

Improvement of Cabin Equipment to Enhance Cabin Safety against Turbulence

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Research Committee on Aircraft Safety Enhancement

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1. Background

In recent years, aircraft cabin safety against turbulence has much improved by introducing effective safety measures such as flight attendant procedures when seat belt signs are turned on and encouraging passengers to keep seat belts fastened at all times while seated. However, injuries to flight attendants and/or unseated passengers often occur when unexpected turbulence such as Clear Air Turbulence is encountered.

In order to find solutions to those cases, a research committee was formed to study current legal requirements for installation of handholds in the cabin, turbulent-related accidents/incidents and existing handholds, then discuss enhancing the effectiveness of the handholds and distributing the handholds effectively. The committee is commissioned by Civil Aviation Bureau of Japan and consists of specialists from National Aerospace Laboratory of Japan, Aircraft and Railway Accidents Investigation Commission, and airlines.

2. Legal requirements for handholds in the cabin

FAR 25.785(j) states the requirements for equipment in the cabin to cope with turbulence as cited below.

“ 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. “

FAA requires the cabin equipment only for moderate turbulence. For severe turbulence, it is assumed that the passengers and flight attendants are requested to take seats and fasten seat belts or harnesses. Therefore, the equipment required in the provision above is interpreted as the equipment to be used by passengers and flight attendants to return to their seats before the onset of severe turbulence.

There is a guideline in FAA Advisory Circular 25-17 “Transport Airplane Cabin Interiors Crashworthiness Handbook” to judge whether the equipment is acceptable or not under FAR 25.785(j) as cited below.

“ The Seat back may serve as a firm hand hold. Since most seats are capable of breaking over, the breakover load must be adequate to be considered firm. A load of 25 pounds minimum, acting horizontally, is considered adequate when applied at the top center of the seat back. “

3. Existing handholds

Photos of existing typical handholds in the cabins of currently used aircraft were taken to show the current status of handhold installations.

3-1 First class cabin

Since first class seats are distributed with a large pitch and the seat backs can be declined to almost flat position, it is considered that the seat backs of first class seats do not conform to the requirements of FAR 25.785(j). To solve the problem, ANA installs Supplemental Hand Hold Stand beside the seats as shown in Figure 1 and JAL installs partitions around the seats as shown in Figure 2.



Figure 1 ANA seats with handholds



Figure 2 JAL seats with partitions

3-2 Handrails/handgrips under the overhead stowage

Handrails/handgrips are installed under the overhead stowage in the cabins of MD90s, A300-600s and A320/321s. The handrails of MD90s are installed throughout the cabin without any gap at 160cm height above the floor that is almost as high as eye levels of flight attendants and designed to be easily recognized and gripped as shown in Figure 3. MD90 handrails are well recognized and used by flight attendants. Handgrips of A300-600s and A320/321s are installed at 169cm height that is a little too high for average Japanese female flight attendants and not so recognizable.



Figure 3 Handrails under the overhead stowage on MD90

3-3 Galleys

Relatively many handholds are installed in the galleys. Horizontal bars are installed at the counters as shown in Figure 4. These bars are designed as handholds against turbulence and well recognized and used by cabin attendants. Vertical bars are installed at the upper stowage as shown in Figure 5. These bars are designed to assist flight attendants to access to the upper stowage. They may be a little too high to be used as handholds against turbulence. Some galley partitions have holes as shown in Figure 5. These holes are not designed as handholds but may be useful to grip in turbulent conditions.



Figure 4 Handholds at the galley counter



Figure 5 Handhold in upper galley and a partition with a hole

3-4 Toilets

Acceptable numbers of handholds are already installed in the toilets. Furthermore, large sized and easy to grip handholds for handicapped are available as options for some new airplane models.

3-5 Outside the toilets

Very few handholds are available outside the toilets. JAL installs suitcase handles on the wall of toilets for passengers waiting for their turns as shown in Figure 6.



Figure 6 Suitcase handles

3-6 Airline requirements for installation of handholds

Handholds are installed as a standard installation by aircraft manufactures or installed as basic airline requirements. Some examples of handhold installations based on the airline requirements are as follows.

- 1) Horizontal bars in the galleys are installed at the same level of the galley counter surfaces.
- 2) Horizontal bars are installed at as many locations as possible in the galleys so that a flight attendant can reach any one of them when her arm is extended.
- 3) Lately, longer bars are used in the galleys for better grip.
- 4) Equipment options for handicapped are adopted for the toilets of some new airplanes.
- 5) JAL installs suitcase handles on the wall of toilets for passengers waiting for their turns.

4. Accident/incident analysis

Since 1990, 13 turbulent-related accidents occurred in Japan and since 1996, 77 turbulent-related incidents were reported from Japanese three major airlines (JAL: Japan Airlines, ANA: All Nippon Airways and JAS: Japan Air System). The total of 89 accidents/incidents were analyzed at the committee (One accident was excluded because it was under investigation). Events with deaths or serious injuries of passengers or crew are categorized as accidents and events with only minor injuries are incidents.

4-1 Number of injuries and injury rates

The total of 175 passengers and flight attendants were injured in the 89 accidents and incidents. The breakdown is shown in Table 1.

	Serious injuries	Minor injuries	Total
Passengers	4	64	68
Flight attendants	9	98	107

Table 1 Breakdown of injuries

The injury rates are 0.36% for passengers and 13.7% for flight attendants. It implies that each

flight attendant was 38 times more likely to be injured by turbulence than any single passenger.

4-2 Status of seat belt signs

Seat belt signs were ON beforehand in 40 accidents/incidents and signs were OFF in 49 accidents/incidents.

4-2-1 Circumstances of injured passengers

41 passengers were injured while the seat belt signs were ON and 27 were injured while the signs were OFF. The circumstances of the injuries are shown in Table 2 below.

Areas	Circumstances	Belt signs ON		Belt signs OFF	
Toilets and the vicinity	Waiting	1	18	0	6
	In use	9		4	
	Exited	7		0	
	On the way back	1		2	
Seats	With belt fastened	2	23	1	11
	Without belt fastened	20		0	
	Unknown	1		10	
Unknown		0		10	
Total		41		27	

Table 2 Circumstances of injured passengers

Passengers are injured while unseated for toilet use or while seated. Injured passengers who are categorized as unknown in areas and circumstances are assumed that they were seated with or without seat belts.

The seated passengers could have escaped from injuries by fastening seat belts at all time except for passengers scalded themselves with hot drinks. For the unseated passengers, some measures should be taken.

4-2-2 Circumstances of injured flight attendants

44 flight attendants were injured while the signs were ON and 63 were injured while the signs were OFF. The circumstances of the injuries are shown in Table 3 below.

Areas	Circumstances	Belt signs ON		Belt signs OFF	
Cabin aisles	Securing the cabin	10	16	0	32
	Servicing (drink or food)	1		28	
	Taking care of a passenger	3		0	
	Unknown	2		4	
Galleys	Securing the galley	8	12	0	24
	At work (not for security)	3		21	
	Taking a meal	0		2	
	Taking care of a passenger	1		0	
	Unknown	0		1	
Attendant seats	With seatbelt (harness)	1	12	1	2
	Without seatbelt (harness)	3		0	
	About to sit	1		1	
	Standing up	2		0	
	Unknown	5		0	
Others		4		5	
Total		44		63	

Table 3 Circumstances of injured flight attendants

Injuries of flight attendants while seat belt signs are ON have been drastically reduced after changing the flight attendant procedure in spring of 2002. The new procedure is that the flight attendants should go back to their seats and secure the harnesses as soon as possible when seat belt signs have turned ON. However, for injuries while seat belt signs are OFF, some measures should be taken.

4-3 Perceivable signs of jolt

FDR data of airplane vertical acceleration were examined to find if there are perceivable signs of jolts beforehand. The 10 accident investigation reports contain FDR vertical acceleration data. These data are categorized into three groups as follows.

- 1) Sudden jolt (no vibration perceived beforehand).....
- 2) Continuous small to medium vibration was perceived3
- 3) Relatively strong vibration started 2 to 4 seconds before jolt6

The result implies that handholds that give quick grips to the passengers and flight attendants within 2 seconds when a strong vibration has started would be effective to prevent turbulence-related injuries.

4-4 Locations of injured persons

Passengers are injured at following locations in the airplane as shown in Table 4.

Locations	Aisles	Toilets	Outside the toilets	Seats	Unknown	Total
Forward	1	2	0	3	0	6
Center	1	1	0	4	1	7
Aft	2	10	7	28	0	47
Unknown	0	0	0	0	9	9
Total	4	13	7	35	10	69

Table 4 Locations of injured passengers

About 59% of injuries occurred when the passengers were seated and about 78% of injuries occurred in the aft cabin.

For flight attendants, Table 5 below gives the figures.

Locations	Aisles	Galleys	Seats	Others	Unknown	Total
Forward	4	2		1		7
Center	10	3	4		1	18
Aft	22	30	9	5		66
Unknown	12	1	1		2	16
Total	48	36	14	6	3	107

Table 5 Locations of injured flight attendants

About 46% of injuries occurred when the flight attendants were walking through the cabin aisles and 35% in the galleys. About 72% of injuries occurred in the aft cabin.

As a result of above analysis, it is concluded that some measures should be considered in toilets and on the way to and from toilets for passengers, and in the cabin aisles and galleys for flight attendants. Especially, aft cabin is an important area when discussing the measures to reduce turbulent-related injuries.

5. Questionnaire survey of handholds on flight attendants

A questionnaire survey was conducted on flight attendants in order to find the effectiveness of handholds, and desirable shapes and locations of handholds from practical points of view. The survey was conducted at three major Japanese airlines (JAL, ANA and JAS) and total of 456 sheets were collected. Table 6 shows the fleets these airlines are operating .

Airlines	Fleets					
JAL	B747	B747-400	B767	B777	DC10	MD11
ANA	B747	B747-400	B767	B777	A320	A321
JAS	A300	A300-600	MD80	MD90	B777	

Table 6 Fleets by airlines

5-1 Experience of a jolt

As shown in Figure 7 approximately two thirds of flight attendants answered that they experienced a jolt of the airplane onboard, that is strong enough to get injured.

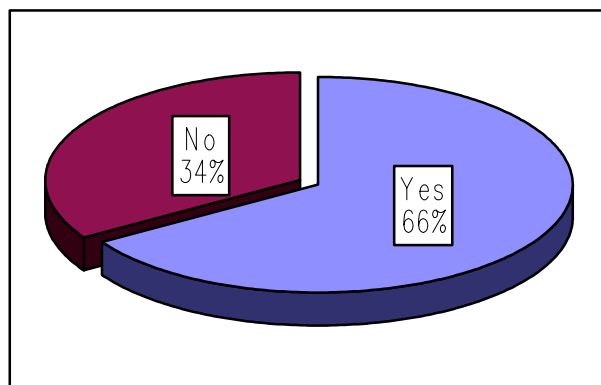


Figure 7 Experience of jolt

The percentage of the flight attendants who experienced a jolt increases as their flight experiences increase, as shown in Figure 8.

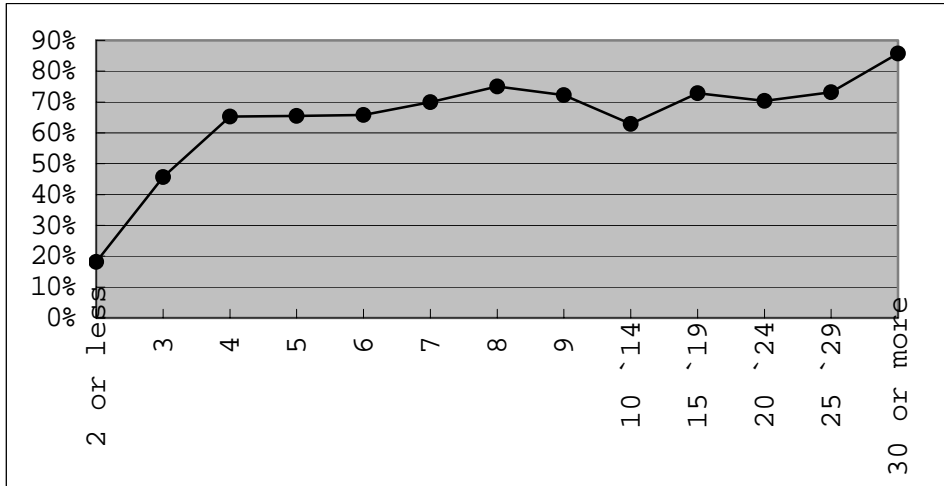


Figure 8 Percentages of flight attendants who have experienced jolt, by flight years

Approximately 70% of flight attendants who have flight experiences of 4 years or more experienced a jolt at least once in their lifetime. It implies that the majority of flight attendants are always exposed to a risk of encountering strong turbulence in flight.

5-2 Perceiving a sign of jolt

Among the flight attendants who experienced a jolt, about half of them perceived a sign of jolt and another half did not, as shown in Figure 9.

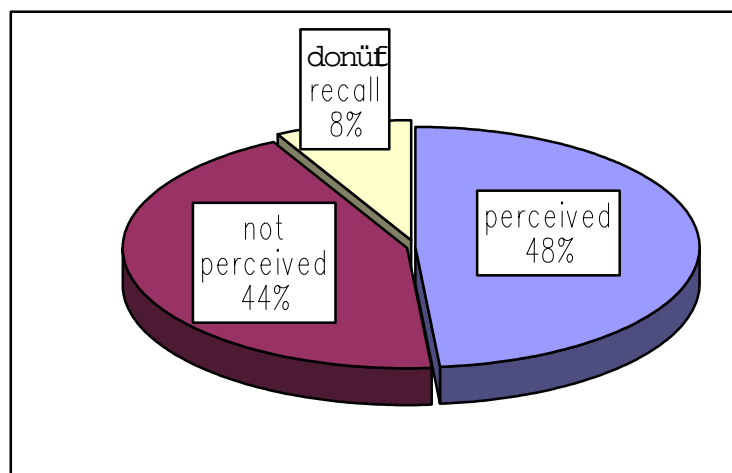


Figure 9 Perceiving a sign of jolt

Among flight attendants who answered that they did not perceive a sign of jolt, the most of them said the reason was that the jolt occurred all of a sudden, as shown in Figure 10. It means that the chance of encountering unexpected strong turbulence such as Clear Air Turbulence is

considerably high.

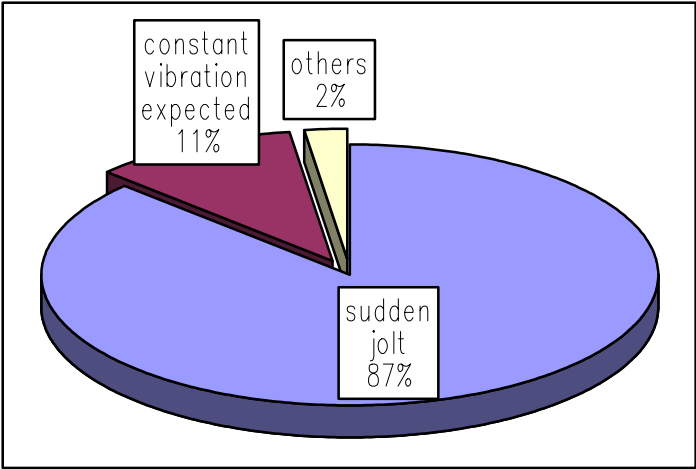


Figure 10 Reason why the sign of jolt was not perceived

5-3 Effectiveness of existing handholds

In order to find out whether the handholds currently installed in the cabin are effective or not against the jolt caused by turbulence, flight attendants who experienced large jolts were asked whether they had escaped from injuries by holding to the handholds. The result is that almost all attendants answered “yes” as shown in Figure 11. It is presumed that the existing handholds are effective to some degree.

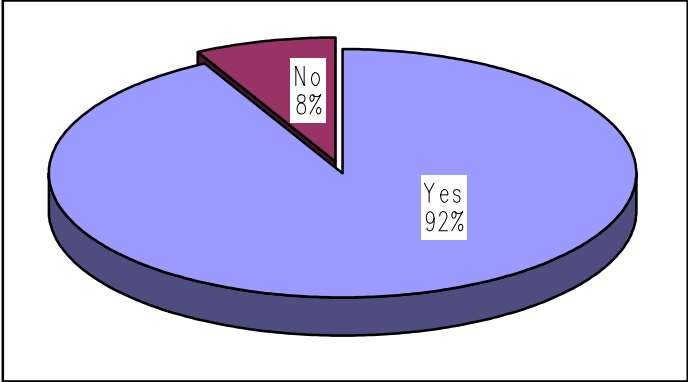


Figure 11 Experience of escaping injury by grabbing handholds

Flight attendants hold to various handholds in the cabin as shown in Figure 12.

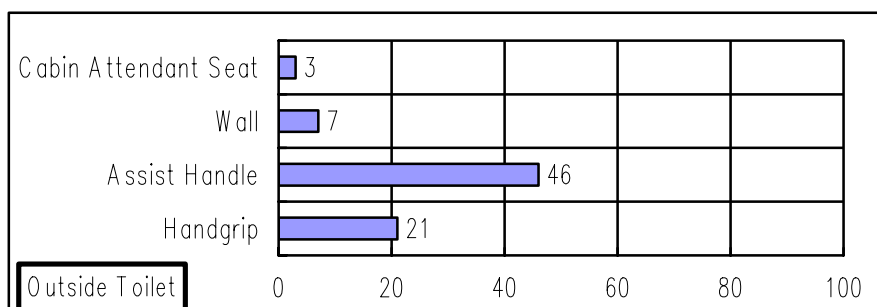
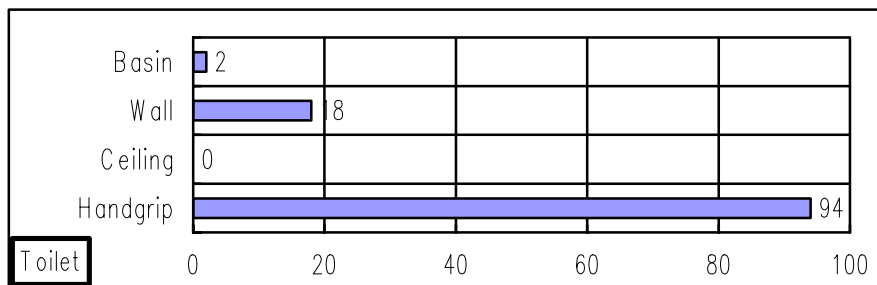
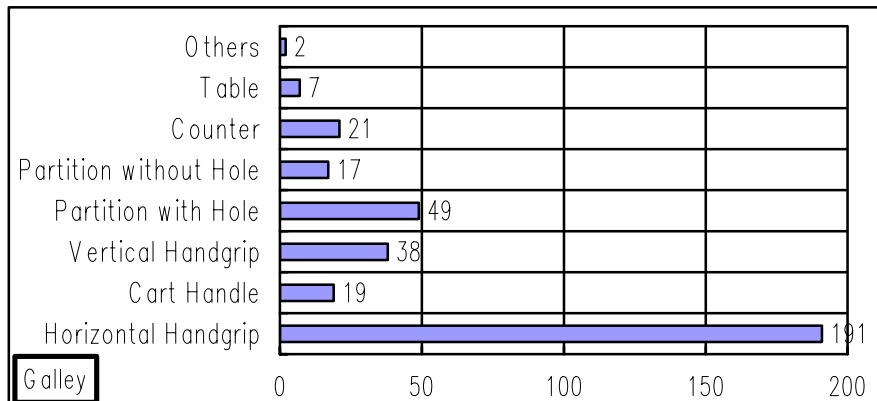
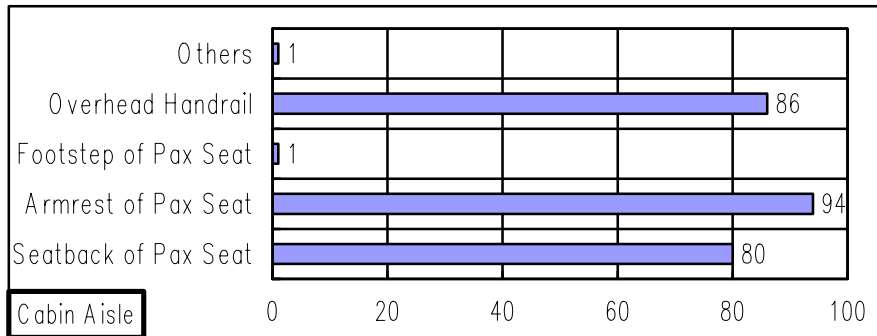


Figure 12 Handholds that flight attendants held to

In the cabin aisle, the numbers of flight attendants who held to seatbacks of passenger seats, armrests of passenger seats and overhead handrails were almost the same. However, the numbers are much different among airlines as shown in Figure 13. The figures reflect the differences in cabin interior designs of aircraft models.

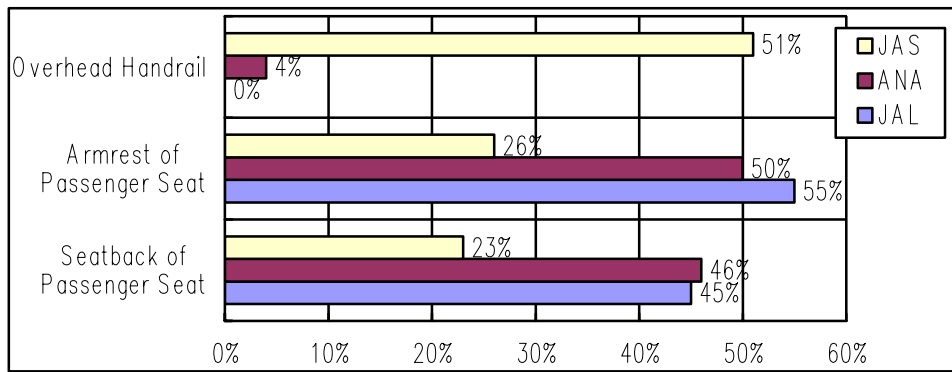


Figure 13 Favorite handholds in cabin aisles, by airlines

JAS is operating MD90s and A300-600s that are equipped with overhead handrails. Flight attendants of JAS are trained to use the handrails in case of turbulence and actually use them quite often. ANA is operating A320s that are also equipped with overhead handrails but the percentage of A320 flights in the total of ANA flights are so small that the training is not conducted in fear of inducing human errors when working on other aircraft models. JAL is not operating any aircraft model that has overhead handrails.

5-4 Evaluation of existing handholds

5-4-1 Most effective handholds

Flight attendants think that the most effective handholds are;

- Horizontal Handgrips in galleys.....91
- Overhead handrails in cabin aisles.....88
- Other handholds 5 or less for each type

Since about 60% of flight attendants did not give the specific name of handhold, the areas where flight attendants evaluate that the most effective handholds are installed are shown in Figure 14, instead.

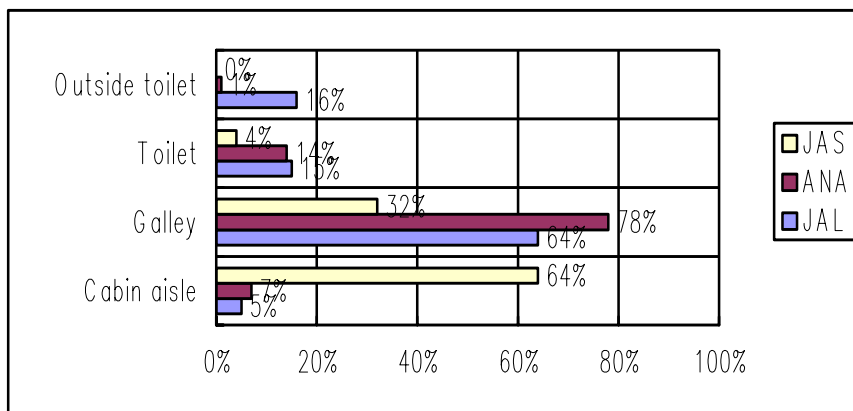


Figure 14 Areas where effective handholds are installed, by airlines

While JAL and ANA flight attendants give high evaluation to galleys, JAS attendants give high evaluation to the cabin aisles because JAS is operating MD90s and A300-600s that are equipped with overhead handrails in the cabin aisles and the handrails are used quite often effectively.

JAL fleet is equipped with suitcase handle outside the toilets and it is considered the reason of high estimation of outside the toilet by JAL flight attendants.

Figure 15 shows which overhead handrail is given higher evaluation by JAS attendants, MD90 or A300-600.

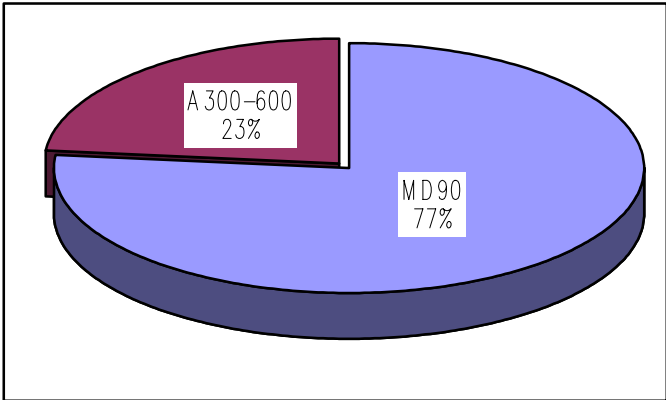


Figure 15 Favorable overhead handrails

MD90 overhead handrail is given higher evaluation than that of A300-600 because MD90 handrail is a bar and can be grasped easily and firmly, and installed at convenient height.

5-4-2 The Area flight attendants feel most uneasy in turbulence

Figure 16 shows the areas in the cabin where flight attendants feel most uneasy when turbulence is encountered.

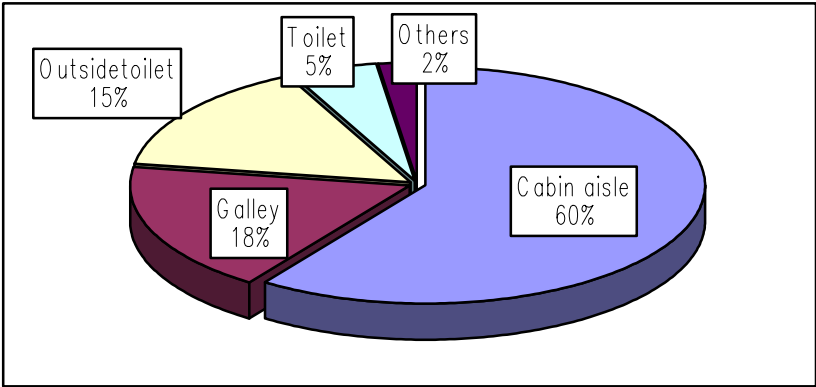


Figure 16 Most uneasy area

Flight attendants feel most uneasy when they are in the cabin aisles because there are few handholds or handholds are not easy to hold. There are many passenger seats along the aisles and the seatbacks and armrests are available as handholds but they are considered to be inadequate to steady persons in strong turbulence.

There are open spaces outside the toilets. Passengers are often standing there to wait for their turns and handholds are not available around them.

5-5 Request for installation of handholds

5-5-1 Cabin aisles

The majority (73%) of JAS flight attendants request to install MD90 type overhead handrails to all aircraft models. The handrails should give firm grips, run the full length of the cabin with no gaps, and be well recognizable by both passengers and flight attendants.

The majority (67%) of JAL and ANA flight attendants request to install handgrips on the shoulder of the passenger seat backs like bus or train seats. However, some attendants expressed concerns about impaired comfort of passengers seated on the aisle side when walking passengers touch the handgrips even in non-turbulent air conditions.

5-5-2 Galleys

Since relatively many handholds are already installed in the galleys, many flight attendants (33) think that the galleys are acceptable as they are. Other flight attendants request for installation of handholds in the galleys as listed below.

- Install handholds at low position so that attendants can hold them when squatting down 49
- Increase the number of handholds 25
- Install handholds on the walls of the galleys 25
- Install handholds as high as the waist 17
- Install handholds all along the counter 15
- Increase the length of the handholds (8)
- Make a hole on the partition 7

5-5-3 Toilets

Many flight attendants (51) request handholds that can be held with both hands at sitting position. Some people provided an idea that handgrips on the both side of toilet seat prevent the occupant from floating in a severe turbulence. Many flight attendants (50) accept existing installation of handholds in the toilets as it is. Other requests are as follows.

- Color and shape of the handholds should be easily recognizable by passengers 15
- Install handholds on the doors and walls 13
- Install handholds in the vicinity of mirrors and sinks 12
- Install handholds as high as the waist 12

Install handholds of handicapped type 9

5-5-4 Outside the toilets

Many flight attendants request to install handholds on the toilet doors or walls next to the toilet doors, because passengers are often standing there waiting for their turns. The shape and installation height of the handholds are requested as follows. Shape

Vertical handgrips 21

Horizontal handgrips 8

Height

Adequate when squatting down 14

Waist 12

Breast 10

Adequate for children 9

Door knob

Shoulder 6

Eye 3

There were also following requests other than shape and height.

Recessed handholds. 17

Color and shape should be easily recognizable by passengers. 7

5-6 Other opinions on handholds

Location, coloring and shape of handholds should be easily recognizable by not only flight attendants but also passengers. 23

The bars should be bold and sturdy for firm grip. (13)

Handholds should be made of such materials that prevent injuries when a person bumps into them. ()

Handholds should be installed at low position so that passengers and flight attendants can hold them when squatting down. ()

Handholds should be recessed, stowed or hollowed so that they do not disturb an evacuation. (6)

6. Discussions

6-1 Strength of turbulence and effectiveness of handholds

Legal requirements and design requirements for handholds have been established only for moderately turbulent conditions, and it is supposed that passengers and flight attendants should take their seats and fasten seat belts or harnesses to cope with stronger than moderate turbulence.

However, through the accident/incident analysis and questionnaire survey, it is found that severe turbulences may occur before passengers and flight attendants can reach to their seats and actually several injuries under such conditions are reported. Although the existing handholds are not designed nor installed as the measures against strong turbulences as mentioned above, through the accident/incident analysis and questionnaire survey, it is found that these handholds are considered to be effective to some degrees for strong turbulence.

Therefore, it is considered to be appropriate to study the way of effective distribution of existing handholds and to devise more effective handholds for stronger than moderate turbulence.

6-2 Locations where installation of handholds should be considered

6-2-1 For passengers

Passengers are often injured when they are unseated for toilet use. Therefore, it is important to distribute handholds so that passengers can stand against turbulence by holding them while unseated for toilet use or can walk from handhold to handhold to go back to their seats.

6-2-2 For flight attendants

Flight attendants are most injured while walking along the cabin aisles. Since the seat backs and armrests of the passenger seats are not considered to be adequate for strong turbulence, more effective handholds are desirable.

Flight attendants are also injured in the galleys. There are already many handholds installed but since flight attendants tend to spend time fairly long in the galleys, it is desirable to make the galleys safer against turbulence.

6-2-3 For passengers and flight attendants

Since about 74% of injuries of passengers and flight attendants are reported in the aft cabin as mentioned above, the measures should be taken in the aft cabin in the first place.

6-3 Considerations for each area

6-3-1 Cabin aisles

The handrails under the overhead stowage are considered effective. However, they are not always feasible in large sized airplanes or match with cabin interior design and have some problems such that short people such as children can not use them. When the handrails are installed, following things should be considered.

They should be a bar type and give firm grips.

The height from the floor is adequate for easy access.

The coloring or marking should be applied for easy recognition.

They should be installed throughout the cabin without gaps.

There are so many flight attendants asking for handgrips installed on the shoulder of passenger seats like trains and busses. This type of handgrip is easily recognized by the passengers and can be used by even children. On the other hand, it may impair comfortableness of the passengers seated on the aisle side. Therefore, when adopting this type of handgrip, safety and comfortableness should be well balanced.

Service carts could be very hazardous equipments. They should be capable of being quickly tied down on the floor at any place when turbulence is imminent.

6-3-2 Galley

The horizontal bars at the counters are found effective through the accident/incident analysis and the questionnaire survey. However, there is a report that a flight attendant gripped the bar but was swung around the bar up and down then got injured in a severe turbulence. In order to prevent this kind of injury, it should be considered a measure to stabilize the body such that installation of another bar at the upper or lower position of existing bar.



Figure 17

A considerable number of flight attendants requested, through questionnaire survey, handholds installed on the partitions and walls of the galleys because there are few handholds available at the entrance of galleys at present. On a certain aircraft type, a hole is open at low position of galley partition as shown in Figure 17. This type of hole is considered to be effective as a handhold and worth considering to apply to other types of aircraft.

6-3-3 Toilets

Many flight attendants request to install handholds that can be held with both hands while seated. If two bars are installed on the both sides of a toilet seat, they are considered to be effective to prevent the occupant from floating in a strong turbulence.

Handholds prepared as an option for handicapped persons are larger than ordinary ones and considered to be effective against turbulence.

Existing handholds in the toilets are painted similar color with interior furnishings and not recognizable.

6-3-4 Outside the toilets

There are few handholds available in this area and passengers waiting for their turns may get injured. Therefore, there should be handholds available for more than one person including children at the same time.

It is pointed out that there is no handhold between toilets and passenger seats and many passengers got injured there. It is necessary to fill up the blank space with appropriate handholds.

6-3-5 Vicinity of flight attendant seats

In order to sit on the flight attendant seat, the seat must be opened first. During turbulent conditions, several flight attendants failed to open the seats or delayed to sit then got injured. It is necessary to consider installing handholds to assist flight attendants sit on their seats in turbulent conditions.

6-3-6 Other places

There are few handholds available in the door areas, aisle crossing zones or vicinity of VTR control panel. It is necessary to consider installation of handholds that can be reached quickly when the onset of turbulence was felt.

7. Conclusions

The accident/incident analysis and questionnaire survey have brought the actual conditions of injuries of passengers and flight attendants into sharp relief. The number of turbulence-related

injuries has been considerably reduced by introducing new flight attendant procedures when seat belt signs are turned on and by encouraging passengers to keep seat belts fastened at all times while seated. However, in the present situation that detection of clear air turbulence is imperfect, injuries to the passengers unseated for toilet use or flight attendants working in the cabin and galleys are still unavoidable. Even when it is thought that the turbulence was encountered all of a sudden, a sign of jolt is often perceivable just a few seconds before it happens. If there are handholds that can be reached within that short time, it is considered to be effective to prevent injuries.

The measures described in paragraph 6.3 are only general ideas at this stage. In order to realize these ideas, it is necessary to verify the effectiveness in preventing turbulent-related injuries, harmlessness during an evacuation and cost effectiveness of the handholds.

In order to reduce turbulence-related injuries and enhance cabin safety, the data collected through the questionnaire survey should be analyzed more deeply. The coming tasks of the committee will be presenting useful information obtained from the analysis and proposing concrete ideas of measures based on the analysis, to the aircraft manufactures and other parties concerned .

8. References

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- 3) “Turbulence Accidents Among U.S. Air carriers: Their Scale and Possible Solutions”, by Robert Matthews, Ph.D. Annual Symposium - International Society of Air Safety Investigators, September, 2001