readily accessible hand fire extinguisher available for use.
- (g) Compartments that contain equipment that is a potential fire source or where smoking is permitted must contain a smoke or fire detection system in accord with 25.xxx(f)(2), however such systems may be temporarily disabled by crewmembers, or by any other means found acceptable to the Agency, provided:
  - (1) It is demonstrated that any fire or smoke within the compartment can be:
    - (i.) Detected by cabin crew or passengers in the cabin within the time that allows for effective fire fighting action, taking into consideration the positioning of those persons throughout the cabin during various phases of flight.
    - (ii.) Controlled without entering the compartment or the access provisions must allow crewmembers equipped for fire fighting to have unrestricted access to the compartment.
  - (2) Signs, which notify when smoking is prohibited, are installed in compartments where smoking is permitted in accord with 25.791(a)

### AMC 25.xxx General

A compartment is considered isolated if it is separated such that passengers or crew located outside may not be immediately aware of a fire starting within the compartment. Isolation can be created by features such as doors, partitions or curtains and can also be created by being located remotely from the main passenger cabin. Compartments that are not occupied during taxi, take-off or landing are considered to be not permanently occupied during flight.

The advisory material is to be developed to provide guidance on compliance with *CS 25.xxx* for aircraft of varying sizes, operational roles and isolated compartment configurations. In particular guidance is to be provided on:

- The types of isolated compartments addressed by the requirements based on occupancy and separation.
- The required compliance demonstration means to be used to determine the adequacy of fire or smoke detection by cabin crew or passengers if a smoke or fire detection system is not installed.
- The potential fire sources that need to be considered in the isolated compartment and the associated safeguards that need to be implemented.
- What constitutes "effective fire fighting action"
- The required safety equipment and its location taking into consideration the likely number and location of crewmembers.
- What constitutes "unrestricted access" to an isolated compartment
- Acceptable means of de-activating fire/smoke detection systems

### 2.2 THE PREFERRED OPTION SELECTED

After due consideration the Agency believes that **Option 2 – Rulemaking Action** to amend CS-25 to specify fire protection measures for compartments not permanently occupied during flight that are isolated or located in remote areas is to be preferred.

# 3 SECTORS CONCERNED

The proposed regulatory change is to CS-25 and hence the aircraft affected will be those for which the application for a type certificate or supplemental type certificate is made after the regulatory change considered in this RIA. There is unlikely to be any additional cost borne by aircraft manufacturers, aircraft converters or aircraft operators for compliance with the proposed regulatory change since the subject is currently being addressed by Special Conditions. There will be a marginal cost to EASA for the rulemaking activities. However, there is a potential benefit in terms of time and cost saving for all sectors concerned from a simplified cabin certification process.

### 4 IMPACTS

### 4.1 ALL IDENTIFIED IMPACTS

### 4.1.1 Safety

Generally, there will be no difference in the level of safety that would be achieved by Option 1 and Option 2. However, a rulemaking action would ensure that the fire protection measures for these compartments are standardised.

### 4.1.2 Economic

### **Option 1** – Do Nothing

The certification of compartments not permanently occupied during flight that are isolated or located in remote areas will continue to be addressed by Special Conditions which incurs additional costs and time.

### **Option 2** – Rulemaking Action

Rulemaking action will result in a reduction in certification costs and time due to the simplified certification process.

### 4.1.3 Environmental

There is no difference between the environmental impact of Option 1 and Option 2. The use of hand-held fire extinguishers or built-in fire extinguishers required by both options should take into consideration the phasing out of Halon 1211/1301 and the availability of their environmentally-friendly replacement extinguishing agents.

### 4.1.4 Social

No social impacts have been identified.

### 4.1.5 Other Aviation Requirements outside EASA scope

No aviation requirements outside the scope of EASA which may be affected by the contents of the NPA have been identified.

### 4.1.6 Foreign Comparable Regulatory Requirements

ICAO Annex 8 does not conflict with the content or overall objectives of this proposed regulatory change.

The FAA has issued SFAR No. 109 which is applicable to Private Use Transport Category Airplanes. The SFAR contains the following requirement:

"For airplanes with a type certificated passenger capacity of 20 or more, there must be means that meet the requirements of Sec. 25.858(a) through (d) to signal the flightcrew in the event of a fire in any isolated room not occupiable for taxi, takeoff and landing, which can be closed off from the rest of the cabin by a door. The indication must identify the compartment where the fire is located. This does not apply to lavatories, which continue to be governed by Sec. 25.854."

For aircraft with a type certificated passenger capacity of 20 or more the SFAR is similar to the proposed regulatory change addressed by this RIA. However, there are some significant differences:

- The EASA proposed regulatory change, addressed in this RIA, requires that isolated compartments that contain equipment that are a potential fire source, for instance a cooktop installation, or where smoking is permitted, are provided with smoke or fire detection systems. However, these systems may be temporarily disabled by crewmembers, or by any other means found acceptable to the Agency. EASA has accepted deactivation of smoke detection systems for short periods in such compartments in previous certifications, provided certain safeguards are implemented.
- 2. The SFAR requires that the smoke or fire detection system indication is provided to the flight crew whereas the EASA proposed regulatory change allows the warning to be provided in the cockpit or in the cabin. This policy is intended to reduce the number of nuisance warnings that might otherwise result in distractions to the flight crew in instances where adequate levels of safety might be achieved by other means.

There are no other rulemaking activities being carried out by the FAA or Transport Canada that are pertinent to this subject. The introduction of new rules in CS-25 will result in differences with FAR 25/CAR 525.

### 4.2 EQUITY AND FAIRNESS ISSUES IDENTIFIED

There are no issues of equity and fairness associated with any of the options considered in this Regulatory Impact Assessment.

## 5 SUMMARY AND FINAL ASSESSMENT

### 5.1 COMPARISON OF THE POSITIVE AND NEGATIVE IMPACTS FOR EACH OPTION EVALUATED

#### **Option 1** – Do Nothing

Whilst certification using Special Conditions has provided the intended level of safety, such process incurs increased costs and time to EASA and manufacturers/converters. The optimum way forward is to capture the safety intent contained within the Special Conditions into CS-25.

#### **Option 2** – Rulemaking Action

Taking into consideration that there is an increasing demand for the installation of private rooms/offices in aeroplanes, special areas in large transport aeroplanes and crew rest compartments, incorporating fire protection requirements currently stipulated in Special Conditions into CS-25 would standardise the required fire protection and reduce certification costs and time. This option would, however, introduce differences with FAR 25/CAR 525.

# 5.2 A SUMMARY DESCRIBING WHO WOULD BE AFFECTED BY THESE IMPACTS AND ANALYSING ISSUES OF EQUITY AND FAIRNESS

In terms of safety impacts, aircraft crew and passengers will not be affected by either option since there is no change in the level of safety currently provided by the fire protection requirements stipulated in the Special Conditions.

In terms of economic impacts, EASA, manufacturers/converters, and ultimately operators would benefit from the reduction of time and costs associated with the certification process if Option 2 is selected.

### 5.3 FINAL ASSESSMENT AND RECOMMENDATION OF A PREFERRED OPTION

After due consideration the Agency believes that Option 2 is to be preferred.

Whilst certification using Special Conditions has provided the intended level of safety, such process incurs increased costs and time to EASA and manufacturers/converters. Reflecting the safety intent contained within the Special Conditions into CS-25 would ensure that the intended level of safety is achieved and certification costs and time can be reduced.

Rulemaking as described under Option 2 above is therefore considered to be justified.

### 6 **REFERENCES**

- 1. RGW Cherry & Associates (2009) *Study on CS-25 Cabin Safety Requirements,* prepared for the European Aviation Safety Agency. United Kingdom Author.
- 2. Federal Aviation Administration, Final Special Condition No. 25-216-SC Boeing Model 777-200 Series Airplanes; Overhead Crew Rest Compartment. United States of America Author.
- 3. Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16 October 1998.
- 4. Federal Aviation Administration, SFAR No. 109, Special Requirements for Private Use Transport Category Airplanes Regulatory Information. United States of America Author.

# Attachment 4

### EASA REGULATORY IMPACT ASSESSMENT

### **RELIABILITY OF THE EMERGENCY FLIGHTDECK ACCESS SYSTEM**

### SEPTEMBER 2009

Issue 1
## EASA REGULATORY IMPACT ASSESSMENT RELIABILITY OF THE EMERGENCY FLIGHTDECK ACCESS SYSTEM

Issue 1 September 2009

# AMENDMENT RECORD

ISSUE NUMBER	DATE	REMARKS
1	September 2009	Initial Issue

# CONTENTS

Abbre	eviations4
1	Purpose and Intended Effect5
1.1 1.2 1.3	Issue which the NPA is intended to address
2	Options8
2.1 2.2	The options identified8 The preferred option selected9
3	Sectors Concerned9
4	Impacts9
4.1 4.2	All identified impacts94.1.1 Safety94.1.2 Economic104.1.3 Environmental104.1.4 Social104.1.5 Other aviation requirements outside EASA scope104.1.6 Foreign comparable regulatory requirements10Issues of equity and fairness10
5	Summary and Final Assessment11
5.1 5.2 5.3	Comparison of the positive and negative impacts for each option evaluated
6	References
Apper	ndix 1 – Other Pertinent Requirements1
Apper	ndix 2 – In-flight Flight Crew Incapacitation3

#### EASA REGULATORY IMPACT ASSESSMENT RELIABILITY OF THE EMERGENCY FLIGHTDECK ACCESS SYSTEM

Issue 1 September 2009

## ABBREVIATIONS

- AAIB Air Accidents Investigation Branch (UK)
- AC Advisory Circular
- AMC Acceptable Means of Compliance (EASA)
- CFR Code of Federal Regulations (US)
- CS Certification Specification
- EASA European Aviation Safety Agency
- FAA Federal Aviation Administration (US)
- FAR Federal Aviation Regulations (US)
- JAA Joint Aviation Authorities
- NPA Notice of Proposed Amendment
- RIA Regulatory Impact Assessment

# 1 PURPOSE AND INTENDED EFFECT

## 1.1 ISSUE WHICH THE NPA IS INTENDED TO ADDRESS

The requirements for a secured flightdeck door originated from the increased flightdeck access security required by the FAA following the terrorist attacks in September 2001.

Despite its significance in improving aviation security, there is evidence the secured flightdeck door has resulted in several issues. There is a concern that with some locking system designs, the cabin crew may not be able to access the flightdeck in the event of flight crew incapacitation or other emergency situations. Accident experience also shows that having a secured flightdeck door can also result in communication difficulties between the flight crew and cabin crew, especially when the interphone system is not functioning.

Those issues highlight the importance of the reliability of the emergency means for cabin crew to unlock the flightdeck door. There is no requirement or guidance material which addresses the reliability of the flightdeck door locking mechanism or the emergency unlocking mechanism, for example the required availability of the electrical power supply.

The CS-25 requirement applicable to this issue is as follows:

25.772 For an aeroplane that has a lockable door installed between the pilot compartment and the passenger compartment: -

(c) There must be an emergency means to enable a crewmember to enter the pilot compartment in the event that the flight crew becomes incapacitated.

This requirement was first introduced in FAR 25 Amendment 25-106 (effective 15 January 2002), and adopted into CS-25 since the Initial Issue (effective 17 October 2003).

All other pertinent requirements are in Appendix 1.

## **1.2 SCALE OF THE ISSUE**

CS-25 Amendment 5 does not specify the required reliability of the emergency flightdeck access system from the cabin.

An in-flight smoke incident to an EMB-190 overhead Edinburgh on 15 January 2009<sup>1</sup> featured a scenario where the power for the emergency unlocking system from the cabin was unavailable because the flight crew had to shut off the main electrical power as part of the 'Electrical System Fire or Smoke' procedure. The cabin crew became concerned that the flight crew might have become incapacitated or that a serious emergency had developed in the flight deck, because they could not establish communication with the flight crew using the interphone system. Due to these concerns, the cabin crew attempted to access the flight deck, but the emergency flightdeck access system did not function due to the loss of main electrical power. Although this incident did not result in injuries or fatalities, and the flight crew were in fact not incapacitated, it raised a concern regarding the reliability of the emergency flightdeck access system.

The safety recommendation issued by the UK AAIB following the EMB-190 incident (Safety Recommendation 2009-020) only recommended Embraer to *"immediately notify all operators, of the Embraer 190 family of aircraft, to inform flight and cabin crew of the functioning of the flight deck access system when the aircraft is supplied only with emergency electrical power".* 

Accident/incident experience shows that there have been many communication/coordination difficulties between the flight crew and cabin crew during emergency situations related to the non-functioning of the interphone system<sup>2</sup>. In such situations, the reliability of the emergency

#### EASA REGULATORY IMPACT ASSESSMENT RELIABILITY OF THE EMERGENCY FLIGHTDECK ACCESS SYSTEM

Issue 1 September 2009

flightdeck access system for cabin crew becomes more crucial as it provides a means for cabin crew to establish direct communication with the flight crew during emergency situations. This issue is significant especially if both systems are affected by the same failure mode e.g. loss of the aircraft's main electrical power. Accident/incident experience shows that there is a relatively high incidence of the failure of the interphone system resulting from the loss of the aircraft's main electrical power<sup>a</sup>.

The incident on the EMB-190 indicated that the design of the emergency flightdeck door unlocking facility might not meet the intent of CS 25.772(c). However, it may be argued that CS 25.772(c) does not explicitly specify that such emergency means should be available at all times, including when the main electrical supplies are not available. There is no guidance material on the subject. In most locking systems, it is possible for the flight crew to unlock the door in the event of a failure of the electrical locking system using a manual override of the door latch; however, this is only operable from the inside of the flightdeck<sup>3</sup>. Such a system would be ineffectual if the flight crew in the flightdeck were to be incapacitated or if the cabin crew could not communicate with the flight deck, which could incapacitate the flight crew and at the same time cause or require disconnection of the main electrical supplies, it may be impossible for the cabin crew to assist the flight crew.

There is no information on the current EASA position on this subject. The JAA Policy Paper on 'Flightcrew Compartment Access Door Design and the Associated Changes in Operational Procedures'<sup>4</sup>, contains a non-exhaustive list of additional operational considerations, which included the following relevant points:

- Communication between flight deck/cabin crew and cabin crew/flight deck in normal, abnormal and emergency situations (including flight deck intrusion and pilot incapacitation)
- Procedures in case one flight crew member leaves the flight deck for, health, safety, security or crew rest reasons.

FAA memorandum 01-115-11 of 3 December 2002 provided guidance for the development of systems that satisfy the requirements of FAR 25.772(c). Included was the potential use of an emergency unlock feature that incorporated an appropriate time delay. Nevertheless, the FAA recommended the requirements of FAR 25.772(c) to be addressed by operational procedures, as reflected in the following excerpt from FAA's Final Rule on 14 CFR Part 25 Amendment No. 25-106 and Part 121 Amendment No. 121-288:

While not explicitly a current requirement, the FAA has long recognized a need to provide for in-flight flightdeck entry by the cabin crew should a flightcrew member become incapacitated; because the consequences of not providing such access could be catastrophic.

A new Sec. 121.313(j) is added to reference the new part 25 standard for the door separating the flightdeck from the passenger compartment. With respect to the requirements of Sec. 25.772(c), which would require systems that would permit entry by flight attendants but not permit entry by other persons, these systems must have a high degree of reliability, and the FAA considers that it may not be practical to develop and install such systems within the compliance time of

<sup>&</sup>lt;sup>a</sup> This loss of main electrical supply resulted from the flight crew being required to switch certain power buses off in an emergency or as a result of engine failure or crash impact. A separate rulemaking activity has been proposed to address this subject.

this rule<sup>b</sup>. However, operational procedures coupled with simpler, more robust systems could be readily implemented. Procedures could include having a flight attendant occupy a flightdeck seat whenever one pilot must leave the flightdeck<sup>c</sup>. Any system that must be activated by a flightcrew member (either to permit or deny entry) must be operable from the crewmember's duty station. Therefore, Sec. 121.313(j) will require each operator to establish methods to enable a flight attendant to enter the flightdeck in the event that a flightcrew member becomes incapacitated. As with Sec. 25.772(c), these methods are intended to be used under emergency conditions and not for routine access to the flightdeck.

It is understood that due to the urgent nature of the issue, National Airworthiness Authorities were given guidance by the JAA to "permit and expedite the installation of door design changes, preceding the formal compliance verification with all applicable airworthiness requirements by the NAA"<sup>d</sup>. It is believed that the rushed, deadline-driven installations of a secured flightdeck door have also resulted in the many operational, security and safety issues, as reported in the United States<sup>5,6</sup> and Australia<sup>7</sup>.

The significance of this issue depends on the likelihood of an event where all three risks below exist:

- there is an emergency situation which requires crew access from the cabin to the flightdeck, and
- the flight crew are unable to unlock the flightdeck door from the flightdeck by any method available to them, and
- the emergency means for cabin crew to access the flightdeck does not function.

Procedures have been used to prevent incapacitation of all flight crew due to common factors such as food or drink poisoning. There could be other factors such as hypoxia<sup>8</sup>, cabin air contamination with noxious fumes or smoke/fire, or windscreen failure (e.g. due to maintenance error<sup>9</sup> or bird impact exceeding the standards provided by the airworthiness requirements<sup>10</sup>). The risk of the incapacitation of all flight crew is considered to be small, but not non-existent (see Appendix 2 for more discussions on flight crew incapacitation). However, there is still a more conceivable risk where one flight deck becomes incapacitated. If the emergency means to enter the flightdeck from the cabin does not have a high degree of reliability, the consequences could be catastrophic. Another conceivable risk is where one of the flight crew, but the flight crew is unable to unlock the door from his station for any reason. There have been reports of pilots being locked out of the flight deck<sup>5</sup>, with the widely publicised occurrence on a CRJ-100 on a flight from Ottawa to Winnipeg in 26 August 2006<sup>e</sup>.

<sup>&</sup>lt;sup>b</sup> According to the Final Rule, "Given the urgency of the situation, such requirements and modifications necessary to meet those requirements should be established by April 2002, such that airplanes operating in the United States, whether foreign or domestic, will have improved flightdeck security by April 9, 2003"

<sup>&</sup>lt;sup>c</sup> As raised by several operators in Australia<sup>7</sup>, on flights with one cabin crew this will result in the cabin being completely unattended.

<sup>&</sup>lt;sup>d</sup> The Policy Paper stated that "not later than 30th April 2003 the operator shall, in case of a noncompliance exists, have installed a design compliant with the applicable airworthiness requirements." <sup>e</sup> In this occurrence, the pilot who left the cockpit to use the aft lavatory before landing found himself locked out upon his return after the door locks on the reinforced cockpit doors malfunctioned. The first officer had remained on the flight deck, but was unable to open the door. Crew members were forced to take the door off its hinges to let him back in after the incident, which happened 30min before the scheduled arrival of the aircraft in Winnipeg (Flightglobal.com, 31/08/06)

#### EASA REGULATORY IMPACT ASSESSMENT RELIABILITY OF THE EMERGENCY FLIGHTDECK ACCESS SYSTEM

#### **1.3 BRIEF STATEMENT OF THE OBJECTIVES OF THE NPA**

The purpose of the NPA is to amend CS-25 to specify the required reliability of the emergency flightdeck access system from the cabin to address the possible risks related to the in-flight incapacitation of the flight crew and the potential communication/coordination problems when the interphone system does not function.

The cabin crew's ability to gain emergency access to the flightdeck needs to be maintained at all times. Some emergency unlocking system designs utilise the aircraft's main electrical power for it to function, resulting in a risk of the cabin crew being unable to access the flightdeck during emergency situations that involve a loss of main electrical power. Since currently the availability of the interphone system is not required to be maintained at all times. this issue will also have the potential to adverselv affect the communications/coordinations between the flight crew and cabin crew.

Considering that in some scenarios the consequences of not providing such access could be catastrophic, an amendment to CS-25 may be required.

## 2 OPTIONS

#### 2.1 THE OPTIONS IDENTIFIED

Two regulatory options are considered in this Regulatory Impact Assessment:

#### **Option 1 – Do Nothing**

No amendments to CS-25 to specify the required reliability of the emergency flightdeck access from the cabin would be made.

# Option 2 – Rulemaking Action – Amend CS-25 to incorporate Acceptable Means of Compliance for CS 25.772(c)

Amend CS-25 to specify the required reliability of the emergency flightdeck access from the cabin in the AMC for 25.772(c). Further explanation may be necessary including examples of good design practice, such as ensuring the preservation, at all times, of the electrical supply to the emergency flightdeck access system (e.g. using a dedicated battery or a supply from the aircraft hot bus. The proposed amendments to CS-25 are as follows:

25.772 For an aeroplane that has a lockable door installed between the pilot compartment and the passenger compartment: -

(c) There must be an emergency means to enable a crewmember to enter the pilot compartment in the event that the flight crew becomes incapacitated (See AMC 25.772(c)).

#### AMC 25.772(c)

The applicant must assess all reasonably probable scenarios where the means might be required and to design the systems, including the electrical power supplies, accordingly.

## 2.2 THE PREFERRED OPTION SELECTED

See Section 5.3.

## 3 SECTORS CONCERNED

The NPA is applicable to aeroplanes required to be equipped with an approved flightdeck door that is capable of being locked and unlocked from either pilot's station<sup>1</sup>.

The sectors affected by this proposal are crew and aeroplane manufacturers that may bear the costs incurred in material costs, design, testing and certification. There will be a marginal cost to EASA in their oversight of the manufacturers in showing compliance with the regulatory change.

## 4 IMPACTS

### 4.1 ALL IDENTIFIED IMPACTS

#### 4.1.1 Safety

#### Option 1 – Do Nothing

This option would not address the potential risks related to the inability of cabin crew to access the flightdeck using the emergency access system during emergency situations, such as flight crew incapacitation. Scenarios involving loss of the aircraft's main electrical power that affects the functioning of the emergency access system will continue to pose such risks. Based on accident/incident experience the overall risk appears to be relatively small; however the consequences could be catastrophic. The potential crew communication/coordination difficulties during emergency situations related to the non-functioning of the interphone system will not be addressed, which is of special significance if both systems are affected by the same failure mode e.g. loss of the aircraft's main electrical power<sup>9</sup>.

# Option 2 – Rulemaking Action – Amend CS-25 to incorporate Acceptable Means of Compliance for CS 25.772(c)

Amending CS-25 would increase safety by minimising the risk of cabin crew being unable to access the flightdeck during emergency situations. The risks related to communication/coordination problems during emergency situations due to the non-functioning of the interphone system, especially if both systems are affected by the same failure mode e.g. loss of the aircraft's main electrical power, will also be minimised<sup>9</sup>.

<sup>&</sup>lt;sup>f</sup> All passenger carrying aeroplanes of a maximum certificated take-off mass exceeding 45 500 kg or with a maximum passenger seating configuration of more than 60 engaged in the commercial transportation of passengers (OR.OPS.035.SEC)

<sup>&</sup>lt;sup>g</sup> If the requirements for the power supplies of the interphone, public address and evacuation alert system are amended, as proposed in a separate regulatory action, this issue will be less significant.

#### EASA REGULATORY IMPACT ASSESSMENT RELIABILITY OF THE EMERGENCY FLIGHTDECK ACCESS SYSTEM

### 4.1.2 Economic

#### **Option 1 – Do Nothing**

There will be no costs related to Option 1, other than the possible costs to operators from accidents/incidents that could occur related to the risks identified in this RIA.

# Option 2 – Rulemaking Action – Amend CS-25 to incorporate Acceptable Means of Compliance for CS 25.772(c)

The proposed amendment will incur initial design and certification costs, and manufacturing costs particularly to the manufacturers of new type certificate aeroplanes. Depending on the design, operators may bear additional fuel costs due to the increased weight of the system. These costs can be considered relatively minimal. Conversely, the costs to operators from accidents/incidents that could occur related to the risks identified in this RIA may be avoided.

#### 4.1.3 Environmental

No significant environmental impacts have been identified. If the improvements to the emergency flightdeck access system were carried out, an increase of  $CO_2$  emission from each flight may occur should the design solutions result in significant additional weight. The amount of this increase will depend on the additional weight, but at worst it is considered to be relatively small.

#### 4.1.4 Social

No social impacts have been identified.

#### 4.1.5 Other aviation requirements outside EASA scope

No aviation requirements outside the scope of EASA which may be affected by the contents of the NPA have been identified.

#### 4.1.6 Foreign comparable regulatory requirements

ICAO Annex 6 and Annex 8 were reviewed and no text was found in conflict with the content or overall objectives of the NPA.

Since there are no current rulemaking activities within the FAA or Transport Canada regarding this subject, a rule change will introduce differences in the standards.

#### 4.2 **ISSUES OF EQUITY AND FAIRNESS**

There are no issues of equity and fairness associated with any of the regulatory options considered in this Regulatory Impact Assessment.

# 5 SUMMARY AND FINAL ASSESSMENT

# 5.1 COMPARISON OF THE POSITIVE AND NEGATIVE IMPACTS FOR EACH OPTION EVALUATED

#### Option 1 – Do Nothing

This option does not mitigate the risks associated with the inability of cabin crew to access the flightdeck during emergency situations. The level of safety achieved will vary greatly on different aeroplane types since there is no guidance available on the required reliability on the emergency flightdeck access system. Although there will not be any direct costs related to Option 1, there are possible costs to operators from accidents/incidents that could occur related to the risks identified in this RIA.

# Option 2 – Rulemaking Action – Amend CS-25 to incorporate Acceptable Means of Compliance for CS 25.772(c)

By incorporating the proposed AMC for 25.772(c), the intent of the requirement can be elaborated further to ensure that design of the emergency flightdeck access means takes into account all reasonably probable scenarios where the means might be required. Considering the possible catastrophic consequences of the inability of the cabin crew to access the flightdeck when required during emergency situations, the costs that may be incurred by this option are considered acceptable.

# 5.2 A SUMMARY DESCRIBING WHO WOULD BE AFFECTED BY THESE IMPACTS AND ANALYSING ISSUES OF EQUITY AND FAIRNESS

Aircraft crew and passengers will be positively affected by the improved level of safety related to Option 2. In terms of economic impacts, Option 2 may incur costs to aeroplane manufacturers which consist of material, design, testing and certification costs. There will be a marginal cost to EASA in their oversight of the manufacturers in showing compliance with the regulatory change. Conversely, the costs to the industry from accidents/incidents that could occur related to the risks identified in this RIA may be avoided.

#### 5.3 FINAL ASSESSMENT AND RECOMMENDATION OF A PREFERRED OPTION

After due consideration the Agency believes that Option 2 - Rulemaking Action is to be preferred.

Considering the possible catastrophic consequences of the inability of the cabin crew to access the flightdeck when required during emergency situations, the costs that may be incurred by this option are considered acceptable.

Rulemaking as described under Option 2 above is therefore considered to be justified.

#### EASA REGULATORY IMPACT ASSESSMENT RELIABILITY OF THE EMERGENCY FLIGHTDECK ACCESS SYSTEM

#### REFERENCES 6

<sup>1</sup> UK Air Accidents Investigation Branch, AAIB Bulletin No: 1/2009, Ref: EW/C2009/01/03, EMB-190, G-FBEH, 15 January 2009, Overhead Edinburgh

<sup>2</sup> RGW Cherry & Associates (2009) Study on CS-25 Cabin Safety Requirements, Report No. 4208/R/000454/KK Issue 4, prepared for the European Aviation Safety Agency <sup>3</sup> UK Air Accidents Investigation Branch, AAIB Bulletin No: 9/2003, Ref: EW/G2003/04/27, Boeing 747-

436 G-BNLC, 20 April 2003, Riga FIR, Latvia

<sup>4</sup> Joint Aviation Authorities, JAA Policy Paper on Flightcrew Compartment Access Door Design and the associated Changes in Operational Procedures. 20 November 2001

<sup>5</sup> "Dysfunctional 'Fortress' Doors Have Caused Numerous Safety & Security Problems", Air Safety Week, August 16, 2004

<sup>6</sup> "The Pilots Speak: Case Studies in Dysfunctional Doors", Air Safety Week, August 16, 2004 <sup>7</sup> Australian Transport Safety Bureau (2005) *Operational and flight safety implications of the installation* of hardened cockpit security doors in passenger aircraft having a seating capacity of 30 seats or more ATSB Transport Safety Investigation Report, Aviation Occurrence Report 200504018 - Final. Canberra: ATSB

<sup>8</sup> Hellenic Republic Ministry of Transport & Communications – Air Accident Investigation & Aviation Safety Board (AAIASB), Aircraft Accident Report 11/2006 – Helios Airways Flight HCY522, Boeing 737-31S at Grammatiko, Hellas on 14 August 2005 <sup>9</sup> UK Air Accidents Investigation Branch, Aircraft Accident Report 1/92 – Report on the accident to

BAC One-Eleven G-BJRT over Didcot, Oxfordshire on 10 June 1990

<sup>10</sup> National Transportation Safety Board, NTSB Identification SEA03FA024, Accident occurred on Horizon Airlines Bombardier DHC-8-401, registration: N409QX on January 08, 2003 in Medford, OR, USA

## **Appendix 1 – Other Pertinent Requirements**

Operations requirements related to flightdeck door are as follows:

OPS.CAT.519.A Internal doors and curtains - Aeroplanes

(a) Aeroplanes with a maximum passenger seating configuration of more than 19 shall be equipped with a door between the passenger and the cockpit with a placard saying "crew only" and a locking mechanism preventing passengers from opening it.

OR.OPS.035.SEC Cockpit security – Aeroplanes

(a) In all complex motor-powered aeroplanes and in all aeroplanes used in commercial operations, which are equipped with a cockpit door, this door shall be capable of being locked, and means shall be provided by which the cabin crew can discreetly notify the flight crew in the event of suspicious activity or security breaches in the cabin.

(b) All passenger carrying aeroplanes of a maximum certificated take-off mass exceeding 45 500 kg or with a maximum passenger seating configuration of more than 60 engaged in the commercial transportation of passengers, shall be equipped with an approved cockpit door that is capable of being locked and unlocked from either pilot's station and designed to meet the applicable airworthiness requirements.

(c) The cockpit door referred to in subparagraph (b) above shall:

(1) be closed and locked from the time all external doors are closed following embarkation until any such door is opened for disembarkation, except when necessary to permit access and egress by authorised persons; and

(2) means shall be provided for monitoring from either pilot's station the entire door area outside the cockpit to identify persons requesting entry and to detect suspicious behaviour or potential threat.

ICAO Annex 6 Chapter 13 Section 13.2 states:

## 13.2 Security of the flight crew compartment

13.2.1

In all aeroplanes which are equipped with a flight crew compartment door, this door shall be capable of being locked, and means shall be provided by which cabin crew can discreetly notify the flight crew in the event of suspicious activity or security breaches in the cabin.

13.2.2

From 1 November 2003, all passenger-carrying aeroplanes of a maximum certificated takeoff mass in excess of 45 500 kg or with a passenger seating capacity greater than 60 shall be equipped with an approved flight crew compartment door that is designed to resist penetration by small arms fire and grenade shrapnel, and to resist forcible intrusions by unauthorized persons. This door shall be capable of being locked and unlocked from either pilot's station.

13.2.3

In all aeroplanes which are equipped with a flight crew compartment door in accordance with 13.2.2:

a) this door shall be closed and locked from the time all external doors are closed following embarkation until any such door is opened for disembarkation, except when necessary to permit access and egress by authorized persons; and

b) means shall be provided for monitoring from either pilot's station the entire door area outside the flight crew compartment to identify persons requesting entry and to detect suspicious behaviour or potential threat.

#### 13.2.4

Recommendation.— All passenger-carrying aeroplanes should be equipped with an approved flight crew compartment door, where practicable, that is designed to resist penetration by small arms fire and grenade shrapnel, and to resist forcible intrusions by unauthorized persons. This door should be capable of being locked and unlocked from either pilot's station.

#### 13.2.5

Recommendation.— In all aeroplanes which are equipped with a flight crew compartment door in accordance with 13.2.4:

a) the door should be closed and locked from the time all external doors are closed following embarkation until any such door is opened for disembarkation, except when necessary to permit access and egress by authorized persons; and

b) means should be provided for monitoring from either pilot's station the entire door area outside the flight crew compartment to identify persons requesting entry and to detect suspicious behaviour or potential threat.

ICAO Annex 8 Chapter 11 Section 11.3 states:

#### 11.3 Protection of the flight crew compartment

Recommendation.— In all aeroplanes, which are required by Annex 6, Part I, Chapter 13 to have an approved flight crew compartment door, and for which an application for amending the type certificate to include a derivative type design is submitted to the appropriate national authority, consideration should be given to reinforcing the flight crew compartment bulkheads, floors and ceilings so as to resist penetration by small arms fire and grenade shrapnel and to resist forcible intrusions, if these areas are accessible in flight to passengers and cabin crew.

## Appendix 2 – In-flight Flight Crew Incapacitation

A study by the Australian Transport Safety Bureau<sup>7</sup> attempted to gain an appreciation of the potential magnitude of the hazard identified in the case of pilot incapacitation in 30 to 59 seat aircraft that included a problematic installation of a hardened cockpit security door.

The study found that in the period January 2000 to July 2005, there had been 43 reports of flight crew incapacitation during the period studied, or an average of about 8 incidents per year. The causes of the pilots' incapacitation varied, but included: the temporary loss of vision as a result of a lightning strike; physical illness, including stomach cramps and nausea; the lodgement of a foreign object in a pilot's eye; and incapacitation as a result of the contamination of the flight compartment. In one instance, both pilots became incapacitated. In many of the reported incidents, a cabin crew member was required to enter the flight compartment to render assistance while the remaining pilot ensured the continued safe conduct of the flight.

The following is the abstract of a study carried out by CAMI<sup>h</sup>:

Although it is not known when the first accident due to pilot in-flight medical incapacitation occurred, a recent survey showed that almost one-third of all pilots who responded had experienced an incapacitation requiring another crewmember to take over their duties, with safety of flight significantly threatened in 3% of cases. The importance of in-flight medical incapacitation and impairment can be better understood when it is realized that each in-flight medical incapacitation or impairment could potentially lead to an aircraft accident. We studied in-flight medical incapacitations and impairments in U.S. airline pilots from 1993 through 1998. We defined in-flight medical incapacitation as a condition in which a flight crewmember was unable to perform any flight duties and impairment as a condition in which a crewmember could perform limited flight duties, even though performance may have been degraded. We found 39 incapacitations and 11 impairments aboard 47 aircraft during the six-year period. All pilots were males. The average age for incapacitations was 47.0 years (range 25 to 59 years). The average age for impairments was 43.3 years (range 27 to 57 years). The in-flight medical event rate was 0.058 per 100,000 flight hours. The probability that an in-flight medical event would result in an aircraft accident was 0.04. Incapacitations significantly increased with age, with more serious categories in the older age groups. The most frequent categories of incapacitation were loss of consciousness, cardiac, neurological, and gastrointestinal. Safety of flight was seriously impacted in seven of the 47 flights and resulted in two non-fatal accidents.

<sup>&</sup>lt;sup>h</sup> DeJohn, C.A., Wolbrink, A.M., and Larcher J.G. (2004) *In-Flight Medical Incapacitation and Impairment of U.S. Airline Pilots: 1993 to 1998, DOT/FAA/AM-04/16.* Oklahoma City: FAA Civil Aerospace Medical Institute

# Attachment 5

## EASA REGULATORY IMPACT ASSESSMENT

# *'RETURN TO SEAT' SIGN AND INTELLIGIBILITY OF PUBLIC ADDRESS SYSTEM IN AREAS WHERE THE OCCUPANTS ARE NOT NORMALLY SEATED*

## SEPTEMBER 2009

Issue 1

#### EASA REGULATORY IMPACT ASSESSMENT 'RETURN TO SEAT' SIGN AND INTELLIGIBILITY OF PUBLIC ADDRESS SYSTEM IN AREAS WHERE THE OCCUPANTS ARE NOT NORMALLY SEATED

Issue 1 September 2009

## AMENDMENT RECORD

ISSUE NUMBER	DATE	Remarks
1	September 2009	Initial Issue

## CONTENTS

Abbre	viations4	
1	Purpose and Intended Effect5	
1.1 1.2 1.3	Issue which the NPA is intended to address	
2	Options7	
2.1 2.2	The options identified7 The preferred option selected8	
3	Sectors Concerned8	
4	Impacts8	
4.1	All identified impacts84.1.1Safety84.1.2Economic94.1.3Environmental94.1.4Social94.1.5Other aviation requirements outside EASA scope94.1.6Foreign comparable regulatory requirements9	
4.2	Issues of equity and fairness9	
5	Summary and Final Assessment10	
5.1	Comparison of the positive and negative impacts for each option evaluated	
5.2 5.3	A summary describing who would be affected by these impacts and analysing issues of equity and fairness	
6	References 11	
•		

#### EASA REGULATORY IMPACT ASSESSMENT 'RETURN TO SEAT' SIGN AND INTELLIGIBILITY OF PUBLIC ADDRESS SYSTEM IN AREAS WHERE THE OCCUPANTS ARE NOT NORMALLY SEATED

Issue 1 September 2009

# ABBREVIATIONS

- AMC Acceptable Means of Compliance
- CAR Canadian Aviation Regulations
- CRI Certification Review Item
- CS Certification Specification
- EASA European Aviation Safety Agency
- FAA Federal Aviation Administration (US)
- FAR Federal Aviation Regulations
- NPA Notice of Proposed Amendment
- RIA Regulatory Impact Assessment

# 1 PURPOSE AND INTENDED EFFECT

### 1.1 ISSUE WHICH THE NPA IS INTENDED TO ADDRESS

The NPA addresses some of the measures that can be implemented to minimise the risk of injuries due to turbulence. Advanced notification from flight crew to cabin occupants when turbulence is forecasted or expected is one of the most effective measures. It is therefore considered that the requirements of CS-25 should ensure that such notifications are provided for all occupants located throughout the cabin during all phases of the flight.

Currently, the flight crew can notify the cabin occupants of impending turbulence by activating the 'Fasten Seat Belt' signs, along with an announcement through the public address system. The relevant CS-25 Cabin Safety requirements are as follows:

- CS 25.791(b) Signs that notify when seat belts should be fastened and that are installed to comply with the Operating Rules must be installed so as to be operable from either pilot's seat and, when illuminated, must be legible under all probable conditions of cabin illumination to each person seated in the cabin.

OPS.CAT.518 requires 'Fasten seat belt' signs for "aircraft in which all passenger seats are not visible from the flight crew seat".

- CS 25.1423 A public address system required by operational rules must -

(c) Be intelligible at all passenger seats, lavatories, and cabin crew member seats and work stations.

A public address system is required by operational rules (OPS.CAT.517) for aeroplanes with a maximum passenger seating configuration of more than 19 and is required to be audible at "all passenger seats, toilets, cabin crew seats and work stations" (AMC OPS.CAT.517).

Instead of 'Fasten Seat Belt' signs, 'Return to Seat' signs are usually installed in lavatories in most aeroplanes. However, there is no explicit requirement within CS-25 or operational rules to install 'Return to Seat' signs in lavatories or any other areas in the cabin where the occupants are not normally seated. Additionally, CS 25.1423(c) does not require the public address system to be intelligible in areas other than passenger seat areas, lavatories, and cabin crew member seats and work stations. Amendments to CS-25 may be required to ensure that 'Return to Seat' signs are installed and public address systems (if fitted) are intelligible in areas where the occupants are not normally seated (e.g. stairways, recreational areas, remote waiting areas for lavatories, showers, prayer rooms, etc). These issues may be particularly relevant to large transport aircraft.

## **1.2 SCALE OF THE ISSUE**

In the period 1998-2007, there were 83 accidents involving turbulence encounters which caused injuries to occupants<sup>1</sup>. The injuries consisted of 263 minor impact injuries, and 98 moderate to serious impact injuries, affecting 139 cabin crew and 222 passengers.

In the majority of those accidents, the injured cabin crew members were carrying out service duties or securing the cabin when the turbulence was encountered. The late activation of the 'Fasten Seat Belt' sign or the occurrence of an unforecasted/undetected turbulence (such as Clear Air Turbulence) were the primary factors in the large number of injured passengers; although passengers' non-compliance with the illuminated 'Fasten Seat Belt' sign (elected to

#### EASA REGULATORY IMPACT ASSESSMENT 'RETURN TO SEAT' SIGN AND INTELLIGIBILITY OF PUBLIC ADDRESS SYSTEM IN AREAS WHERE THE OCCUPANTS ARE NOT NORMALLY SEATED

Issue 1 September 2009

leave their seats or not fastening their seat belts) were often the primary cause of passengers' injuries. The following chart shows the circumstances in which the passengers were affected.



Providing firm handholds (seatbacks or hand rails) as required by CS 25.785(j) may provide protection in "moderately rough air". However, the more effective means of preventing injuries during a forecasted or expected turbulence is by ensuring that the passengers are secured in their seats. This can be achieved by timely activation of the 'Fasten Seat Belt' signs and announcement of the impending turbulence through the public address systems.

In some aeroplanes, typically very large transport aeroplanes, there are areas that the passengers are permitted during flight that are not fitted with seats. With regard to the safety risks discussed in this RIA, these areas are not addressed explicitly in CS-25 since CS 25.791(b) and CS 25.1423(c) refer to seated passengers. Additionally, there is no requirement for the installation of signs to prompt occupants in lavatories or other areas where the occupants are not normally seated to return to their seats.

A Certification Review Item issued by EASA for the use of the stairs between decks for the A380<sup>2</sup> requires the following special conditions:

- Non smoking and return to seat signs should be installed and be visible in the stairway both going up and down and at the stairway entrances.
- The public address system should be audible in the stairway during all flight phases.

In addition to the stairway areas, at the Very Large Transport Aeroplane Conference<sup>3</sup> a concern was raised regarding out-of-seat activities at recreational/open spaces and it was recommended that sufficient means of providing protection in these places should be considered.

### **1.3 BRIEF STATEMENT OF THE OBJECTIVES OF THE NPA**

The objective of the NPA is to amend CS-25 to address the lack of an explicit requirement for 'Return to Seat' signs and the intelligibility of the public address system (if fitted to comply with the operating rules) in areas where the occupants are not normally seated. Currently, the relevant requirements only specify 'Fasten Seat Belt' signs in seated passenger compartments and for the public address system to be intelligible at all passenger seats, lavatories, and cabin crew member seats and work stations.

This issue is considered significant especially since 'out-of-seat' areas such as recreational areas, prayer rooms, bars, etc., specifically on large/very large transport aeroplanes, may be more prevalent in the future.

## 2 OPTIONS

#### 2.1 THE OPTIONS IDENTIFIED

Two regulatory options are considered in this Regulatory Impact Assessment:

#### **Option 1 – Do Nothing**

This option means there will be no improvements to CS-25 in relation to the installation of 'Return to Seat' signs and the intelligibility of public address systems (if fitted to comply with the operating rules) in areas of aeroplanes where the occupants are not normally seated.

#### **Option 2 – Rulemaking Action – Amend CS-25**

This option will amend CS-25 for the following subjects:

- Add the requirement for the installation of 'Return to Seat' signs throughout the cabin where passengers or crew are permitted, excluding areas where 'Fasten Seat Belt' signs are required by CS 25.791(b).
- Amend CS 25.1423(c) to require the public address system (if fitted) to be intelligible in all areas in the cabin where passengers or crew are permitted. A draft CRI on crew rest compartments<sup>4</sup> requires that provisions must be provided so that occupants of the crew rest compartment will not be disturbed with normal, non-emergency announcements made to the passenger cabin. This will be included in the proposed amendment.

The proposed wordings of the amendments are as follows:

#### *CS 25.791(x)*

Signs operable by a flight crew member that notify when the cabin occupants should return to their seats must be installed in a manner to be visible under all probable conditions of cabin illumination to all persons throughout the cabin areas where passengers or crew members are permitted; except where sub-paragraph (b) of this paragraph applies.

CS 25.1423 A public address system required by operational rules must –

(c) Be intelligible during all flight phases at all passenger seats, lavatories, cabin crew member seats and work stations, **and any other areas where passengers or crew are** 

#### permitted. Provisions must be provided so that occupants of crew rest areas will not be disturbed with normal, non-emergency announcements made to the passenger cabin.

### 2.2 THE PREFERRED OPTION SELECTED

See Section 5.3.

## 3 SECTORS CONCERNED

The proposed regulatory change is to CS-25 and hence the aeroplanes affected will be those for which the application for a type certificate or supplemental type certificate is made after the regulatory change considered in this RIA. For the proposed amendment to CS 25.1423, only aircraft with a maximum passenger seating configuration of more than 19 will be affected (i.e. those required by the operational rule to have a public address system). The proposed amendment to CS 25.791 will primarily affect aeroplanes that feature special (standing) areas. The primary cost of the regulatory change will be borne by the aircraft manufacturers and aircraft converters. These costs will result from any increases that may be incurred in material costs, design and testing. Aircraft operators will also be affected should any of the design solutions result in significant weight increases. There will be a marginal cost to EASA in their oversight of the manufacturers/converters in showing compliance with the proposed regulatory change.

## 4 IMPACTS

#### 4.1 ALL IDENTIFIED IMPACTS

#### 4.1.1 Safety

#### **Option 1 – Do Nothing**

Most aeroplanes already have 'Return to Seat' signs installed in lavatories; however, manufacturers can elect to not do so since it is not mandatory. If Option 1 is selected, the installation of 'Return to Seat' signs and the audibility of the public address system in special areas (e.g. stairway areas, recreational areas, prayer rooms, etc.) are likely to be addressed by Certification Review Item/Special Conditions.

#### **Option 2 – Rulemaking Action – Amend CS-25**

This option means adopting current industry practice and Special Conditions into formal airworthiness requirements, which will standardise the requirements for the installation of 'Return to Seat' signs and the intelligibility of the public address systems in areas in the cabin where the occupants are not normally seated. Amending CS-25 to address these subjects will improve the safety level for the passengers and the cabin crew.

### 4.1.2 Economic

#### **Option 1 – Do Nothing**

There will be no economic impact related to Option 1, other than the costs of injuries related to turbulence accidents that could have been mitigated by the implementation of the proposed amendments to CS-25.

#### **Option 2 – Rulemaking Action – Amend CS-25**

The proposed amendments will incur costs to the aircraft manufacturers/converters for new/supplemental type certificates related to the design and installation of the signs. Operators will bear additional fuel costs should any of the design solutions result in significant weight increases. These incremental costs can be considered relatively minimal because in many cases such signs are already being, and would continue to be, installed and thus additional costs and weight increases will be small. There will be a marginal cost to EASA in their oversight of the manufacturers/converters in showing compliance with the proposed regulatory change. Overall, these costs may be offset by the time and cost savings from a simplified certification process<sup>a</sup>.

#### 4.1.3 Environmental

No significant environmental impacts have been identified. An increase of  $CO_2$  emission from each flight may occur should the design solutions result in significant additional weight. The amount of this increase will depend on the additional weight, but even at worst it is considered to be relatively small.

#### 4.1.4 Social

No social impacts have been identified.

#### 4.1.5 Other aviation requirements outside EASA scope

No aviation requirements outside the scope of EASA which may be affected by the contents of this NPA have been identified.

#### 4.1.6 Foreign comparable regulatory requirements

ICAO Annex 6 and Annex 8 were reviewed and no text was found in conflict with the content or overall objectives of the NPA.

Since there are no current rulemaking activities within the FAA or Transport Canada regarding this subject, a rule change will introduce differences in the airworthiness standards.

#### 4.2 **ISSUES OF EQUITY AND FAIRNESS**

There are no issues of equity and fairness associated with any of the regulatory options considered in this Regulatory Impact Assessment.

<sup>&</sup>lt;sup>a</sup> Currently EASA raise CRIs to address "Return to Seat" signs on every project requiring such signs.

## 5 SUMMARY AND FINAL ASSESSMENT

# 5.1 COMPARISON OF THE POSITIVE AND NEGATIVE IMPACTS FOR EACH OPTION EVALUATED

#### **Option 1** – Do Nothing

Currently, CS-25 does not require 'Return to Seat' signs to be installed anywhere on the aeroplane, or the public address system (if fitted) to be intelligible in areas other than at all passenger seats, toilets, cabin crew seats and work stations. The requirements on this subject are considered inadequate because out-of-seat areas are likely to be more common in the future. With this option, the level of safety with regard to the installation of 'Return to Seat' signs depends heavily on industry practice. Additionally, there could be costs of injuries related to turbulence accidents that could be averted by the implementation of the proposed amendments.

#### **Option 2** – Rulemaking Action – Amend CS-25

Amending CS-25 to require 'Return to Seat' signs in areas where the occupants are not normally seated and to require the public address system (if fitted) to be intelligible in all areas in the cabin where passengers or cabin crew are permitted will increase the level of safety and standardise existing industry practice. This option would reduce the risk of injuries due to turbulence especially since out-of-seat areas are likely to be more common in the future.

There may be costs related to this option which might be offset by the reduction of costs of injuries related to turbulence accidents in the long term. However, this option would introduce differences with FAR 25/CAR 525.

# 5.2 A SUMMARY DESCRIBING WHO WOULD BE AFFECTED BY THESE IMPACTS AND ANALYSING ISSUES OF EQUITY AND FAIRNESS

Compared to Option 1, Option 2 will improve the level of safety associated with turbulence encounters for the cabin crew and passengers.

There will be cost burdens to EASA, manufacturers/converters, and operators related to Option 2. However, any costs might be offset by the cost savings from the simplified certification process and the reduction in costs of injuries related to turbulence accidents in the long term.

#### 5.3 FINAL ASSESSMENT AND RECOMMENDATION OF A PREFERRED OPTION

After due consideration the Agency believes that **Option 2 – Rulemaking Action to amend CS-25** is to be preferred.

Amending CS-25 to require 'Return to Seat' signs in areas where the occupants are not normally seated and to require the public address system (if fitted) to be intelligible in all areas in the cabin where passengers or cabin crew are permitted will increase the level of safety and standardise an existing industry practice. This option would reduce the risk of injuries due to turbulence especially since out-of-seat areas are likely to be more common in the future. Any costs that may be incurred might be offset by the reduction of costs in

#### EASA REGULATORY IMPACT ASSESSMENT 'RETURN TO SEAT' SIGN AND INTELLIGIBILITY OF PUBLIC ADDRESS SYSTEM IN AREAS WHERE THE OCCUPANTS ARE NOT NORMALLY SEATED

Issue 1 September 2009

injuries related to turbulence accidents in the long term. It is expected that FAA and Transport Canada may consider the more stringent proposed requirements for harmonisation with their standards.

Rulemaking as described under Option 2 is therefore considered to be justified.

## 6 **REFERENCES**

<sup>1</sup> RGW Cherry and Associates (2009) *Study on CS-25 Cabin Safety Requirements 4208/R/000454/KK Issue 4,* prepared for the European Aviation Safety Agency

<sup>2</sup> European Aviation Safety Agency, A380 Certification Review Item, *Use of the stairs between decks – Special Condition, Ref. D-6 Issue 3, Date 13/12/02* 

<sup>3</sup> Proceedings of the Very Large Transport Aeroplane Conference, Noordwijkerhout, The Netherlands, 13-16 October 1998.

<sup>4</sup> European Aviation Safety Agency, *Airbus A350 Certification Review Item – Special Conditions Ref. D-04, 21.08.2008 (Draft Issue)* 

# Attachment 6

## EASA REGULATORY IMPACT ASSESSMENT

## **EXTERNAL VIEWING MEANS**

## **O**CTOBER 2009

Issue 2

Issue 2 October 2009

# AMENDMENT RECORD

ISSUE NUMBER	DATE	Remarks
1	September 2009	Initial Issue
2	October 2009	Incorporation of Comments

# CONTENTS

Abbr	Abbreviations5		
1	Purp	oose and Intended Effect	.6
1.1	lssu	e which the NPA is intended to address	.6
1.2	Scal	e of the issue	.6
1.3	Brie	f statement of the objectives of the NPA	10
2	Opti	ons	11
2.1	The options identified11		11
2.2	The preferred option selected		13
3	Sectors Concerned1		14
4	Impa	acts1	15
41	Onti	on 1 – Do Nothing	16
	4.1.1	Safety	16
	4.1.2	Economic	16
	4.1.3	Environmental	16
	4.1.4	Social	16
	4.1.5	Other aviation requirements outside EASA scope	16
	4.1.6	Foreign comparable regulatory requirements	16
	4.1.7	Conclusions	16
4.2	Opti	on 2 - Amend CS-25 to reflect the current FAR 25.809	
	Requ	uirement regarding external viewing means	17
	4.2.1	Safety	17
	4.2.2	Economic	17
	4.2.3	Environmental	18
	4.2.4	Social	18
	4.2.5	Other aviation requirements outside EASA scope	18
	4.2.6	Foreign comparable regulatory requirements	18
	4.2.7	Conclusions	18
4.3	Opti	on 3 – Carry out further research into external viewing means at	
	eme	rgency exits	19
	4.3.1	Safety	19
	4.3.2	Economic	19
	4.3.3	Environmental	19
	4.3.4	Social	19
	4.3.5	Coner aviation requirements outside EASA scope	19
	4.3.0	Conclusions	19
5	Sum	mary and Final Assessment	20
-	0		
5.1	Com	iparison of the positive and negative impacts for each option	~
	evaluated		
5.2	A su	mmary describing who would be affected by these impacts and	
	anal	ysing issues of equity and fairness	20

### EASA REGULATORY IMPACT ASSESSMENT EXTERNAL VIEWING MEANS

	5.2.1	The aeroplane manufacturers	20
	5.2.2	The operators	20
	5.2.3	EASA	21
	5.2.4	Issues of equity and fairness	21
5.3	Fina	I assessment and recommendation of a preferred option	21
6	Refe	erences	22

#### EASA REGULATORY IMPACT ASSESSMENT EXTERNAL VIEWING MEANS

Issue 2 October 2009

## ABBREVIATIONS

- AMC Acceptable Means of Compliance
- ARFFS Aircraft Rescue and Fire Fighting Service
- ATSB Australian Transport Safety Bureau
- CCM Cabin Crew Member
- CS Certification Specification
- CSRTG Cabin Safety Research Technical Group
- EASA European Aviation Safety Agency
- EWIS Electrical Wiring Interconnection System
- FAA Federal Aviation Administration
- FAR Federal Aviation Regulations
- NPA Notice of Proposed Amendment
- NTSB National Transportation Safety Board (United States of America)
- RIA Regulatory Impact Assessment
- SCCM Senior Cabin Crew Member

# 1 PURPOSE AND INTENDED EFFECT

### 1.1 ISSUE WHICH THE NPA IS INTENDED TO ADDRESS

A study carried out for the EASA (Reference 1) involved a review of the current cabin safety threats and the degree to which they were addressed by CS-25 requirements. This study identified that issues related to "External Viewing Means" at Emergency Exits could be more effectively addressed by the requirements. Consideration has therefore been given to amending CS-25 in this respect. This Regulatory Impact Assessment (RIA) addresses the regulatory options available to the EASA to mitigate the threat and their potential impacts.

#### **1.2 SCALE OF THE ISSUE**

The EASA study (Reference 1) identified several accidents where the "External Viewing Means" was considered to be an issue regarding safe evacuation of occupants:

#### Toronto A340 July 2005

The Transportation Safety Board Canada (TSB) Accident Report (Reference 2) states:

"In this occurrence, the L3 cabin attendant did not use the viewing window to assess the exterior conditions because it was too small for her to clearly observe the conditions outside. She left the attendant station, went into the passenger seating area, looked out a cabin window, and saw the fire outside. She subsequently returned to the emergency exit, blocked it, and redirected passengers.

The only thing visible to the L1 cabin crew through the viewing window was light. When the emergency exit was opened, it was usable.

The R3 cabin attendant assessed the exterior conditions using the viewing window but did not see the fire below the exit or the wreckage in the slide deployment path. When the emergency exit door was opened, black smoke entered the cabin and the slide deflated when it contacted sharp pieces of wreckage.

The R1 cabin attendant assessed the exterior conditions using the viewing window, but did not see that there was a creek outside until the exit was opened. When the slide deployed, the foot of it was very near the water. The cabin crew blocked the exit and redirected passengers.

Although it was raining heavily, none of the cabin crew felt that their ability to visually assess the outside conditions was hampered by the rain." (ADB Ref. 20050802A)

The TSB accident investigation report discussed the issue of viewing windows, citing a 1992 NTSB investigation into an accident on an L-1011 aircraft. The NTSB identified the risk to passenger safety created by cabin crew when they leave their emergency exit and enter the passenger seating area to assess exterior conditions.

The TSB Accident Report (Reference 2) states:

"In a 1992 investigation, the NTSB identified the risk to passenger safety created by cabin crew when they leave their emergency exit and enter the passenger seating area to assess exterior conditions. On 30 July 1992, during daylight hours, a Lockheed L-1011 was destroyed by fire after the crew executed a take-off followed by an immediate emergency landing at JFK. The cabin attendant responsible for exit L2 was unable to clearly see the conditions outside through the viewing window, and left her exit and moved to a passenger window to see the conditions outside. After assessing the conditions through the passenger window, she found it impossible to return to her exit because passengers blocked the aisle leading to it. Another cabin attendant assumed her position at the exit and, when told by the L2 cabin attendant that it was clear outside, opened the exit door, allowing passengers to escape from the burning aircraft.

The NTSB examined a viewing window on another Lockheed L-1011 operated by the air carrier to determine why the cabin crew had been unable to clearly see the conditions outside through the viewing window. They found that several of the outside window panes were crazed or scratched to the extent that it was difficult to view the ground clearly. Some other window panes also had scratches or crazing that interfered with a clear view, especially when looking aft. Due to extensive fire damage, it could not be determined if the condition of the viewing windows on AFR358 contributed to the cabin attendant's difficulty in assessing the conditions outside the aircraft in this occurrence."

Another problem with the current design of viewing windows is that, due to their location, some hazards may not be visible from the viewing window position:

#### Sydney B747 July 2003

The Australian Transport Safety Bureau (ATSB) Accident Report (Reference 3) states:

"The over-wing slide deployment did not directly hamper the ARFFS crew from fighting the fire in the right body landing gear. However, the close proximity of the slide to the wheel well may have presented a problem in the event of a more substantial fire, or if the fire had spread.

The operator's evacuation procedures directed the cabin crew to look through the windows adjacent to their exit for signs of fire. If no fire was evident, they were to open the exit, deploy the slide and commence passenger evacuation.

However, it was not possible to see the landing gear area from the over-wing exits or the adjacent windows. Therefore, during brake fires an accurate assessment of the extent of fire could not be obtained by viewing through the number- three left and right doors or adjacent windows and the potential to evacuate passengers into a fire hazard area existed." (ADB Ref. 20030702B) Following the investigation of this accident, the following safety recommendations were made by the ATSB:

#### Safety Recommendation R20050003

The Australian Transport Safety Bureau recommends that Qantas Airways Ltd, review the adequacy of their procedures for the deployment of over-wing slides during known brake fire situations. This review should take into consideration the visual cues used and potential risk to passengers of evacuating within close proximity of a fire zone.

#### Safety Recommendation R20050004

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority, review the adequacy of operator procedures for the deployment of over-wing slides during known brake fire situations. This review should take into consideration the visual cues used and potential risk to passengers of evacuating within close proximity of a fire zone.

#### Stansted B737 February 2002

The inability to assess external hazards, by cabin crew, flight crew, or passengers, presents a danger to occupants during evacuation. Fire and rescue personnel might inform the flight crew regarding external hazards; however this is not always successful. This issue is illustrated by the following text contained within the AAIB Investigation report (Reference 4) into an occurrence at Stansted Airport, UK in February 2002:

"At approximately 1721:30 hrs, the commander ordered the passengers and crew to evacuate the aircraft. In accordance with Company Standard Operating Procedures, he left the decision as to which exits were to be used to the cabin crew. At that time 'Fire One' called the aircraft saying:

"[Operator] FROM FIRE ONE, CAN YOU MAKE SURE YOU EVACUATE PORT SIDE"

This was not acknowledged. The cabin crew opened the Type I exits at the front and rear of the cabin. The No 2 CCM found the forward right door (R1) difficult to open and sought the assistance of the SCCM after he had opened his door (L1). Likewise the No 3 CCM required help from a male positioning cabin crew member to open the rear right door (R2). Both the SCCM and the positioning crew member were each able to operate these doors unaided. Passengers opened the overwing exits. Four positioning cabin crew assisted the operating cabin crew during the evacuation. About 40 passengers evacuated onto the right side of the aircraft, including six onto the right wing. This placed them in the vicinity of the right engine and the area where the fire crews were directing their firefighting efforts. These six passengers were instructed by the fire crew to return inside the aircraft and seek an alternative exit. The passengers who evacuated on the left side used the doors. Members of the fire crew, cabin crew and airfield staff escorted the passengers away from the aircraft.

#### EASA REGULATORY IMPACT ASSESSMENT EXTERNAL VIEWING MEANS

The use of the over-wing slides during the evacuation, presented passengers with the potential hazard of being placed in close proximity to the fire source." (ADB Ref. 20020227B)

A similar problem was identified by the NTSB in a safety study of emergency evacuations of commercial airplanes (Reference 5) as follows:

#### Charlotte F100 November 1997

"The airplane landed normally, but then experienced a failure and separation of its right main landing gear. The first officer called the tower controller to report that the airplane had stopped on the runway and asked if there was any fire on the airplane. The tower responded, "No." Because of lack of fire, the captain ordered an evacuation through the R1 exit only. A flight attendant opened the door and inflated the slide. A passenger opened the overwing window exit at seat 12F prior to the evacuation notice but went forward after hearing the evacuation announcement. At the exit, the flight attendant was commanding, "Sit and slide." After 10–15 passengers evacuated, the first officer at the bottom of the slide noticed fire on the left main gear and ordered the right window exits to be used also. A passenger opened the overwing window exit at seat 11F. The flight attendants reported that many passengers attempted to take their belongings. There were no reported injuries. The only reported equipment problem was condensation that covered the viewer for assessing conditions outside the R1 door."

Although viewing windows are already installed on the exits on many aeroplanes in service, they are not required by CS-25. However, FAR 25.809 at amendment 25-116 requires an outside viewing means at emergency exits. This requirement is applicable to all type certificate applications made after November 26, 2004. The FAA did not require retrofit due to the technical difficulties and costs of modification.

The amended FAR Part 25 requirement (amendment 25-116) states:

Sec. 25.809 Emergency exit arrangement

(a) Each emergency exit, including each flightcrew emergency exit, must be a moveable door or hatch in the external walls of the fuselage, allowing an unobstructed opening to the outside. In addition, each emergency exit must have means to permit viewing of the conditions outside the exit when the exit is closed. The viewing means may be on or adjacent to the exit provided no obstructions exist between the exit and the viewing means. Means must also be provided to permit viewing of the likely areas of evacuee ground contact. The likely areas of evacuee ground contact must be viewable during all lighting conditions with the landing gear extended as well as in all conditions of landing gear collapse.

Unlike FAR Part 25, CS-25 does not require emergency exits to have outside viewing means. The current CS 25.809(a) reads:

(a) Each emergency exit, including a flight crew emergency exit, must be a movable door or hatch in the external walls of the fuselage, allowing unobstructed opening to the outside.

Several issues arise from both the in-service experience and the current regulations:

Passenger emergency exit viewing windows on current in-service aircraft have proven to be inadequate in certain accident scenarios. The evidence shows they may be susceptible to surface damage or condensation that reduces the ability of the cabin crew to see through them clearly. However, perhaps more importantly they may not provide a means for identifying all external threats to the escape path – in particular fires that are not located immediately outside of the exit and also in situations when there are inadequate external lighting levels (e.g. in darkness or conditions of smoke obscuration).

FAR 25.809 (a) is considered to be a good design objective. However, difficulties may arise in meeting the regulatory intent. The primary problem is in regards to finding a practical means of adequately illuminating the very large area onto which evacuee ground contact may occur (i.e. the various landing gear collapsed states result in revised fuselage attitudes which always move a fixed fuselage mounted spotlight beam in an adverse direction, i.e. away from the revised evacuee ground contact point).

#### **1.3 BRIEF STATEMENT OF THE OBJECTIVES OF THE NPA**

It is evident that a means of assessing the external conditions to determine whether an exit is safe to use is an important aspect in the safe evacuation of occupants. FAR 25.809 (a) requires that a viewing means is provided that permits viewing of the likely areas of ground contact during all lighting conditions. A similar requirement is not currently incorporated into CS-25 although many in-service aeroplanes are already equipped with viewing windows.

This Regulatory Impact Assessment considers options for amending CS-25 to add a requirement for external viewing means. Consideration is also given to:

- 1. Enhancing the levels of illumination required along the evacuee escape route to ensure that, for most of the accident scenarios likely to be encountered, the entire route is illuminated
- 2. Improving the acuity of the viewing means to ensure that the cabin or flight crew member is able to view the escape route without the need to move away from the emergency exit

## 2 OPTIONS

### 2.1 THE OPTIONS IDENTIFIED

Three regulatory options are considered in this Regulatory Impact Assessment:

#### Option 1 – Do Nothing

The "Do nothing" option means to make no changes to CS-25 to require external viewing means at emergency exits.

# Option 2 – Amend CS-25 to reflect the current FAR 25.809 requirement regarding external viewing means at emergency exits

This option means to amend CS-25.809(a) to harmonise with FAR 25.809(a).

Compliance might be established by the use of viewing windows of the type installed in emergency exits on many current in-service aircraft or by the use of optical viewing devices. The viewing means would need to be optimised to maximise the area of ground viewable.

For passenger emergency exits, external lighting would be required with an illumination area sufficient to accommodate the likely locations of evacuee ground contact for all potential undercarriage collapse scenarios. The lighting source would probably need to be mounted in the fuselage. Depending on the length of the evacuation slide, the illuminated area may be relatively distant from the viewing window located at the exit, so it is therefore envisaged that the light intensity would need to be high, particularly on large aeroplanes. The light intensity would also need to be sufficient to overcome any loss in viewing capability caused by reflections of the cabin interior in the viewing window or by any loss of light that may be inherent in optical viewing devices. The resulting lighting system would require powerful external lamps. There may be potential for utilising the external emergency lighting system (required by CS 25.812), but it is likely that significant additional power would be necessary. The increased area of coverage could be provided by additional lamps or lamps with wider beams. The additional electrical power required for the lighting system, with attendant larger batteries, may result in a questionable cost/benefit balance.

There may be potential compliance difficulties on some aeroplanes caused by the wing blocking the view from an over-wing exit to the ground contact area.

For flight crew emergency exits, which generally utilise cockpit windows or roof mounted hatches, and often include an assist means comprising a rope, the ground contact area may be readily visible via the cockpit side windows. However, particularly on very large aircraft, visibility of the precise ground contact area may be difficult to achieve. As with passenger emergency exits, lighting of the ground contact area would be necessary.

The proposed amendments to CS-25 are as follows:

#### CS 25. 809 Emergency exit arrangement

(a) Each emergency exit, including each flightcrew emergency exit, must be a moveable door or hatch in the external walls of the fuselage, allowing an unobstructed opening to the outside. In addition, each emergency exit must have means to permit viewing of the conditions outside the exit when the exit is closed. The viewing means may be on or adjacent to the exit provided no
#### EASA REGULATORY IMPACT ASSESSMENT EXTERNAL VIEWING MEANS

obstructions exist between the exit and the viewing means. Means must also be provided to permit viewing of the likely areas of evacuee ground contact. The likely areas of evacuee ground contact must be viewable during all lighting conditions with the landing gear extended as well as in all conditions of landing gear collapse.

In addition to the text for the new requirement shown above, advisory material should be issued to address:

- The required illumination levels provided by the lighting system, taking into account the size of the aeroplane and length of the evacuation slides (if fitted).
- The field of view, location and level of acuity of the viewing means necessary in order for the outside conditions to be adequately assessed.
- Environmental effects likely to degrade the viewing acuity (e.g. scratching, crazing, condensation and internal reflections).

#### **Option 3 – Carry out further research into external viewing means at emergency exits**

Current external viewing means installed on aircraft may not always provide the cabin crew with the information required regarding the threat that might be posed to the occupant escape route; however these means are relatively inexpensive. Advances in technology may provide the desired levels of safety but may be prohibitively expensive. This option proposes research into current available technologies that may provide enhanced external viewing means that could be shown to be cost beneficial. The research that is needed for passenger and flight crew emergency exits is as follows:

- 1. Consideration of what is likely to constitute an evacuee escape route for aircraft of varying sizes and exit configurations. This should include the potential obstructions to the required viewing area both with the aircraft landing gear extended as well as in all conditions of landing gear collapse.
- 2. Identification of the possible options for external viewing means. These may be viewing windows or optical devices; however consideration should also be given to cameras that have the ability to view obstructions and fire threats that might be along or close to the likely evacuee escape route.
- 3. Consideration of issues highlighted by accident experience including degradation of viewing acuity caused by condensation or the effects of ageing including scratches and crazing.
- 4. The required light intensity levels and type/installation of illumination device(s) required to view the likely evacuee escape route. This may be dependent on the viewing means with optical devices possibly requiring higher levels of illumination.
- 5. Consideration of the required location of the viewing and illumination means taking into account any installation difficulties that might be involved in achieving the regulatory intent required by Option 2.
- 6. An assessment of the likely costs and potential improvements to safety of viewing means considered to be practical solutions.

Issue 2 October 2009

# 2.2 THE PREFERRED OPTION SELECTED

After due consideration the Agency believes that **Option 3 – Carry out further research into external viewing means at emergency exits** is to be preferred.

# **3 SECTORS CONCERNED**

The proposed regulatory change is to CS-25 and hence the aircraft affected will be those for which the application for a type certificate is made after the regulatory change considered in this RIA. All newly designed CS-25 aircraft will need to comply. The primary cost of the regulatory change will be borne by the aeroplane manufacturers. These costs will result from increases associated with the design, testing and manufacture of the required external viewing means. Aircraft operators will also be affected since the design solutions are likely to result in weight increases and additional maintenance. There will be a marginal cost to the EASA in their oversight of the manufacturer in showing compliance with the regulatory change and costs may also be incurred by the Agency if further research is carried out.

# 4 IMPACTS

Each option is considered separately in relation to regulatory change against the following impacts:

- Safety
- Economic
- Environmental
- Social
- Other aviation requirements outside of EASA scope
- Foreign comparable regulatory requirements

Equity and fairness issues are also addressed for each of the regulatory options.

# 4.1 OPTION 1 – DO NOTHING

## 4.1.1 Safety

Whilst many aircraft are equipped with external viewing means they are not required by regulation. The Do Nothing option will therefore mean that future aircraft designs may not have adequate viewing means at emergency exits. Whilst no determination has yet been made of the effects that this might have on occupant survival, the issues identified by accident investigating authorities, discussed in Section 1.2 of this RIA, will not be addressed, with a consequential adverse effect on occupant survival.

## 4.1.2 Economic

The Do Nothing option will result in the manufacturers and aircraft operators not bearing the costs associated with Option 2 and EASA not bearing the costs that might be associated with Option 3.

## 4.1.3 Environmental

There are no environmental issues associated with the Do Nothing option.

## 4.1.4 Social

There are no social impacts associated with the Do Nothing option.

#### 4.1.5 Other aviation requirements outside EASA scope

There are no aviation requirements outside the EASA scope associated with this option.

#### 4.1.6 Foreign comparable regulatory requirements

FAR 25.809(a) requires external viewing means at emergency exits. Adoption of the Do Nothing option will result in a lack of harmonisation between the EASA and FAA with regard to 25.809(a). Consequently, in the event of an aeroplane being newly type certificated to CS-25 requirements but not to FAR Part 25 requirements, viewing means at emergency exits will not be required. Whilst this may adversely affect the level of safety, this will not adversely affect the competitiveness of European industry.

## 4.1.7 Conclusions

Based on the rationales contained in Sections 4.2 and 4.3 and summarised in Section 5.1 regarding the alternative options it is concluded that this is not the preferred option.

# 4.2 OPTION 2 - AMEND CS-25 TO REFLECT THE CURRENT FAR 25.809 REQUIREMENT REGARDING EXTERNAL VIEWING MEANS

## 4.2.1 Safety

This option would introduce a requirement that increases the level of safety beyond what is currently afforded by CS-25 and would also provide harmonisation with the FAA requirements. However, some of the safety deficiencies identified by accident investigating authorities may not be fully addressed.

Compliance with the requirement may be achieved by installing viewing means similar to those that are often found on current in-service aircraft; however their design would need to be optimised to maximise the area of view. Also, significant additional exterior lighting will be required to allow viewing in all lighting conditions and this will require additional battery power on the aircraft.

There may be potential compliance difficulties on some aeroplanes, caused by the wing blocking the view from an over-wing exit to the ground contact area. Restricted view of the ground at cockpit emergency exits may also present compliance difficulties.

## 4.2.2 Economic

It is expected that to comply with Option 2, aeroplanes will need to be equipped with new and additional parts. This will add the following costs:-

#### (a) Manufacturers

Compliance with this requirement may not be straightforward and it is expected that significant research and development will be necessary to maximise performance whilst minimising economic impacts. These costs are expected to be high but may progressively reduce as more aeroplane types are certificated, since knowledge will be read across to new aeroplane designs. These development costs will be borne by the aeroplane manufacturers.

Parts will be required to be designed and tested. This is likely to be carried out by specialist suppliers and airframe manufacturers. The engineering cost of some parts may be amortised across more than one aeroplane type (e.g. high powered fuselage lamps with a suitable light beam). These costs will be borne by the aeroplane manufacturers and are expected to be minimal once amortised across many aeroplanes.

Material cost per aeroplane is expected to be minimal.

#### (b) Operators

Operators will incur marginal costs associated with increased maintenance due to additional parts.

The additional parts, including lamps, higher capacity batteries, EWIS and improvements to viewing windows or the addition of optical devices will increase aeroplane weight and thus there will be a fuel-weight penalty over existing designs. The additional weight will be roughly proportional to the number of emergency exits on an aeroplane, although it may be possible for lighting to be shared between a pair of adjacent over-wing exits. The exact weight increase is unknown at this stage, but it may be in the region of 1 to 2 kg per exit. It would appear that due to the additional electrical power required for the lighting system, with attendant larger batteries, there may be a questionable cost/benefit balance. Additional fuel costs due to aeroplane weight increase will be borne by the operators.

#### (c) EASA

There will be marginal costs incurred by EASA in their oversight of the manufacturer in showing compliance with the regulatory change.

## 4.2.3 Environmental

It is expected that to comply with Option 2, aeroplanes will need to be equipped with additional parts. Carbon dioxide emissions to the atmosphere will consequently increase, resulting from parts manufacture and increased fuel burn associated with increased aeroplane weight.

No other environmental impacts have been identified.

## 4.2.4 Social

There are no social impacts associated with this option.

## 4.2.5 Other aviation requirements outside EASA scope

There are no aviation requirements outside EASA scope associated with this option.

#### 4.2.6 Foreign comparable regulatory requirements

FAR 25.809(a) requires external viewing means at emergency exits. Adoption of this option will result in harmonisation of the regulatory text between the EASA and FAA with regard to 25.809 (a). This would not adversely affect the competitiveness of European industry.

#### 4.2.7 Conclusions

Based on the rationales contained in Sections 4.1 and 4.3 and summarised in Section 5.1 regarding the alternative options it is concluded that this is not the preferred option.

# 4.3 OPTION 3 – CARRY OUT FURTHER RESEARCH INTO EXTERNAL VIEWING MEANS AT EMERGENCY EXITS

## 4.3.1 Safety

The adoption of Option 3 will delay harmonisation between the EASA and FAA with regard to 25.809(a). This would adversely affect the level of safety if a new aeroplane design were to be certificated to CS-25 requirements and not to FAR Part 25 requirements.

#### 4.3.2 Economic

It is unlikely that any research will be undertaken by organisations other than the world's primary Airworthiness Authorities – EASA, FAA and Transport Canada. Hence there will be an economic burden on these Authorities should this Option be adopted.

#### 4.3.3 Environmental

This is not applicable to this research activity.

#### 4.3.4 Social

There are no social issues associated with the research other than those that might relate to any testing that might be carried out (e.g. evacuation testing). It is expected that these will be accommodated by the procedures that will be put in place by the test facilities.

#### 4.3.5 Other aviation requirements outside EASA scope

This is not applicable to this research activity.

#### 4.3.6 Foreign comparable regulatory requirements

FAR 25.809(a) requires external viewing means at emergency exits. Adoption of this option will delay harmonisation between the EASA and FAA with regard to 25.809(a). Consequently, in the event of an aeroplane being newly type certificated to CS-25 requirements but not to FAR Part 25 requirements, viewing means at emergency exits will not be required. Whilst this may adversely affect the level of safety, this will not adversely affect the competitiveness of European industry.

#### 4.3.7 Conclusions

Based on the rationales contained in Sections 4.1 and 4.2 and summarised in Section 5.1 regarding the alternative options it is concluded that Option 3 is the preferred option.

# 5 SUMMARY AND FINAL ASSESSMENT

# 5.1 COMPARISON OF THE POSITIVE AND NEGATIVE IMPACTS FOR EACH OPTION EVALUATED

Option 1 does not achieve the desired safety intent and would result in a lack of harmonisation with the FAA. Option 2 would introduce a new requirement and improve on the safety standard afforded by CS-25. However some of the safety deficiencies relating to external viewing means at emergency exits identified by accident investigating authorities may not be fully addressed. Compliance with this requirement may not be straightforward and it is expected that significant research and development will be necessary to maximise performance whilst minimising economic impacts. On this basis it is considered that further research is required, as defined for Option 3 in Section 2.1, prior to regulatory action being taken by the EASA.

# 5.2 A SUMMARY DESCRIBING WHO WOULD BE AFFECTED BY THESE IMPACTS AND ANALYSING ISSUES OF EQUITY AND FAIRNESS

#### 5.2.1 The aeroplane manufacturers

#### **Option 1 - Do Nothing**

This option will have no impact on the aeroplane manufacturers.

# Option 2 - Amend CS-25 to reflect the current FAR 25.809 requirement regarding External Viewing means

This option will result in an economic impact on aeroplane manufacturers, due mainly to increased engineering costs resulting from the research, design, development and installation of the required external viewing means. The costs incurred will be restricted to future type certificated aircraft.

# Option 3 – Carry out further research into external viewing means at emergency exits

This option will have no impact on the aeroplane manufacturers.

#### 5.2.2 The operators

#### Option 1 Do Nothing

This option will have no impact on the aircraft operator

# Option 2 - Amend CS-25 to reflect the current FAR 25.809 requirement regarding External Viewing means

This option will result in an economic impact on aircraft operators due to the additional fuel burn associated with the weight of any external viewing means that might not have otherwise been installed on the aircraft. Operators will also incur marginal costs associated with increased maintenance due to additional parts.

## **Option 3 – Carry out further research into external viewing means at emergency exits**

This option will have no impact on the aircraft operator

## 5.2.3 EASA

## **Option 1 - Do Nothing**

This option will have no impact on the EASA.

# Option 2 - Amend CS-25 to reflect the current FAR 25.809 requirement regarding External Viewing means

This option will result in a small economic impact on the EASA due to the rulemaking activity required and the subsequent oversight of the industry to ensure compliance with the proposed regulatory change.

#### **Option 3 – Carry out further research into external viewing means at emergency exits**

This option could have an economic impact on the EASA in contributing to the funding required for research. However, the level of commitment from EASA may be reduced by combining the research with any that may be undertaken by the FAA and Transport Canada.

#### 5.2.4 Issues of equity and fairness

There are no issues of equity and fairness associated with any of the regulatory options considered in this Regulatory Impact Assessment.

#### **5.3 FINAL ASSESSMENT AND RECOMMENDATION OF A PREFERRED OPTION**

Based on the assessments made in this Regulatory Impact Assessment the preferred option is **Option 3 - Carry out further research into external viewing means at emergency exits.** 

# 6 **REFERENCES**

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- 3. Australian Transport Safety Bureau, Boeing 747-738, VH-OJU, Sydney Aerodrome, NSW, 2 July 2003
- 4. Air Accidents Investigation Branch, Boeing 737-8AS EI-CSA Incident, London Stansted Airport, Essex, 27 February 2002, AAIB Bulletin No. 7/2004 Ref. EW/C2002/02/07
- 5. National Transportation Safety Board (2001) Safety Study Emergency Evacuation of Commercial Airplanes, NTSB/SS-00/01. Washington D.C.: NTSB

# Attachment 7

# EASA REGULATORY IMPACT ASSESSMENT

## PASSENGER EMERGENCY EXIT LOCATOR SIGN

## SEPTEMBER 2009

Issue 1

Issue 1 September 2009

# AMENDMENT RECORD

ISSUE NUMBER	DATE	Remarks
1	September 2009	Initial Issue

# CONTENTS

Abbre	viations	4
1	Purpose and Intended Effect	5
1.1 1.2 1.3	Issue which the NPA is intended to address Scale of the issue Brief statement of the objectives of the NPA	5 5 6
2	Options	6
2.1 2.2	The options identified The preferred option selected	6 7
3	Sectors Concerned	7
4	Impacts	7
4.1	All identified impacts         4.1.1       Safety         4.1.2       Economic         4.1.3       Environmental	7 7 7 7
4.2	<ul> <li>4.1.4 Social</li> <li>4.1.5 Other Aviation Requirements outside EASA scope</li> <li>4.1.6 Foreign comparable regulatory requirements</li> <li>Equity and fairness issues identified</li> </ul>	7 7 8 8
5	Summary and Final Assessment	8
5.1	Comparison of the positive and negative impacts for each option evaluated	
5.2	A summary describing who would be affected by these impacts and analysing issues of equity and fairness	
5.3	Final assessment and recommendation of a preferred option	8
6	References	9

#### EASA REGULATORY IMPACT ASSESSMENT PASSENGER EMERGENCY EXIT LOCATOR SIGN

Issue 1 September 2009

# **ABBREVIATIONS**

- CRI Certification Review Item
- CS Certification Specifications (EASA)
- EASA European Aviation Safety Agency
- ELOS Equivalent Level of Safety (FAA)
- ESF Equivalent Safety Findings (EASA)
- FAA Federal Aviation Administration (USA)
- FAR Federal Aviation Regulations (FAA)
- NPA Notice of Proposed Amendment
- RIA Regulatory Impact Assessment
- SFAR Special Federal Aviation Regulations (FAA)

# 1 PURPOSE AND INTENDED EFFECT

## 1.1 ISSUE WHICH THE NPA IS INTENDED TO ADDRESS

CS 25.811(d)(1) requires there to be a passenger emergency exit locator sign above the aisle near each passenger emergency exit, or at another overhead location if there is insufficient headroom.

In some smaller aircraft, no overhead location is practical for the emergency exit locator sign and they have not been able to comply with CS 25.811(d)(1). It has therefore been necessary for some aircraft to be certificated using Certification Review Item/CRI (Equivalent Safety Findings/ESF, or ELOS in the case of FAA certification), which allowed the installation of combined emergency exit marking and locator signs. It should be noted that the requirements for passenger emergency exit locator signs have not presented any significant compliance issues for larger transport aeroplanes for commercial use.

This NPA addresses the difficulty on smaller transport aeroplanes in complying with CS 25.811(d)(1) due to their low headroom, regardless of their type of operation.

#### 1.2 SCALE OF THE ISSUE

The difficulty in compliance with the requirement CS 25.811(d)(1) on the smaller transport aeroplanes was identified during the review of certification documents carried out in a study for EASA<sup>1</sup>. An accident review carried out in the same study shows that there have been no threats specifically related to the emergency exit locator or marking signs not being visible or legible. The issues discussed here are therefore related only to certification/compliance issues.

EASA has issued, amongst others, a CRI (No. 190/D-29) for the ERJ-190-100ECJ (max. 19 passengers) allowing the passenger emergency exit locator sign to be combined with the exit marking sign. For this category of aeroplanes, the issue was the difficulty in installing an overhead emergency exit locator sign because it would present a head strike hazard due to the low headroom of the cabin.

A review of FAA ELOS and Exemptions for smaller transport category aeroplanes<sup>2</sup> (up to a maximum certificated passenger capacity of 60) in the period January 1994 to February 2006, found that the request for a combined emergency exit marking and locator sign was the third most frequent subject of application. These applications (ST5542NY-T-S-1, SP5109SE-T-C-1, ST3302WI-T-A-1, AT5177AT-T-C-1, ANM-113-04-01, TC2548WI-T-AG-4) were made for 9 different aircraft models consisting of Bombardier BD-100-1A10 (max. 16 passengers), Cessna Model 680 (max. 13 passengers), Dassault Falcon Models 50, 900, 900EX and 2000 (max. 19 passengers), Gulfstream Model GV-SP and GIV-X (max. 19 passengers), and a Bombardier CL600-2B16 (max. 19 passengers).

The FAA issued a Final Rule in SFAR No. 109 'Special Requirements for Private Use Transport Category Airplanes' on 8 May 2009. Paragraph 8 of the SFAR permits the use of a single exit sign to meet the requirements of 25.811(d)(1) and (2) as follows:

8. Emergency Exit Signs. In lieu of the requirements of Sec. 25.811(d)(1) and (2) a single sign at each exit may be installed provided:

- (a) The sign can be read from the aisle while directly facing the exit, and
- (b) The sign can be read from the aisle adjacent to the passenger seat that is farthest from the exit and that does not have an intervening bulkhead/divider or exit.

The text of the above requirements was used as the basis of the proposed amendment to CS-25 on this subject.

## **1.3 BRIEF STATEMENT OF THE OBJECTIVES OF THE NPA**

The purpose of the NPA is to amend CS 25.811(d)(1) to include a requirement that caters for small transport category aeroplanes that do not have a practical overhead location for the passenger emergency exit locator sign. An alternative means utilising the exit marking sign required by CS 25. 811(d)(2) has been certificated via ESF by EASA (ELOS by the FAA). There is no evidence that such installations could pose a safety risk to the occupants. Incorporation of this amendment into CS-25 will reduce certification costs for manufacturers and EASA.

# 2 OPTIONS

#### 2.1 THE OPTIONS IDENTIFIED

Two regulatory options for Agency action are considered in this Regulatory Impact Assessment:

#### Option 1 – Do Nothing

The "Do Nothing" option means no amendments to CS-25 in relation to the passenger emergency exit locator signs will be made. Installation of exit locator signs on small transport category aircraft with low headroom will continue to be addressed by means of ESF.

#### **Option 2 – Rulemaking Action**

This option means amendment of CS-25 to allow using the exit marking sign as the exit locator sign if there is no practical overhead location for the exit locator sign due to low headroom, provided that the compensating factors are achieved. This amendment would incorporate the provisions that have been implemented using ESF.

The proposed amendment would be accomplished by replacing the existing CS 25.811(d)(1) with the following text:

- (d) The location of each passenger emergency exit must be indicated by a sign visible to occupants approaching along the main passenger aisle (or aisles). There must be
  - (1) A passenger emergency exit locator sign above the aisle (or aisles) near each passenger emergency exit, or at another overhead location if it is more practical because of low headroom; except -
    - (i) that one sign may serve more than one exit if each exit can be seen readily from the sign; and
    - (ii) a sign may be omitted if no overhead location is practical; provided that the emergency exit marking sign can be read from the aisle while directly facing the exit, and can be read from the aisle adjacent to the passenger seats that are farthest from the exit in each direction except where there is an intervening bulkhead/divider or exit.

Issue 1 September 2009

## 2.2 THE PREFERRED OPTION SELECTED

See Section 5.3.

# 3 SECTORS CONCERNED

The proposed regulatory change is to CS-25 and hence the aircraft affected will be those for which the application for a type certificate is made after the regulatory change considered in this RIA. Only newly designed CS-25 aeroplanes will be affected and it is envisaged that only smaller aeroplanes will benefit from the regulatory change. There will be no additional cost borne by aircraft manufacturers, aircraft converters or aircraft operators for compliance with the proposed regulatory change. There will be a marginal cost to EASA for the rulemaking activities. There is a potential benefit in terms of time and cost saving for aircraft manufacturers and EASA from a simplified cabin certification process.

# 4 IMPACTS

#### 4.1 ALL IDENTIFIED IMPACTS

#### 4.1.1 Safety

In terms of safety impacts, aircraft crew and passengers will not be affected by Option 1 or Option 2 since there is no change in the level of safety currently provided by the requirements stipulated in the ESF.

#### 4.1.2 Economic

#### **Option 1** – Do Nothing

The certification of combined emergency exit marking and locator sign will continue to be addressed by ESF, which incurs additional costs and time.

#### **Option 2** – Rulemaking Action

This option would result in a marginal cost to EASA for the rulemaking activities, which may be offset by the cost savings associated with a simplified certification process. The simplified certification process will also benefit the manufacturers of aeroplanes with low headroom due to the reduced time and costs.

#### 4.1.3 Environmental

No environmental impacts have been identified.

#### 4.1.4 Social

No social impacts have been identified.

#### 4.1.5 Other Aviation Requirements outside EASA scope

There would be no impact on other aviation requirements outside EASA scope.

Issue 1 September 2009

#### 4.1.6 Foreign comparable regulatory requirements

ICAO Annex 8 was reviewed and no text was found in conflict with the content or overall objectives of this NPA.

As discussed in Section 1.2, the FAA has issued SFAR No. 109 which allows the installation of a combined emergency exit marking and locator sign in aeroplanes with VIP configurations (for private use). There are no other rulemaking activities being carried out by FAA or Transport Canada that are pertinent to this subject. The introduction of new rules in CS-25 will result in differences with FAR 25/CAR 525.

#### 4.2 EQUITY AND FAIRNESS ISSUES IDENTIFIED

There are no issues of equity and fairness associated with any of the options considered in this Regulatory Impact Assessment.

# 5 SUMMARY AND FINAL ASSESSMENT

# 5.1 COMPARISON OF THE POSITIVE AND NEGATIVE IMPACTS FOR EACH OPTION EVALUATED

#### **Option 1** – Do nothing

Certification of the combined emergency exit locator and marking signs will continue to use ESF, which incurs increased costs and time to EASA and manufacturers/converters.

#### **Option 2** – Rulemaking Action

There are benefits in amending CS-25 to allow the use of emergency exit marking signs as emergency exit locators when the installation of emergency exit locator signs on any overhead location is impractical, provided that the compensating factors are achieved. Amendment of CS-25 would remove the additional certification costs incurred by manufacturers and EASA as a result of the necessity for certification using ESF, without reducing the level of safety.

This option would introduce differences with FAR 25/CAR 525.

# 5.2 A SUMMARY DESCRIBING WHO WOULD BE AFFECTED BY THESE IMPACTS AND ANALYSING ISSUES OF EQUITY AND FAIRNESS

In terms of safety impact, aircraft crew and passengers will not be affected by either option since there is no change in the level of safety currently provided by the requirements stipulated in the ESF (or ELOS).

In terms of economic impacts, EASA, manufacturers/converters, and ultimately operators would benefit from the reduction of time and costs associated with the certification process if Option 2 – Rulemaking Action is selected.

#### **5.3 FINAL ASSESSMENT AND RECOMMENDATION OF A PREFERRED OPTION**

After due consideration the Agency believes that **Option 2 - Rulemaking Action** is to be preferred.

There are benefits in amending CS-25 to allow the use of emergency exit marking signs as emergency exit locators when the installation of emergency exit locator signs on any overhead location is impractical, provided that the compensating factors are achieved. Amendment of CS-25 would remove the additional certification costs incurred by manufacturers and EASA as a result of the necessity for certification using ESF, without reducing the level of safety.

Rulemaking as described under Option 2 above is therefore considered to be justified.

# 6 **REFERENCES**

 <sup>1</sup> RGW Cherry & Associates (2009) Study on CS-25 Cabin Safety Requirements, Report No. 4208/R/000454/KK Issue 4, prepared for the European Aviation Safety Agency
 <sup>2</sup> RGW Cherry & Associates Limited (2006) An Evaluation of Equivalent Levels of Safety Findings and Exemptions Relating to Cabin Safety Regulations for Smaller Transport Aeroplanes, Prepared for Transport Canada, 0945/R/000343/KK Issue 1