

## Issues in Stairway Design Aboard Transport Category Airplanes

## RATIONALE

This document addresses issues of onboard stairway safety.

## 1. SCOPE

- 1.1 This document 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.
- 1.2 This document addresses only design issues related to interior stairways meant for use by passengers and not stairways meant to be used exclusively by crewmembers or maintenance workers.

## 2. REFERENCES

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of the other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

### 2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

- ARP503 Emergency Evacuation Illumination
- AIR512 Airplane Cabin Illumination
- ARP836 Design and Safety Criteria for Passenger Boarding Stairways.

### 2.2 Other Publications

- 2.2.1 VLTA Conference, The Netherlands, 12 August 2004. A Summary. Available at <http://www.faa.gov/ats/asc/nlaweb/links.htm>
- 2.2.2 Crashed on a partially closed runway during takeoff. Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, CKS Airport, Taoyuan, Taiwan, October 31, 2000. ASC-AAR-02-04-001.
- 2.2.3 Templer, J. Archea, J. & Cohen, H. (1985). Study of factors associated with risk of work-related stairway falls. *Journal of Safety Research*, 6, 183-196.

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- 2.2.4 Archea, J. Collins, B. & Stahl F. (1979). Guidelines for stair safety. NBS Building Science Series 120. WA: National Bureau of Standards, (now National Institute of Science and Technology). WA: U.S. Department of Commerce.
- 2.2.5 Coconut Grove Fire. (1942, Dec. 7) Newsweek.
- 2.2.6 Templer, J. (1992). The staircase: studies of hazards, falls and safer design. Cambridge, MA: MIT Press.
- 2.2.7 Life Safety Code Handbook. (2003). Quincy, MA: National Fire Protection Association.
- 2.2.8 Joint Aviation Authorities, JAA Research Paper 2003/x. Very Large Transport Airplane (VLTA) Emergency Requirements. Research Evacuation Study (VERRES) - A Project Summary. [http://fseg.gre.ac.uk/fire/verres\\_WP4%20.pdf](http://fseg.gre.ac.uk/fire/verres_WP4%20.pdf)
- 2.2.9 NIST NCSTAR 1 (Draft). (2005). Federal building and fire safety investigation of the world trade center disaster. Final report of the national construction safety team on the collapses of the world trade center towers (draft). Chapter 7. WA: National Institute of Standards and Technology, U.S. Department of Commerce.
- 2.2.10 ICC/ANSI A117.1-2003. (2004). Accessible and usable buildings and facilities. International Code Council. IL: Country Club Hills.
- 2.2.11 Human Factors Design Standard (HFDS) (2003). DOT/FAA/CT-03/05. U.S. Department of Transportation, Federal Aviation Administration Technical Center, Atlantic City International Airport, NJ 08405.
- 2.2.12 International Building Code. Country Club Hills, IL: International Code Council.
- 2.2.13 Pauls, J. L., Fruin, J. J., and Zupan, J. M. (2005). Minimum stair width for evacuation, overtaking movement and counterflow. The 3rd International Conference on Pedestrian and Evacuation Dynamics. <http://www.ped2005.com>
- 2.2.14 Maki, B. E., Bartlett, S. A., & Fernie, G. R. (1984). Influence of stairway handrail height on the ability to generate stabilizing forces and moments. Human Factors, 26(6), 705-714.
- 2.2.15 ASTM F 1166. Standard Practice for Human Engineering Design for Marine Systems, Equipment, and Facilities. West Conshohocken, PA: ASTM International.

### 3. CONSIDERATIONS AND RECOMMENDATIONS

#### 3.1 Multi-Deck Airplanes

For purposes of this document multi-deck airplanes are those having one passenger deck located above another with a stairway intended for passenger use connecting the two.

#### 3.2 More Stair Use on Multi-Deck Airplanes

Stairs are commonly used by many passengers during normal boarding and debarking. They have also been used during emergency evacuations (Ref. 2.2.2). Because they can be expected to be used on future multi-deck airplanes, stairway design will be of greater importance in the future aviation field than in the past.

#### 3.3 Falls, Injuries Are Common On Stairways

Stairs present one of the most serious safety hazards encountered in the everyday environment (Ref. 2.2.3). In the U.S. an estimated one million serious injuries and approximately 4000 deaths occur annually to stair users (Ref. 2.2.4). While nearly 10 times that number die in vehicular accidents, people spend comparatively much more time in vehicles than on stairways. Stairways, then, are more dangerous than automobiles when exposure is considered.

### 3.4 Stairways in Flight May Be More Hazardous

Changes in airplane orientation and movement in flight, including turbulence-related changes in attitude, will make stair use challenging. More missteps may occur on multi-deck airplanes than on stationary stairways.

### 3.5 Stairs Cause Congestion

A stairway can produce a bottleneck during emergency evacuations because the horizontal velocity of stair users is less than that of passengers on level surfaces. This can result in pushing and falls as people attempt to escape. A person who falls will then slow crowd flow even more. If this happens passengers attempting to reach an exit may exhibit panic, for example, by climbing over and seriously injuring others who have fallen (Ref. 2.2.5).

### 3.6 Stair Design Affects User Safety

Certain characteristics of a stairway affect whether a person will have a misstep, a precursor to a fall. Stairs that are difficult to see, are too steep, have excessive variability in step geometry, are inadequately illuminated or have handrails that are difficult to grasp increase the chance that an individual will fall (Ref.s 2.2.1 & 2.2.6).

### 3.7 Stair Design Affects Stair Usage in Evacuations

Other stairway characteristics can affect the speed and efficiency with which groups of passengers can evacuate. These include the width of the stairway in relation to the width of the aisles feeding it, the capacity of the discharge area, and whether there are openings in intermediate handrails that allow people to cross from one side to the other in order to pass slower-moving passengers (Ref. 2.2.7, Sections 7.3.3 and 12.2.5.6.7).

### 3.8 New Research And Standards Are Needed - According to Ref. 2.2.8:

"New research to evaluate the safety of the stairs to be used by large numbers of passengers will be important in order to minimize the risk of injuries. This may lead to regulatory specification of minimum dimensions and requirements for handrails etc. It must also be considered if the staircases should be treated as an exit in the respect 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, with some initial trials under the VERRES program ...

"In relation to the stair design, it was felt that the most important factor during design is that all passengers can use the stairs safely and quickly. It was felt that although passengers may be required to go to the upper deck via the stairs in an emergency, going down stairs in an emergency had more risks associated with it and is where research at this stage should be focused.

"The physical dimensions of the stairs will need to be fully researched. Issues that will need to be reviewed include the capacity for descent, the staircase width, the angle or steepness of the stairs, the stair tread width, the number of stairs, the number of lanes and the inclusion or not of handrails. Once the optimum staircase design has been researched, it will also be important to assess the number of sets of stairs and their location on the airplane i.e. fore, central or aft, for optimal evacuation egress."

### 3.9 Stairs Used In Building Evacuations

Stair use in large-scale building evacuations (Ref. 2.2.9) has shown that evacuees may move considerably slower than anticipated. In the evacuation of the World Trade Center Building Number 1 the downward travel rate was just over one floor per minute, slower than the slowest speed measured in non-emergency evacuations. The mobility-impaired occupants did not evacuate as evenly as the general population. Those mobility-impaired occupants who were ambulatory generally walked down the stairs with one hand on each handrail, taking one step at a time, and another occupant typically accompanied them. These two people blocked others behind them from moving more rapidly. This has implications for handrail design in multi-deck airplanes; specifically, there may be a need for those behind to be able to safely bypass slower evacuees. Thus, if a person is moving too slowly, or falls and blocks the exit route, those behind should be able to easily cross through openings in intermediate handrails to a path that is flowing at a higher rate.

### 3.10 Emergency Illumination

Compared to the minimum lighting considered adequate in public buildings, the amount recommended or allowed onboard commercial airplanes is many times lower. (See Appendix.) The minimum lighting considered adequate in public buildings for level floors is 1 ft-c (10.8 lux), and for stairways, 10 ft-c (108 lux). Measurements are to be taken at floor level (Ref. 2.2.7). The ANSI building standard (Ref. 2.2.10) states that, on stairs, luminaires shall be capable of providing 10 ft-c (108 lux) of illuminance, as measured at the center of tread surfaces and on landing surfaces within 24 inches (610 mm) of step nosings.

The FAA's Human Factors Design Standard requires those same levels for emergency situations, and twice those lighting levels for normal working environments (Ref. 2.2.11, Sec. 12.2.1.8 Illumination).

3.10.1 ARP503 allows an *average* level of 0.05 ft-c (0.54 lux), for both floors and stairways inside of an airplane when measured at armrest height. If measured at floor level there may be even less available light. Further, the minimum illumination at any spot along the path can be less than half of these already-low levels. Thus, ARP503 allows 20 times less light than that recommended for level floors in public buildings, and 200 times less light than that recommended for stairways. The recommended lighting level on external boarding stairs, as provided in ARP836, is 5 ft-c (53 lux) and even this may not be adequate for interior stairways on multi-deck airplanes during normal conditions.

### 3.11 Stairway Design

ARP836 allows boarding stairs to have riser heights (the height of one step above another) of up to 8.0 inches (203 mm) and depth of the tread (distance of the tread in the direction of travel, also known as the "run" or "going") as short as 9.5 inches (241 mm). Research has shown that risers greater than 7 inches (178 mm), or runs shorter than 11 inches (280 mm), increase the incidence of missteps and are less efficient (Ref.s 2.2.3 & 2.2.6). Common standards and codes for new public buildings in the United States require stairs to conform to these dimensions: risers shall have a height of 4 – 7 inches (102 – 178 mm) and runs shall be no less than 11 inches (280 mm) (Ref. 2.2.7, Sec. 7.2.2.1; Ref. 2.2.12, Sec 1009.3). The same stairway dimensions are recommended for use in the marine environment (Ref. 2.2.15, Fig. 81). Efforts should be made to conform to these minimums aboard multi-deck airplanes.

### 3.12 Straight and Curved Stairs

Both straight and curved stairways are appropriate in either normal or emergency conditions so long as they meet certain design specifications. A spiral stairway poses little problem if designed appropriately. But a winder, which is a tapered tread used to change the direction in which a straight stair runs, introduces variation in stair geometry, and variation increases the probability of missteps and falls. According to Ref. 2.2.12, winders are to be avoided.

### 3.13 Landings

Depending upon stairway length, an intermediate landing can reduce the incidence of severe injuries after a misstep, since the landing limits the distance a person would tumble down the stairs.

### 3.14 Emphasized Stair Nosings

Surface coverings can increase stair safety by making it easier for users to visually detect the nosings. Difficult-to-detect nosings are more likely to result in a misstep and fall. Some carpet designs, such as those having lines running parallel to the nosings, and some textured designs, camouflage the nosings. Nosings should be emphasized, especially under low illumination levels.

### 3.15 Stairway Width

When two people walk on the same treads simultaneously, either going in the same or opposite directions, they need adequate width to keep from bumping into each other. If the width is too narrow difficulties will occur in normal stair use as well as in emergency evacuations (Ref. 2.2.13).