A Report on Improvement of Cabin Equipment to Enhance Cabin Safety against Aircraft Jolt in Flight

March 2003

Research Committee on Aircraft Safety Enhancement

commissioned by
Civil Aviation Bureau of Japan
(JCAB)

and, supported by
Association of Air Transport Engineering and Research
(ATEC)

This report was created in Japanese originally then translated into English by ATEC.

Contents

Preface

Violent aircraft jolts caused by air turbulence, abrupt maneuver or aircraft system malfunction rarely result in fatal accidents but inflict serious or minor juries on passengers and flight attendants frequently. In the last fiscal year, the committee had conducted case studies in incidents caused by aircraft jolts in mainly the domestic flights and had discussed measures to prevent such injuries. In this fiscal year, the committee has analyzed the distribution of injured persons in the cabin and conditions in which persons suffered injuries. then studied about some handholds that can be helpful in walking in the cabin in turbulent air and to prevent galley carts from jumping when aircraft jolted. This is the report from that committee activities.

Chapter 1 Background and purpose of the research

1. Background

Aircraft and Railway Accidents Investigation Commission(ARAIC) of Japan released the accident investigation report on the near midair collision accident caused by two Japan Airlines airplanes(B747-400 and DC-10), which occurred while flying over the vicinity of Yaizu, Japan on January 31, 2001. ARAIC made several proposals and recommendations to Minister of Land, Infrastructure and Transport (MLIT) of Japan which in order to prevent similar accidents and injuries of passengers and flight attendants when the aircraft jolted violently.

Among the proposals, there were two proposals which encourage MLIT to consider some safety measures to prevent injuries of passengers and flight attendants when airplanes jolt violently. One proposal is to prevent galley carts from floating and another is to install handgrips which are accessible from cabin aisle while walking in the cabin.

2. Purpose

In order to answer the proposals, the purpose of the committee is to research in accidents including foreign cases, measures already taken by aircraft and aircraft seat manufacturers then work out safety measures such as preventing galley carts from floating and handgrips which are easily accessible from the cabin aisle and discuss about their feasibility.

Chapter 2 Composition of the committee

Chairman	Dr. Hiroyuki TERADA	National Aeronautics and Space Laboratory of Japan
Members	Dr. Seiichi ITO	National Aeronautics and Space Laboratory of Japan
	Kazuhiro SHIRAI	Japan Airlines
	Kazuo IWAMOTO	All Nippon Airways
	Masao NAKAYAMA	Japan Air System
	Ikuo ISHIGURI	Koito Industires, LTD
	Hiroyuki HOZUMI	JAMCO Corporation
	Shin-ichi DOHO	Aircraft and Railway Accidents Investigation Commission
Observers	Kazunari DAIKI	Airworthiness Division, JCAB
	Makoto KITAZAWA	Flight Standards Division, JCAB
	Takao OKADA	Airworthiness Division, JCAB
	Tetsuo KOBAYASHI	Airworthiness Division, JCAB
	Sadao KONDO	Association of Air Transport Engineering and Research (ATEC)
Secretariat	Toshiaki KURIBAYASHI	
	Toru DOMOTO	
	Shozo HIROSE	

Chapter 3 Activity of the committee

First meeting on October 24, 2002

-Discussions on the purpose of the committee

-Discussions on the methodology of the research

-Discussions on proposed countermeasures

Second meeting on December 05, 2002

-Discussions on the results of research on accidents

-Discussions on proposed countermeasures

-Discussion on the structure of the report

Third meeting on March 07, 2003

-Discussions on the report

Chapter 4 Discussions

1. Proposals based on JAL Flight 907 Near Midair Collision Accident

ARAIC proposals related to prevention of passenger and flight attendant injuries read as follows;

"In order to prevent passengers and flight attendants from injury when airplane jolts while being operated, following countermeasures should be taken other than stated in the recommendation as keeping passengers well informed to fasten their seatbelts while seated.

(1)Safety measures in the cabin

As many as 12 flight attendants along with many passengers injured in Flight 907 accident, and two of them injured seriously. When the accident occurred, flight attendants were engaged in cabin services and floated with galley carts then dropped and injured. One flight attendant jumped with galley cart to the ceiling and rested on the ceiling.

In consideration of this accident situation, it is necessary to study feasibility of safety measures as follows then take necessary actions as necessary.

a) To prevent galley carts from floating by means of fix galley carts during cabin services.

b) To furnish hand grips easily accessible for passengers and flight attendants while walking around in the cabin.

2. Accident analysis

2-1 Sources of accident information

The committee conducted a research into past accidents caused by aircraft jolt during flight. There are 98 accidents found in US, UK and Japan from 1997 to 2002, in which 143 persons injured seriously and one person died.

Necessary data for analysis such as numbers of seriously injured persons, causes of aircraft jolts, injury situations were extracted from NTSB, AIBB and ARAIC accident investigation reports.

2-2 Causes of aircraft jolts

Causes of aircraft jolts in flight are divided into following four categories in this report.

a) Air turbulence

Air disturbance generated by natural phenomenon such as Clear Air Turbulence, mountain wave, blowout from weather front.

b) Abrupt maneuver

Intentional maneuver of aircraft such as collision avoidance maneuver indicated by TCAS or GPWS warning, or maneuver to comply with ATC instruction. However, the maneuver was too abrupt.

c) Aircraft upset

Unintended maneuver of aircraft caused by malfunction of autopilot or flight control system.

d) Wake vortex

Vortex generated by preceding aircraft.

The distribution of the causes of jolts is shown in Figure 1 and 2. Air turbulence is the majority in number of accidents and injuries. Abrupt maneuver accounts for only 11% of number of accidents but for 17% of injuries. It mean that the less advance warning is available, the more damage occurs.

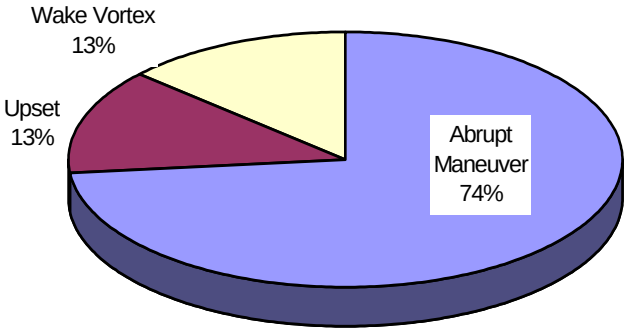


Figure 1. Accidents by causes of jolt.

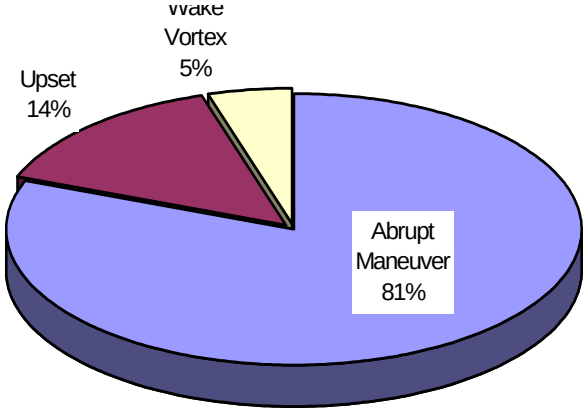


Figure 2. Injuries by causes of jolt.

2-3 Numbers of seriously injured and injury rates

The breakdown of seriously injured persons is shown in Table 1.

	Onboard	Serious injuries	Rate
Passengers	12,891	57(including one fatality)	0.44
Cabin attendants	553	87	15.73

Table 1. Breakdown of injuries

The injury rates are 0.44% for passengers and 15.73% for flight attendants. It implies that each flight attendant was 36 times more likely to be injured by aircraft jolt than any single passenger.

2-4 Trend of the numbers of accidents and the seriously injured

The numbers of accidents and the numbers of seriously injured persons of the Japan, U.S. and UK from 1997 to 2002 which were investigated this time are shown in Figure. 3 for every calendar year. The number of accidents and the number of seriously injured persons show the downward tendency.

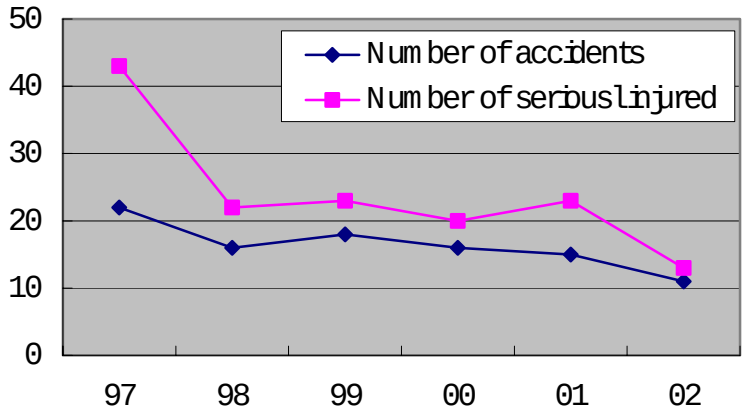


Figure 3. Trend of the numbers of accidents and the seriously injured by aircraft jolts in US, UK and Japan

Furthermore, in a longer-term viewpoint, the line is connected with the chart of the numbers of accidents and the seriously injured by turbulence in the U.S. by 2000 which indicated in the report of this committee issued in 2002 in order to see whether this downward tendency is true, as shown in Figure. 4. In Figure. 4, the consistency on statistics is secured by eliminating accidents in Japan and UK, and accidents caused by other factors than turbulence.

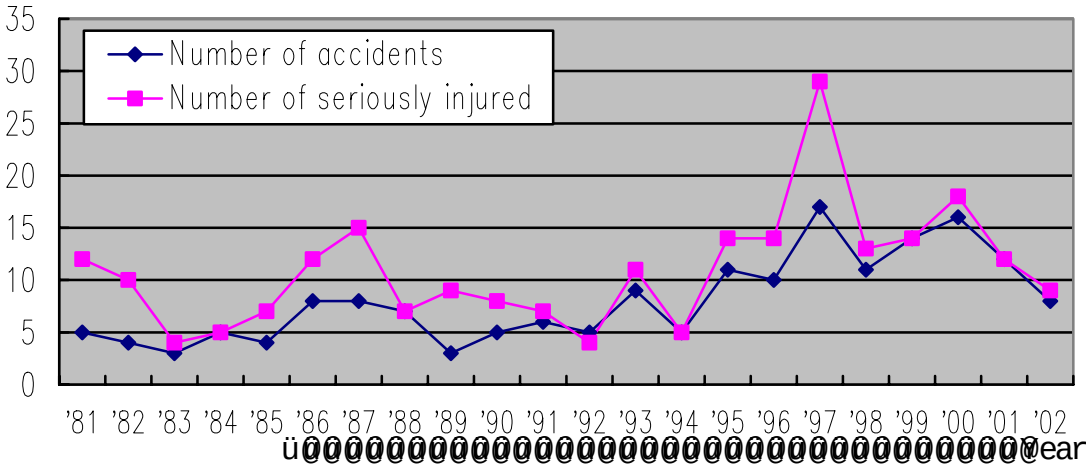


Figure 4. Trend of numbers of accidents and injuries
caused by turbulence

The numbers of accidents and serious injuries are decreasing for the last two years and seem to approach the level of the first half of the 1990s as shown in Figure 4. In order to see whether it is the effect of the latest safety measures such as fastening seat belts all the time while seated and thoroughness of a flight attendant's turbulence procedure, the numbers of the passengers who probably escaped the serious injuries if they fastened seat belts all the time (passengers who got seriously injured because of not fastening their seat belts) and flight attendants who probably escaped the serious injuries if they took seats immediately after the seat belt signs illuminated (flight attendant who got seriously injured because of not returning to their seat immediately after the seat belt signs illuminated) are plotted in Figure 5 and Figure 6, respectively.

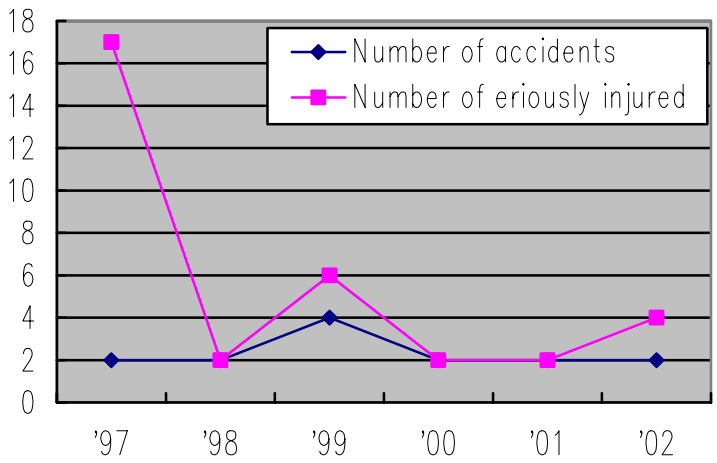


Figure 5. The effect of fastening seat belt all the time while seated (passengers)

Although the number of seriously injured passengers decreased greatly, the number of accidents hardly changed in last six years. Therefore, it is not evident from Figure 5 that fastening seat belts all the time while seated is effective enough for decreasing accidents caused by aircraft jolts.

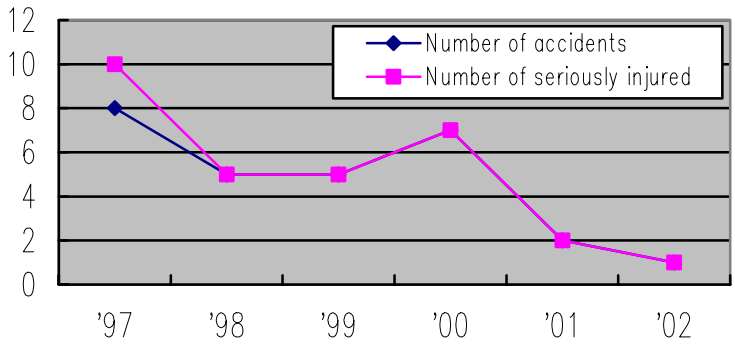


Figure 6. The effect of turbulence procedure (flight attendants)

On the other hand, the number of flight attendants who got seriously injured because of not returning to their seats immediately after seat belt signs illuminated decreased greatly in last two years as shown in Figure 6. It is guessed that the turbulence procedure is very effective to reduce flight attendant injuries.

2-5 Status of seat belt signs (ON or OFF)

There are 85 accidents in which the status of seatbelt signs is clearly stated or presumable among 98 accidents surveyed. Among these, seat belt signs were ON beforehand in 71 accidents and signs were OFF in 14 accidents. Many accidents occurred when seat belt signs were ON. Therefore, It is considered that the new turbulence procedure in which passengers and flight attendants should go back to their seats and secure the seat belts or harnesses as soon as possible when seat belt signs have turned ON has a great effect in injury prevention of passengers and flight attendants.

2-5-1 Circumstances of injured passengers

There were 34 passengers injured while the seat belt signs were ON and 14 passengers 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	Waiting	1			
	In use				
	On exiting				
	On the way from				
	On the way to				
Seats	With belt fastened		24	1	10
	Without belt fastened	21			
Others or Unknown					
Total		34		14	

Table 2. Circumstances of injured passengers

Most passengers injured while unseated for toilet use or while seated. The majority is seated passengers and most of them were seated without seat belts fastened. There were 4 passengers who were seated with their seat belts fastened. They were;

-a child scalded himself with hot coffee spilled from a coffee pot on the galley cart,

-a lady injured by a bag tumbled from overhead compartment, and

-a couple floated from their seats because the seat belt fittings were broken.

Therefore, these four cases do not deny the effectiveness of seat belts.

All the seriously injured passengers relevant to the toilets while seat belt signs illuminated were injured in turbulence. Five passengers out of seven did not have enough time to go back to their seats and fasten seat belts. For these passengers, handgrips installed inside or outside of the toilets are desirable.

For other two passengers, it is important to make it a practice to return to their seats and fasten seat belts immediately after seat belt signs illuminated.

The accident which occurred during toilet use while seat belt sign was not illuminated was caused by collision avoidance maneuver, and the passenger broke the coccyx. Probably, the handrail for making it not lose touch with a toilet seat will be required in order to prevent such an accident.

As a result of above analysis, it is considered that the great portion of injuries of passengers can be prevented by fastening seat belts all the time while seated. However, other measures should be taken for unseated passengers and for injury by loose objects or scald which may get injured even if the passengers are seated and fastened seat belts.

2-5-2 Circumstances of injured flight attendants

There were 63 flight attendants injured while the signs were ON and 11 flight attendants 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	16	19		
	Servicing (drink or food)				
	Taking care of a passenger				
	Answering cockpit call				
Galleys	Securing the galley	13	30		
	At work (not for security)	17			
Attendant seats	With seatbelt (harness)				
	Without seatbelt (harness)				
	About to sit				
Others or Unknown					
Total		63		11	

Table 3. Circumstances of injured flight attendants

Although it is considered that measures have been already taken for injuries of cabin attendants while seat belt signs are ON, some measures should be taken for injuries while seat belt signs are OFF,.

2-6 Distribution of injured persons

2-6-1 Passengers

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

	Aisles	Galley	Toilets	Outside toilets	Seats	Total
Forward	0	0	0	1	0	1
Center	0	0	0	0	7	7
Aft	4	0	4	0	6	14
Unknown	2	0	0	1	5	8
Total	6	0	4	2	18	30

Table 4. Distribution of injured passengers

About 60% of injuries occurred when the passengers were seated and about 64% (excluding unknown) of injuries occurred in the aft cabin.

2-6-2 Flight attendants

For flight attendants, Table 5 below gives the figures.

	Aisles	Galleys	Toilets	Outside toilets	Attendant seats	Passenger seats	Total
Forward	0	0	0	0	0	0	0
Center	2	0	0	0	0	0	2
Aft	8	30	0	0	2	1	41
Unknown	7	6	0	0	5	0	18
Total	17	36	0	0	7	1	61

Table 5. Distribution of injured flight attendants

About 59% of injuries occurred in the galleys and 28% in the cabin aisles when flight

attendants were walking through and about 95% (excluding unknown) of injuries occurred in the aft cabin.

2-6-3 The main point of the safety measures based on a distribution of the seriously injured

In the sum total of a passenger and flight attendants, about 85% (excluding unknown) of injuries occurred in the aft cabin. It should be noted that the flight attendants seriously injured in the aft galleys account for about 46% (excluding unknown) of total seriously injured persons.

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 safety measures for reducing injuries caused by aircraft jolts.

2-7 Accidents caused by galley carts

Although no one was hurt by a galley cart in JAL Flight 907 accident, a galley cart jumped to the ceiling and rested on the ceiling. The passengers were forced to be relocated as a precaution against the fall of the galley cart.

For this reason, the preventive measures of galley cart flotation are proposed in the Flight 907 accident investigation report. Then, the committee investigated how much the galley carts would actually cause injuries.

Among 98 accidents reviewd, the cases in which galley carts caused serious injuries amounted to 9 cases (9%) and 10 persons (4 passengers and 6 flight attendants) (7%). It shows that galley carts may cause serious injuries.

Moreover, although no one was hurt by a galley cart, there were 6 cases in which galley carts might have moved wildly and caused injuries. It means that there were 15 cases (15%), including afore mentioned 9 cases, in which galley carts were the causes or possible causes of injuries. Therefore, it is considered that a galley cart should not be disregarded as a factor of accident caused by aircraft jolt in flight.

2-8 Proposed safety measures and their effects

The committee estimated the effects of proposed safety measures using the accident data

surveyed. The result is shown in table 6

Effects on injury prevention			
Conceivable measures		Passengers	Cabin attendants
Software	Seat belt fastened all the time while seated	29	
	Turbulence procedures		29
	Prohibition of loading a overhead compartment with heavy articles		
Hardware	Improving or increasing handholds in galleys		24
	Installation of handgrips on passenger seats		10
	Fixing galley carts on the floor		
	Installation of handgrips on attendant seats		
	Installation of handgrips in toilets		
	Installation of handgrips outside the toilets		
	Coffee pot with a lid		
	device to indicate seat belt status		
Total		39	72

Table 6. Proposed measures and their effects on injury prevention

The result supports widely known safety measures such as fastening seat belt all the time while seated and turbulence procedures. These measures have large effects on injury prevention of passengers and flight attendants respectively.

Other than those measures, there are several safety measures such as improving or increasing handholds in galleys, installation of handgrips on passenger seats and attendant seats, and fixing galley carts on the floor can be taken. They have some effects on injury prevention of flight attendants. For passengers, installation of handgrips inside and outside of

the toilets, and fixing galley carts on the floor can be taken.

3. Examples of measures already taken or being considered

3-1 Measures taken by aircraft manufacturers

The research committee report issued in 2002 (reference 2) was sent to aircraft manufacturers (Boeing and Airbus) along with questions concerning prevention of injuries due to airplane jolt. They responded are as follows.

Question 1 */ What do you think about installing protective devices in the cabin, except seat belts & harnesses, against more than moderate turbulence?*

Response 1 /

Boeing

The installation of protective devices, other than seat belts & harnesses, for turbulence conditions greater than moderate, would need to take into account other design considerations (i.e., emergency evacuation, head strike, etc.). In addition, structural considerations would need to be considered when placing any tie downs, etc., to the cabin floor and/or seat tracks.

Boeing still believes that the best protective device for moderate/extreme turbulence is the seat belt, for passengers, and the attendant seat harnesses, for the flight attendants. The FAA's Safer Skies program has also focused on this principle of promoting the use of the seat belt at all times.

Airbus

As commented in our previous response, we believe that the best and safest situation for passengers and cabin crew in case of turbulence and especially more than moderate turbulence, is to be seated and belted. We nevertheless agree that passengers or cabin crew may experience rough air conditions while being not seated and restrained.

The question then is to define what is a "more than moderate turbulence", up to which level of turbulence can a handgrip provide a safe means to stabilize. This is probably the reason why the regulator only addressed the case of moderate turbulence, bearing in mind that the objective is for the passenger and cabin crew to be able to reach their respective seat when turbulence is announced.

It is otherwise believed that design can still be improved in zones like toilets, door area, galley area, either by improvement of already provided handholds or identification of adequate features in the most exposed zones.

Question 2 */ What do you think about installing handgrips on the shoulders of passenger seats?*

Response 2 /

Boeing

The installing of hand grips on the shoulders of passenger seats would need to take into account other design considerations such as aisle width, emergency exit access, etc.

Airbus

Seat backs already provide a means of stabilization for people in the aisles (as stated in the rule). This kind of handhold could be improved by the installation of handgrips or specific design of the seat back itself. This kind of evolution in seat design is closely linked to the operator's choice and seat manufacturer offer, both being influenced by many other considerations such as passenger comfort, seat design...On this particular item Airbus can only make recommendations.

Question 3 */ Do you have any idea for tying the service carts down on the floor at any place when turbulence is imminent?*

Response 3 /

Boeing

Tie down fittings, also called mushroom fittings, have been used by many airlines over the years to provide additional restraint for carts once they are removed from the galley. However, the seat tracks are not designed to support the load of service carts being tied to them and thus the mushroom fittings have been used in selected areas only. As discussed previously, any design changes to incorporate service cart tie downs would need to account for other design considerations. For instance, the tied down cart cannot impede an emergency evacuation.

Airbus

Existing potential solutions are based on floor mounted retractable "mushrooms" on which the carts can be secured. These mushrooms can only be placed in given zones and must be designed such that they do not interfere in any case with emergency evacuation.

3-2 Measures taken by aircraft seat manufacturers

We inquired following eight aircraft seat manufactures about their experiences on installing handgrips to passenger seats

(1) AVIOINTERIORS S.P.A (Italy)
(2) B/E AEROSPACE, INC. (USA)
(3) Brice Manufacturing Co. (USA)
(4) Britax Aircraft Seating (UK)
(5) Goodrich Corporation (USA)
(6) RECARO Aircraft Seating Gmbh & Co. (Germany)
(7) SICMA AERO SEAT (France)
(8) WEBER AIRCRAFT LP (USA)

Four manufactures responded and two of them answered that they have no experiences. Only two manufacturers, SICMA AERO SEAT of France and B/E AEROSPACE of USA, provided their information.

SICMA supplies passenger seats equipped with handgrips to Air France and All Nippon Airways as shown in Figures 5 and 6. However, these seats are furnished as mainly first class seats which have 63 inches or more seat pitches in order to fulfill legal requirements of FAR25.785(j) and FAA Advisory Circular 25-17 as cited below.

> FAR 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.
>
> FAA Advisory Circular 25-17 “Transport Airplane Cabin Interiors Crashworthiness Handbook” (related part only)
>
> “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.”

Figure 7. Passenger seat with a vertical bar behind an armrest (SICMA)

Figure 8. Passenger seat with a horizontal bar on an armrest (SICMA)

Figure 9. Passenger seat with a handgrip behind an armrest (SICMA)

Handgrips in Figures 7 to 9 are installed on the armrests. These seats are already approved by FAA and installed in some airplanes.

Moreover, SICMA is working on the passenger seats with handgrips installed on the backshell as shown in Figure 10. The handgrips in Figure 10 are made of aluminum. There may be a concern regarding the possible head injury problem, nevertheless the material should be sufficiently hard to give confident grip which is the first purpose of the handgrip : to be sufficiently strong and rigid to allow to a passenger to be supported in case of turbulence.

Figure 10. Passenger seat with a handgrip on the backshell (SICMA)

On the other hand, B/E AEROSPACE supplies seats equipped with handgrips to Japan Airlines. The photograph of these seats is shown in Figure 11. These seats are for business classes, and are to fulfill the legal requirements of FAR25.785 (j) and FAA Advisory Circular 25-17 like SICMA.

Figure 11. Passenger seats with handgrips in the backshell (BEA

3-3 Measures taken by airlines

Some Japanese airlines are carrying out following improvements about the handrail in a cabin by considering the research result of this committee in 2001-2002 other than passenger seats equipped with handgrips shown in 3-2.

3-3-1 Handrails equipped on the toilet outer wall (Figures 12 and 13)

Figure 12. The embedding type handrail equipped on the toilet outer wall

Figure 13. The suitcase handle equipped on the toilet outer wall

3-3-2 Improvement of handholds in galleys (Figures 14 and 15)

The gap between the galley counter and the handhold was widened so that hands can be inserted easily for easy grasping.

Figure 14. Improved handholds in a galley

Figure 15. Improved handholds in a galley

4. Discussions on proposed measures

4-1 Classification of aircraft jolts

It is necessary to classify the aircraft jolts by available times to prepare for the jolts in flight in order to work out countermeasures. Here, suppose that they are divided into the following four levels.

Level 4 : Jolts with no time available for preparation

Aircraft encounters a jolt all of a sudden without any information or sign of jolt such as CAT encounter or abrupt maneuver to avoid midair collision. As there is no time to prepare, it is necessary that all associated parts are always engaged each other.

Level 3 : Jolts with 2 to 4 seconds available for preparation

In many cases, when encountering a strong turbulence, preceding vibration starts 2 to 4 seconds before a big jolt. In this case, a possibility of escaping an injury will become high if the preparation for the jolt is completed within 2 to 4 seconds of onset of preceding vibration.

Level 2 : Jolts with about 30 seconds available for preparation

It is possible to detect CAT to 5 miles ahead with the present LIDAR (Light Detection and Ranging) technology. Although it is sufficient to take nearby seat and fasten seatbelt, it may be impossible to stow a galley cart in a galley, or to come out from a toilet then return to his/her seat and fasten a seatbelt.

Level 1 : Jolts with 2 to 3 minutes available for preparation

The aviation industry is demanding a time margin of 2 to 3 minutes from LIDAR. With such time available, it is possible to prepare for the jolt with the present equipment in the cabin.

Jolt level	Number of accidents	Number of injuries		
		Passenger	Cabin attendants	Total
Level 4	15	15	15	23
Level 3	7	4	7	15
Level 2	13	12	13	15
Level 1	18	16	18	37

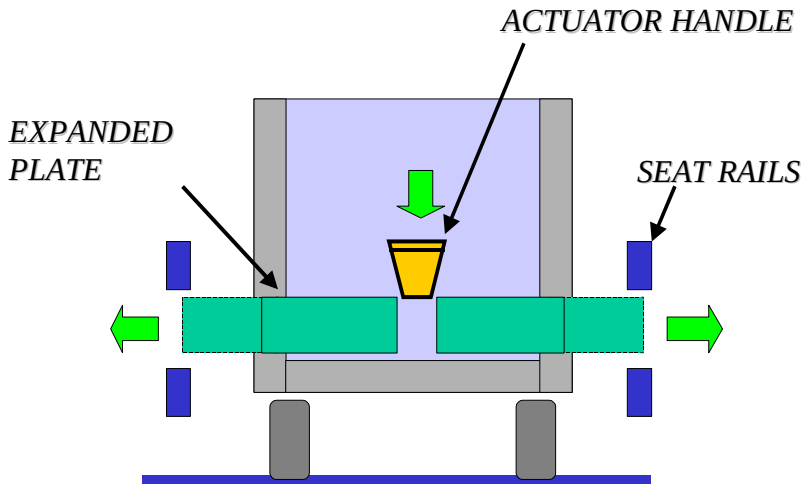
Table 7. Classification of jolt levels for the accidents surveyed

Table 7 shows the result of classification of accidents by jolt levels. Since there are many seriously injured persons by airplane jolts of the level exceeding level 1 as shown in table 7,

the countermeasures against airplane jolts of these levels are necessary.

4-2 Prevention of galley cart floating

4-2-1 Manual engagement with passenger seat



This method is to project movable plates attached in the galley cart right and left, and carry out engagement to parts of passenger seats.

The movable plates are actuated by a handle, because interlocking of movable plates and brake pedal needs complicated mechanism, and the plates should not be actuated when not necessary.

Plates are used, instead of rods, for light weight and simple structure. The plates are attached in the undersurface instead of a door of the cart, because cabin service is done with the door open and the door cannot be closed during the servicing.

Evaluation

(1) It can cope with jolt level 2. If a jolt occurs in good timing, it may be able to cope with level 3 as well. Moreover, if it is engaged always except for the time of movement, it can cope with level 4, since the time of movement is much shorter than the time of engagement.

(2) When carrying out cabin service using a cart, a flight is stable in many cases, and unless engagement is forced, it is thought that the frequency in use of the engagement will become very low. Manual activation of the mechanism which is hardly used will become very uncertain mechanism. Moreover, if the handle operation is troublesome, it will not be adopted.

Design considerations

(1) Passengers often walk through the side of a galley cart. The plate may be tramped down or a passenger may stumble over the plate. Moreover, there is a possibility of injury by the projected parts.

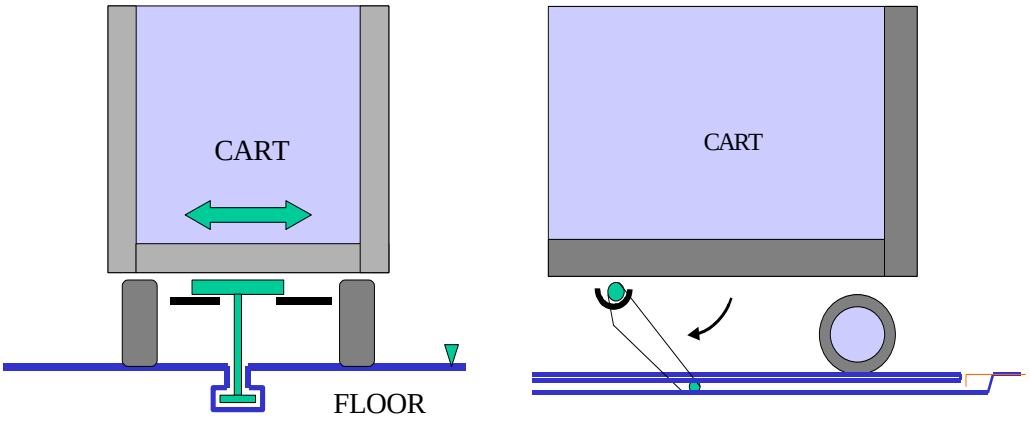
(2) Baggage bar (about 2.5 inches height) is expected as an engagement part of passenger seat. On some aircraft models, a passenger's leg may enter between baggage bar and seat leg. There is a danger of hitting the leg when the plate projects.

(3) Since the width of the cabin aisle varies depending on the cabin configuration and the structure of the portion of the passenger seat where the plate engages varies depending on the seat specifications, it is very difficult to design the system that can cope with all situations. It is necessary to redesign not only the galley cart but also passenger seats.

(4) The weight of the cart will increase.

(5) In order for hot water and detergent 70 degrees C or more to wash a cart each time, it fully needs to take water resistance and durability into consideration.

4-2-2 Rail system



A rail which has a slot in it is laid along the cabin aisle, and a rod or a cable is used to tie the rail and the galley cart. Some margin is given to the rod or the cable so that the cart can be shifted when a passenger walks through the side of the cart.

Evaluation

(1) Since the cart is always engaged to the rail, it can cope with jolt level 4. Moreover, a

flight attendant can stop his/her own floatation by holding to the cart.

(2) High-heeled shoe may be caught in the slot and it is necessary to consider prohibition of use of high-heeled-shoes in the cabin. If the slot is clogged, it becomes impossible to move the cart.

(3) It is necessary to consider the procedures for emergency evacuations.

(4) It is necessary to redesign the aircraft structure, and retrofit cost would be immense. However, it can be adopted by a newly developed airplane.

Design considerations

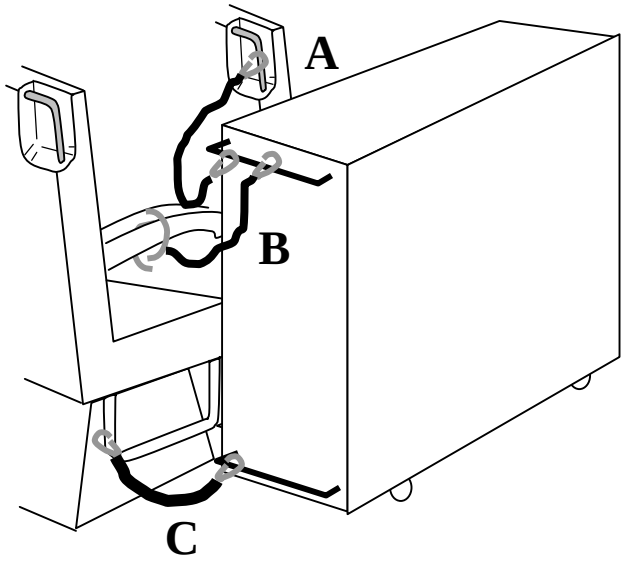
(1) The retrofit cost should be reduced substantially. The cost for a newly developed airplane should be reduced as well.

(2) It is necessary to consider that high-heeled shoes are not caught in the slot, or the slot is not clogged with small articles. Moreover, it is necessary to consider the prevention of the corrosion by spilled drinks and the removal procedure of clogged articles.

(3) A means should be provided to engage the cart with the rail.

(4) It is necessary to take a cabin aisle shift in accordance with the cabin configuration change into considerations.

4-2-3 Tying down with ropes



A galley cart and a passenger seat are tied with ropes which both ends are hooked. There may be three places in the seat where the hook can be hung.

A. A handgrip on the seatback

B. An armrest

C. A footstep

The hook should be latched by one action like handcuffs. Moreover, the hook should be usually embedded in the side of the cart.

Evaluation

(1) It can cope with jolt level 2. In order to cope with jolt level 3 or 4, it is necessary to hang the hooks every time the cart moves. However, in this case, flight attendant's workload would be too high considering the phenomenon may occur only about once in several thousand times.

(2) Manual activation of the mechanism which is hardly used will be a very uncertain mechanism.

(3) Since the flight attendant does the best of his/her ability for holding down his/her own floatation, he/she does not have remaining power to hook the cart. If there is time to hook, it is considered that it is better to return to the galley.

(4) Although redesign of the cart may be minimum, redesign of passenger seat is also required.

(5) The hook is more effective as it is hooked at the lower part of the seat such as the footstep(C). However, the rear side of the cart is not restrained and the cart can not avoid rotating and floating.

(6) Although it is better to hook in the upper part of the seat in order to improve workability, the cart will become easy to float and approach to the passengers.

(7) Carrying the ropes will pose sanitary problems.

(8) The consideration in respect of security is required for a rope so that it may not be abused for a crime.

Design considerations

(1) The hook should be applied by one action like a clip or handcuffs.

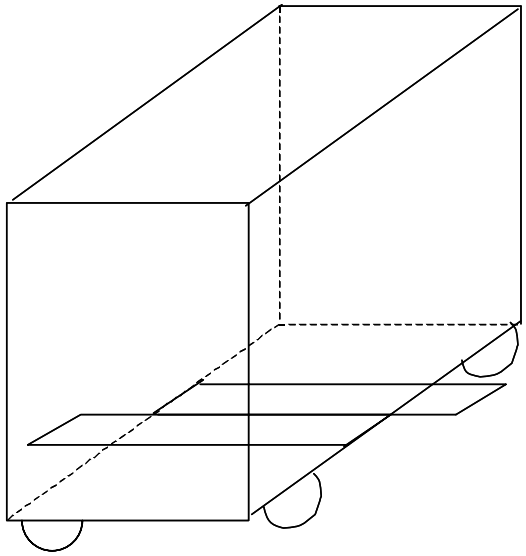
(2) Since the form of a place of hooking is of infinite variety, regarding flexibility as vital will make the hook too large and it’s handling will become troublesome.

(3) Since an armrest does not have enough strength against upward load, it must be strengthened. Moreover, if the footstep is used, it is necessary to redesign the form of the footstep.

(4) The ropes should be flexible to some extent in order to avoid hammering force.

(5) The ropes should be fire resistant.

4-2-4 Automatic engagement with passenger seat



It is the mechanism in which plates attached in the undersurface of a cart project to right and left automatically at the moment of the floating, and engage with a part of passenger seat, then prevent subsequent floatation.

A spring is attached to the caster of the cart. When minus G starts, plates comes out to the both sides automatically and engage with somewhere in the seat. A G-sensor is not necessary.

By installing the plates in the center of the undersurface (on the center-of-gravity line) of the cart, it is possible to stop floatation and rotation simultaneously.

An engage lever is added so that the button switch is not activated during conveyance. The engage lever is set to ON during cabin service only. After a jolt has subsided, the flight attendant puts back and latch the plates in the cart manually.

Evaluation

(1) If the galley cart is positioned so that the center of the cart is close to the baggage bars during cabin service, no additional operation is necessary to cope with even level 4 jolt. However, it is necessary to educate cabin attendants to position the cart every time close to the baggage bars.

(2) Flight attendants can prevent their own floatation by holding to the cart.

(3) Activation range of G can be adjusted by adjusting the spring force.

Design considerations

(1) Since the width of the cabin aisle varies depending on the cabin configuration and the structure of the portion of the passenger seat where the plate engages varies depending on the seat specifications, it is very difficult to design the system that can cope with all situations. It is necessary to redesign not only the galley cart but also passenger seats.

(2) The structure of the cart becomes complicated and the weight of the cart will increase

(3) In order for hot water and detergent 70 degrees C or more to wash a cart each time, it fully needs to take water resistance and durability into consideration.

(4) There is a possibility of injury by the projected parts.

(5) Doing cabin service worrying about the position of the cart every time will be a burden for flight attendants. If the plates are installed at the front and rear ends of the cart, any one plate may engage with any one seat independent of the cart position because the distance between the two plates is almost 80 cm.

4-3 Handgrips easily accessible from cabin aisle

4-3-1 Handgrips on the top of passenger seats

A handgrip is installed on the top of a seatback without deforming the external shape of the seat. If the seat pitch is 31 inches or under, a passenger in the backseat may hit his/her forehead against the handgrip, it can be used only for the backmost row. Assumed design load is set to 300 pounds.

Evaluation

(1) It can cope with jolt level 3.

(2) Since a passenger in the backseat will hang on to the handgrip when gets up from the

seat, the passenger in the front seat feels uncomfortable.

(3) Since the backrest is not thick enough, a passenger or flight attendant who grasps the handgrip may touch the head of the seated passenger simultaneously.

(4) Since the handgrip tends to be conspicuous, passengers use it frequently, and the backrest is shaken each time and the seated passenger feels uncomfortable.

(5) There is a possibility that a hand is caught in the handgrip during emergency evacuation.

Design considerations

(1) It is necessary to be made of such material that is fire resistant, strong enough to resist up to the load of 300 pounds and soft enough not to hurt passenger's head when hit against it. Such handgrips can be installed on any seat other than in the backmost row.

(2) It must be designed so that it meets the height limitation of 45 inches for backrests.

(3) It is necessary to consider not to catch passenger's hand or belongings during emergency evacuation.

4-3-2 Handgrip on the shoulder of passenger seat

A handgrip is installed on the shoulder of a seatback where the cushion is scooped out. It is applicable to any seat position because passengers have no risk of hitting their foreheads against it. Assumed design load is set to 300 pounds.

Evaluation

(1) It can cope with jolt level 3.

(2) Since it is hidden in backrest and is hard to be seen from front side, passengers may not use it frequently. However, flight attendants can fully utilize it because they know it is there.

(3) Since it is not used frequently, seated passenger’s comfortableness will not impaired.

(4) Although it is not used frequently, if it is used, backrest will be shaken and a seated passenger feels uncomfortable.

(5) If it sticks out in the aisle, it may impede emergency evacuation.

(6) There is a possibility that a hand is caught in the handgrip during emergency evacuation.

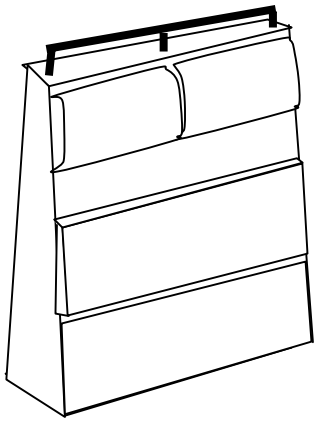
Design considerations

(1) In order to eliminate a possibility that hands are caught in the handgrip, it is necessary just to secure enough space between seatback and handgrip

(2) In order not to impede emergency evacuation and in order to reduce a possibility that a hand is caught in the handgrip inadvertently, it is necessary to design a handgrip that does not stick out from the outline of a cushion of the seatback.

(3) In order to prevent the seatback from being shaken, adoption of soft materials should be taken into consideration.

4-3-3 Handgrip on the top of attendant seat



A handgrip is installed on the top of a flight attendant’s jump sheet.

Evaluation

(1) It can cope with jolt level 3

(2) It is considered very effective if flight attendants use it when they are going back to their own seat from galley or cabin in a turbulent air. In a heavy turbulent air, even if they are managed to get to their jump seat, they sometimes can not open the seat and sit on the seat. In that case, the handgrip is considered very effective.

(3) Since it does not affect comfortableness of passengers, it will not cause any trouble.

(4) Since jump seats are often installed near the toilet, passengers waiting for their turn of a toilet can use them.

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Design considerations

(1) It is necessary to consider a possibility that a hand of those who move along the aisle during emergency evacuation may be caught in a handgrip.

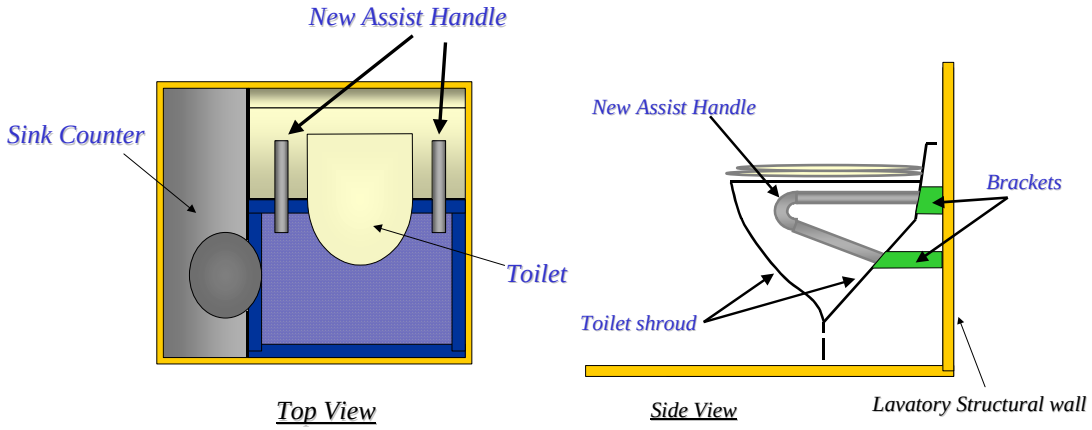
(2) Some types of jump seat have a backrest which slides up and down when the seat is used. For those seats, it is necessary to consider the position of a handgrip so that a hand may not be caught.

(3) Aircraft manufacturers need to adopt it as a basic specification because jump seats for flight attendants are SFE.

(4) It is necessary to make the both ends of a handgrip round so that it will not hurt anyone.

(5) Since a free standing flight attendant seat of A300 have a triangle headrest, a handgrip will be designed to surround the headrest. The headrest is a good mount for the handgrip because it is integrated with the seat structure and sturdy.

4-3-4 Handgrips in toilets



Horizontal bars are installed on both sides of a toilet seat. Assumed design load is set to 300 pounds. Although it is clean around the toilet seat in case of vacuum type toilet and it is possible to make as illustrated, in case of circulation type toilet, since a tank is placed under the seat and a shroud is large, bars as illustrated are not installed.

Evaluation

(1) It can cope with jolt level 3. If those who are always holding the bars can cope with jolt 4.

(2) A sanitary problem is a big issue.

(3) It will be effective if the bars have enough strength. Although there is a sanitary problem, safety should be considered first.

(4) Although it depends on a design, it is thought that maintenability becomes poor.

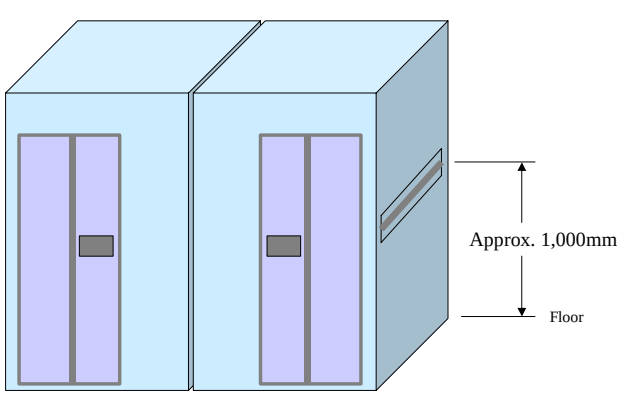
Design considerations

(1) The following considerations are required so that a person with a large size can use them conveniently.

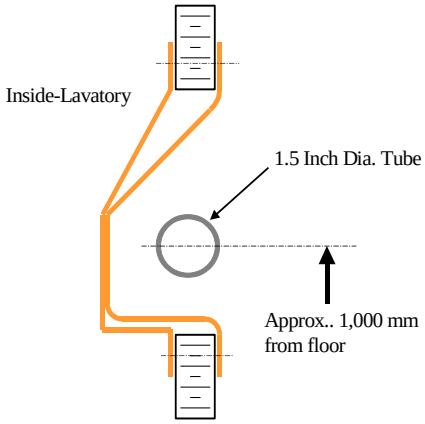
- To install the bars below the upper surface of the toilet seat as illustrated.
- To install two bars with enough distant. However, there will be a problem of space.
- To design the bars so that the front ends of the bars can be open.

(2) It is better to extend an existing handgrip downward so that a seated parson can hold it. An additional bar may be installed horizontally at another position. It is better to install grips on the inside wall of toilet as much as possible.

4-3-5 A handrail outside of toilet



Lavatories



An oblong handrail will be installed horizontally in the scooped outer wall of toilet for standing passengers waiting for their turns or going in and out the toilet. The handrail will be installed at 1,000mm above the floor considering the structure of the toilet. Although it is necessary to examine the strength of the wall thoroughly, it will be possible.

Evaluation

(1) It can cope with jolt level 3.

(2) It is very effective and it will not conflict with requirements, such as FAR. (3) Even when there is no jolt, it can support aged passengers.

(4) When a passenger is holding the handrail located in the hollow and pulled upwards by a strong jolt, there is a danger of prying the back of a hand.

(5) The space in the toilet may become small.

Design considerations

(1) It is necessary to rearrange the position of the fixtures in a toilet to secure the space for the handrail.

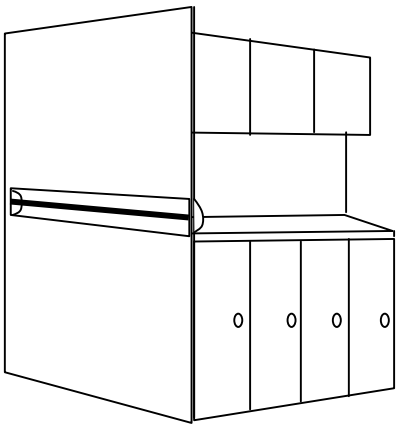
(2) It is better to consider that a handrail will bulge out of the wall a little, if the standard of cabin aisle width is satisfied. It is conspicuous and easy to be hold onto. If it bulges out gently so that it may not hurt anyone, it will be clearly recognized as a handrail and may be approved by authorities. However, it is necessary to evaluate the effect in an evacuation simulation.

(3) A retractable handrail should be studied to save the space.

(4) Since the toilet wall is scooped, it is necessary to be reinforced.

(5) On some aircraft, jump seats are installed on the toilet wall. In that case, the handrail should be installed avoiding seated attendant's head. It may be a little too high for a handrail, though.

4-3-6 A handrail outside of galley



An oblong handrail is installed horizontally on the galley wall facing the cabin aisle so that passengers walking along the aisle and flight attendants going in and out the galley are able to hold onto. The structure and installation of a handrail are equivalent to the handrail installed

on the toilet wall. Since there is no margin in the galley, there may be space and workability problems.

Evaluation

(1) It can cope with jolt level 3.

(2) Even when there is no jolt, it can support aged passengers.

(3) Since space in the galley becomes small, it is necessary to fully examine the workability in the galley.

Design considerations

(1) It is necessary to examine whether it is possible to secure the space for the handrail by rearranging the fixtures in the galley.

(2) It is necessary to design a small galley which can secure the width of aisle when a handrail is installed bulging out a little.

(3) The specification of a galley varies considerably from airlines to airlines, and installation of a handrail on the whole surface may not be possible. In that case, the length of the handrail may be limited to 40 to 50cm.

(4) On some aircraft, jump seats are installed on the toilet wall. In that case, the handrail should be installed avoiding seated attendant's head. It may be a little too high for a handrail, though.

4-4 Conclusions on the proposed measures

4-4-1 Prevention of galley cart floatation

Four proposed measures for preventing galley cart floatation were examined (refer to Table 7). Although a rail system is expected the most effective, it requires large-scale redesign of aircraft and immense cost if it is applied to existing aircraft. Therefore, installing a rail system on existing aircraft is not a realistic solution. However, there is a possibility that a newly designed aircraft is equipped with a rail system. Airbus Industries may have interest in a rail system (refer to 3-1). This system has an advantage that can be equipped regardless of a passenger seat arrangement, but many problems which should be solved are still left behind.

Tying down the cart with ropes to a passenger seat can not cope with sudden jolt such as CAT because tying down a cart continually will require high workload of flight attendants and solutions for sanitary problems. However, it may be effective when an imminent turbulence is announced by the flight crew or there is no time to stow the cart in the galley. Moreover, it is necessary to determine how and when a judgment be made to use the tie-down system, and the

cart should be tied down with two or more ropes to prevent a cart from rotating.

Manual engagement is a very reliable and effective method because a flight attendant can always check that the cart is surely engaged with a seat, and it is possible to cope with CAT as well. However, since the projecting plates are activated independently from a brake because interlocking mechanism between a brake and projecting plates could be troublesome, it is anticipated that a flight attendant may not use it frequently. It is necessary to determine how and when a judgment be made to activate the plates.

Automatic engagement requires only one operation that is to stop the cart at the center of the footstep of a passenger seat, and it can cope with jolt level 4 with hands off. However, if the position of a cart is not adequate, it may float. Therefore, an education for stopping a cart at the position is required. Or it is necessary to work out a mechanism that will surely engage with a seat irrespective of the position of the cart.

It is concluded that, although each proposal above has merits and demerits, some of these will become more feasible through further studies.

4-4-2 Handgrips easily accessible from cabin aisle

Six proposed measures for handgrips that passengers and flight attendants can easily hold onto in case of aircraft jolt were examined (refer to Table 8).

Although the handgrips installed on the passenger seats are expected very effective for reduction in passengers and cabin crews injuries due to aircraft jolts, comfortableness of seated passengers will be impaired if other passengers hold on them and shake the seatbacks even then no jolt is expected. However, flight attendant seats do not have such problem and passenger seats may be also possible to avoid such problem by selecting adequate materials for the handgrips or devising the seat arrangement.

Although the bars installed horizontally on the both sides of toilet seat are considered very effective against aircraft jolts, there is a sanitary problem. passengers will not use them if they think the bars are dirty, and they are not effective any more. Therefore, the feasibility of the bar installation is entirely depended upon how sanitation be maintained in good condition.

Handrails installed on the outer walls of toilets and galleys are expected effective for passengers who use toilets and flight attendants who use galleys.

Since the spaces in the toilets and the galleys are small and already utilized thoroughly, it is necessary to redesign them ingeniously in order to add new equipments. Moreover, it is necessary to consider that the bulged handrail will not hamper an emergency evacuation.

It is concluded that the proposed handgrips are effective and feasible. It is necessary to carry

out concrete evaluation and examination to materialize these ideas hereafter.

	Manual engagement with passenger seat	Automatic engagement with passenger seat	Rail in the floor	Tied down by rope
Applicable jolt level	Level 2, or possibly Level 3 if jolt occurs timely, or Level 4 except while moving if engage at every stop.	Level 4 except while moving	Level 4	Level 2, or possibly Level 4 if engage at every stop.
Feasibility	Cart must be re-designed. Seat may be altered	Cart must be re-designed. Seat may be altered	Total re-design of floor structure and partial re-design of cart are necessary. Almost impossible to apply to existing airplanes.	Partial re-design will make it possible. In case of utilizing armrests, they must be strengthened.
Developmental elements	Medium	Medium	Large	Small (Medium if utilize armrest)
Installation cost	Medium	Medium	High	Low
Weight increase	Small	Small	Large	Small
Operability and workload	Cart must be stopped at predetermined point. Engaging at every stop demands high workload	Cart must be stopped at predetermined point	No special operation is required	Engaging at every stop demands high workload
Remarkable merit		Low workload	Very effective	low cost
Remarkable demerit	High workload		High cost	Loose tying-down

Table 7. Comparison of proposed methods of galley cart tie-down

	Handgrip on the top of passenger seat	Handgrip on the shoulder of passenger seat	Handgrip on the top of attendant seat	Handgrip in toilet	Handrail outside of toilet	Handrail outside of galley
Applicable jolt level	Level 3	Level 3	Level 3	Level 3	Level 3	Level 3
Feasibility	Applicable to the seats at the most aft row	Need to consider comfortableness of seated passengers	No demerit and highly feasible	Sanitation must be assured	Toilet must be re-designed	Galley must be re-designed
Developmental elements	Small	Small	Small	Medium	Medium	Medium
Installation cost	Medium	Medium	Low	Medium	Medium	Medium
Weight increase	Small	Small	Small	Small	Small	Small
Accessibility	Well recognized and easily access	Hardly recognized if installed on the backside of seat			For easier access, handrails may be installed off-wall	
Considerations for emergency evacuation	Suitable gap and material of handgrip will be necessary to prevent hands from being caught		Not required		The handrails shall not be obstacles to the flow of people.	
Remarkable merit	Easily accessible	Easily accessible	Easily accessible	Effective for preventing floatation	Easily accessible	Easily accessible
Remarkable demerit	Uncomfortable-ness of seated passenger	Uncomfortable-ness of seated passenger	None	Sanitation	None	None

Table 8. Comparison of proposed handgrips

5. Future tasks

5-1 Structural strength

5-1-1 Maximum loads for conforming to the regulations

The equipments such as proposed devises that fix the galley cart to the passenger seat should be tested to verify they are resistible not only dynamic load during the gust but also a maximum load in operation (refer to FAR Part25.561 and 562)

In order to obtain the approval of the authorities, it is necessary to verify the strength of the equipments by dynamic load test or reasonable analysis. However, it is unclear whether the whole structural system should be tested or analyzed or simply the fitting is tested or analyzed.

5-1-2 Requirements for structural strength

Since the proposed equipments and fittings may not exceed the level of structural elements, it is enough to design them to satisfy the fundamental dynamic conditions.

5-1-3 Strength margin

Since these equipments are installed in addition to the approved equipments to prevent the flight attendants from floating, it is considered that strength margin is unnecessary. Therefore, although a flight attendant's weight (170 lb) is added to the load of retaining a cart, it is unnecessary to give 1.5 as a margin and 1.33 which is required for metal material would be enough

5-2 Demonstration for effectiveness

It is necessary to prove that, except for the rail system, the proposed measures are effective for prevention of floating of the galley cart in relation with the passenger seat. Moreover, it is necessary to demonstrate that they are useful in the aspect of operability and workableness under the actual operating conditions.

For handgrips, it is necessary to verify about conspicuous, operable and effective for steady themselves.

5-3 Evaluation and examination by the flight attendants

The proposed galley carts and handgrips should be evaluated and examined by the flight attendants, in terms of effectiveness, workload, operability, etc.

5-4 Conformity with regulations

It is necessary to prove not only effectiveness and operability but also conformity with regulations such as FAR in terms of;

- Structural strength

- Head impact
- Emergency evacuation
- Fire resistance

5-5 Asking manufacturers for their opinions

This report will be sent to aircraft manufacturers and aircraft seat manufacturers in order to collect their opinions on the proposed equipments.

Chapter 5 Conclusions

The research committee discussed practical safety measures to enhance cabin safety against turbulence or abrupt maneuver. Some of the proposed measures are considered to be effective and feasible. It will bring about beneficial results to passengers and flight attendants when those measures are given further refinements and put to practical use.