National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 23, 2012

In reply refer to: A-12-1 through -6

The Honorable Michael P. Huerta
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

This letter discusses the circumstances of several survivable accidents[1] that have occurred in the last 3 years in which overhead bins and passenger service units (PSU)[2] on Boeing 737 airplanes became separated from their attachments during the accident sequences, likely increasing the number of reported occupant injuries, particularly injuries to the head and face. In addition to this occupant safety hazard, the negative-*g* strap[3] attachment bracket (used as part of the flight crew five-point restraint assembly) failed in two cases, possibly contributing to back injuries to the flight crewmembers. Findings in these investigations (some of which are ongoing) suggest that current crashworthiness test requirements do not provide an adequate basis on which to evaluate how these items will withstand impact forces during survivable accidents.

Recent Accidents

Aires Airlines Flight 8250

On August 16, 2010, about 0149 local time, Aires Airlines flight 8250, a Boeing 737-700, HK-4682, crashed short of the runway at San Andreas Island Airport, San Andres Island, Colombia. Of the 121 passengers and 6 crewmembers on board, 2 occupants were fatally injured, 15 sustained serious injuries, and 66 sustained minor injuries. The airplane was

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[1] In keeping with the definition of survivable accident established in previous National Transportation Safety Board (NTSB) safety studies, the NTSB defines a survivable accident as one in which the forces transmitted to the occupant through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupant's immediate environment remains substantially intact to the extent that a livable volume is provided throughout the crash sequence.

[2] Secured to the underside of overhead bins, PSUs contain passenger supplemental oxygen generators and oxygen masks, ventilation air vents, and reading lights.

[3] When used as part of a five-point restraint system at flight crews' seating positions, the negative-*g* strap extends between the occupants' legs to provide proper lap belt positioning necessary to comply with the dynamic testing requirements of 14 *Code of Federal Regulations* (CFR) 25.562, "Emergency Landing Dynamic Conditions."

substantially damaged.[4] Postaccident examination of the passenger cabin[5] revealed that 24 of the 30 PSUs installed in the forward cabin (rows 1 through 5) were released and fell when their outboard clamps fractured. The PSUs above rows 6 through 9 were not accounted for because of a break in the fuselage in that section. With the exception of the PSUs above row 19 (seats A, B, and C), which were missing as a result of the accident, all of the PSUs in the mid-cabin (rows 10 through 18) and aft cabin sections (rows 19 through 27) were released and fell when the outboard clamps fractured. These PSUs were found hanging in the seat rows or lying in passenger seats or in the aisle. Most of the overhead bins were dislodged from the airframe in the forward cabin section and at the aft break in the fuselage, at row 19. All of the remaining overhead bins in the main cabin remained secured to the airframe. A correlation of injuries with the cabin damage is continuing for this accident investigation; however, preliminary information provided by the Colombia Civil Aviation Authority indicates that some passengers sustained head injuries, such as skull fractures and lacerations to the head and face.

American Airlines Flight 331

On December 22, 2009, about 2222 eastern standard time, American Airlines flight 331, a Boeing 737-823, N977AN, ran off the departure end of runway 12 after landing at Norman Manley International Airport, Kingston, Jamaica. Of the 148 passengers and 6 crewmembers on board, 85 sustained injuries ranging from minor to serious. The airplane was substantially damaged.[6] Postaccident examination of the passenger cabin[7] revealed that most overhead bins and all PSUs in the forward cabin (rows 3 through 6) were dislodged. An approximate 6-foot-wide opening in the fuselage completely compromised the right side of the cabin between rows 6 and 7. Most PSUs in rows 7 through 28 were also released and fell when the outboard clamps fractured; they were found on passenger seats and in the aisle, hanging by their electrical bundles and air ducts. The fuselage structure at row 23 exhibited substantial damage, and the overhead bins in this row were also separated from the airframe. All of the remaining overhead bins in the main cabin remained secured to the airframe. Preliminary information indicates that some passengers sustained head injuries, such as lacerations to the head and face, and bruising of the back and shoulders. These injuries could be consistent with PSUs striking passengers in their seats as the PSUs became separated from their attachments; this likely contributed to the number and severity of injuries.

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[4] The Colombia Civil Aviation Authority (CCAA) is conducting the investigation of this accident. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the NTSB is participating in the investigation, representing the State of Manufacture and Design.

[5] The NTSB conducted the examination of the passenger cabin on behalf of the CCAA, with the assistance of Boeing Aircraft Company (Boeing).

[6] The Jamaican Civil Aviation Authority (JCAA) is conducting the investigation of this accident. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the NTSB is participating in the investigation, representing the State of the Operator, as well as Manufacture and Design. On December 7, 2011, the NTSB issued Safety Recommendations A-11-92 through -95 to the Federal Aviation Administration (FAA) and reiterated Safety Recommendation A-07-61 addressing training and operational procedures to prevent runway overruns.

[7] The JCAA conducted the examination of the passenger cabin, with assistance from the NTSB, the FAA, American Airlines, the Association of Professional Flight Attendants, and Boeing.

Turkish Airlines Flight 1951

On February 25, 2009, about 1034 local time, Turkish Airlines flight 1951, a Boeing 737-800, Turkish registry TC-JGE, incurred substantial damage when it impacted the ground approximately 1 mile north of the runway 18R threshold at Amsterdam Schiphol Airport. Of the 128 passengers and 7 crewmembers onboard, 9 occupants (4 crewmembers and 5 passengers) sustained fatal injuries; 120 serious and minor injuries were reported.[8] Postaccident examination of the passenger cabin[9] revealed that, in rows 1 through 7, all PSU outboard clamps were fractured. An opening in the fuselage more than 3-feet wide compromised the right side of the cabin near rows 7 and 8. The corresponding left side of the cabin buckled inward. In rows 8 through 29, several PSUs were released and fell when the outboard clamps fractured. The PSUs were found lying on passenger seats and in the aisle. Most overhead bins remained secured to the airframe aft of row 7.

Continental Airlines Flight 1404

On December 20, 2008, about 1818 mountain standard time, Continental Airlines flight 1404, a Boeing 737-500, N18611, departed the left side of runway 34R during takeoff from Denver International Airport, Denver, Colorado. A postcrash fire ensued. Of the 115 occupants (110 passengers and 5 crewmembers), 5 passengers and 1 crewmember sustained serious injuries, and 45 passengers sustained minor injuries. The airplane was substantially damaged. Postaccident examination of the passenger cabin revealed that all PSUs in rows 19 through 24 were released and fell when the outboard clamps fractured. They were hanging by their maintenance lanyards; the overhead bins in the aft section of the cabin remained secured to the fuselage. In addition, the outboard aircraft rails that support the PSUs separated from the fuselage aft of the break in the aft fuselage. Of the 18 passengers seated in rows 19 through 24, 5 sustained bruises to the face and head, which may have occurred when the PSUs became dislodged and encroached into the passengers' occupiable space. After the accident, a passenger[10] reported on an NTSB questionnaire, "I saw the plastic trap doors come down during the crash and hit people on the head."

Installation Design and Test Requirements for PSU Attachments and Overhead Bins

For all of the Boeing 737 accidents cited, the overhead bin and PSU installations were of common design and manufactured, installed, and inspected per Boeing specifications. Two polymer plastic clamps attach the outboard side of the PSU to the aircraft rail and fuselage side wall; two polymer cam latch mechanisms attach the inboard side of the PSU to the bin rail. The bin rail is fastened to the underside of the overhead bin (see figure 1). A maintenance lanyard is connected to the inboard side of the PSU to allow it to hang from the overhead bin for ease of

[8] The Dutch Safety Board (DSB) conducted the investigation of this accident. In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the NTSB participated in the investigation, representing the State of Manufacture and Design.

[9] The DSB conducted the examination of the cabin with assistance from the NTSB, the FAA, the Dutch cabin crew union (Vakbond van Nederlands Cabinepersoneel or VNC), and Boeing.

[10] This passenger was seated in the aft of the airplane, in seat 23C, where the overhead bins remained attached. Therefore, the NTSB concludes the passenger was referring to the PSUs that became dislodged in this area of the airplane.

access when conducting maintenance (see figure 2). The overhead bin is suspended from the fuselage ceiling and side walls with the use of tie rods (labeled (A), (B), (C), and 9 *g* in figure 3).[11]

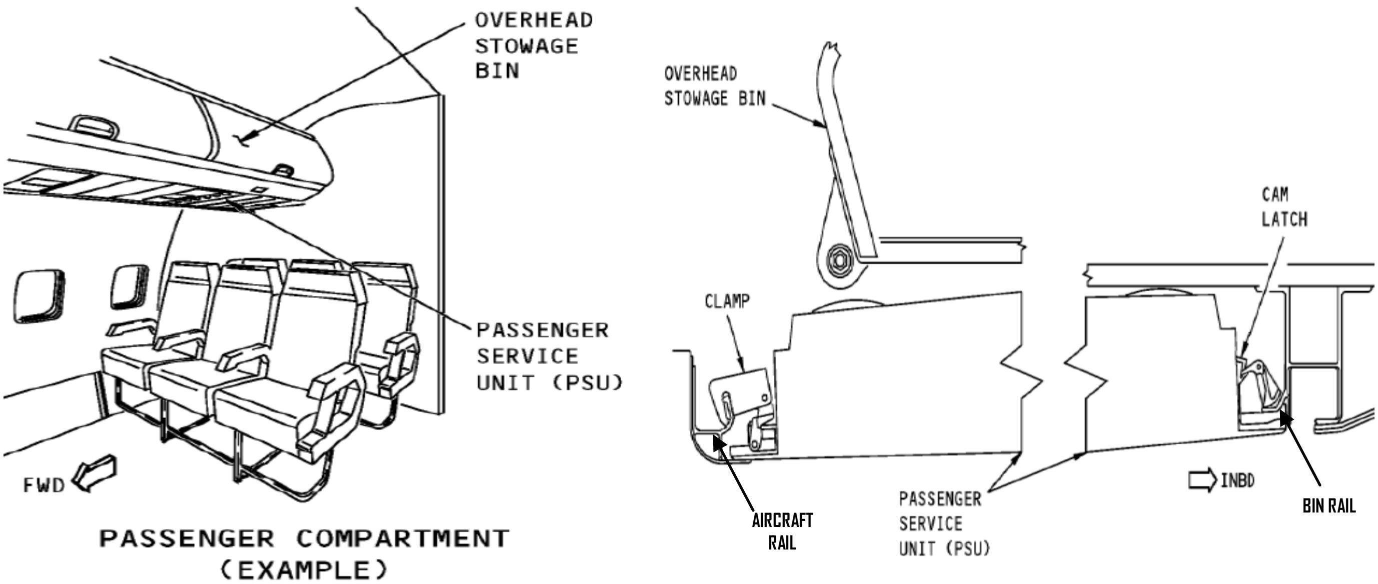

Figure 1. Diagram of a 737 PSU and overhead bin installation.

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[11] According to a Boeing representative, these tie rods comprise the structural system that has been certified to carry, when all are intact, the required crash load from the overhead bins.

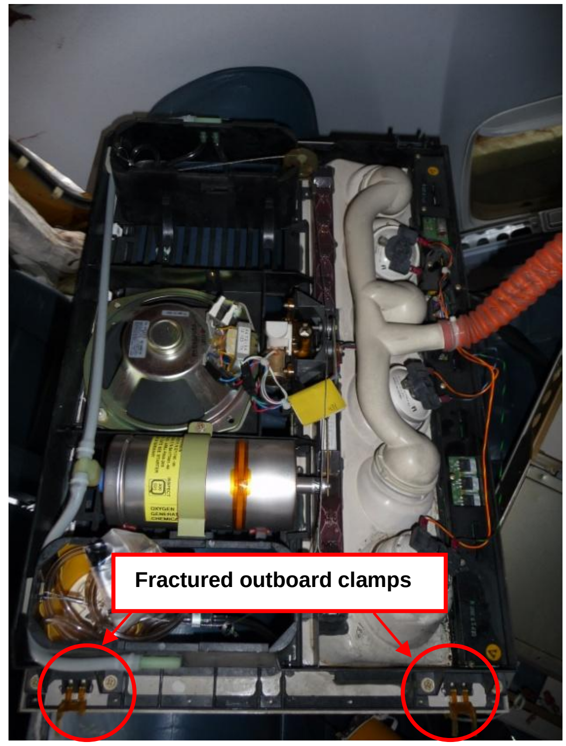

Figure 2. Photographs of a dislodged PSU, showing the maintenance lanyard and fractured outboard clamps.

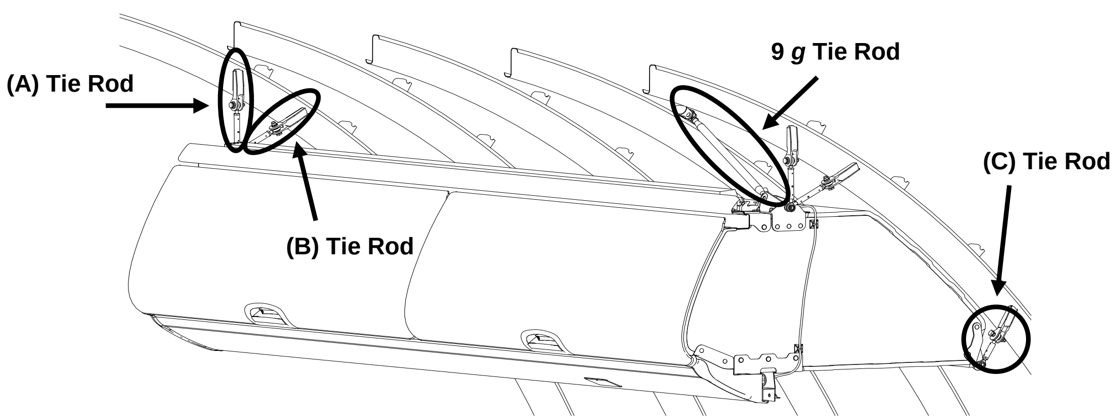

Figure 3. Diagram of a 737 overhead bin installation, showing tie rod structural system.

According to Boeing's records, the design of the outboard clamp used for the PSU installation was created in 1980 based on an older design.[12] Given the success of the outboard clamp on a wide variety of different aircraft, Boeing considered the basic design to be effective

[12] Airplanes that used the older clamp design include Boeing models E-3A, E-6, 707, 727-100, 727-200, and 737-200.

and created a new clamp that differed only in material composition, using Ultem 1000[13] rather than aluminum. After undergoing two revisions to improve the part strength and fit, in 1992 the strengthened clamp was subjected to static certification testing[14] for next generation 737 (737NG) panels and was certified for use on all 737NG airplanes.[15]

The airplane wreckages from the Aires flight 8250, American Airlines flight 331, and Continental Airlines flight 1404 accidents were reexamined[16] to further study the releases of the PSUs during an accident, and two potential failure modes were identified. The first was noted as a result of the examination of the American Airlines flight 331 and Aires flight 8250 airplanes. On the flight 331 airplane, overhead bins remained attached, except for the bins in the first-class cabin and at the fuselage breaks; however, the (C) tie rods on many overhead bins were broken, and many of the 9 *g* tie rods were bent and broken. The outboard aircraft rails remained attached. Similarly, the reexamination of the Aires flight 8250 airplane found that some overhead bin (C) tie rods were broken and 9G tie rods were bent and broken and that the outboard aircraft rails remained attached. To measure the load and rail deflection necessary for the outboard clamps to fail and a PSU to fall, static load tests were conducted by installing an engineering sample PSU (without an oxygen canister) in the flight 331 fuselage. Using chains and a turnbuckle, an inboard load (similar to the directional load that occurred during the accident sequence) was applied to the bin rail. A load cell between the turnbuckle and the chain measured the applied loads as the turnbuckle was tightened. A load of 487 pounds[17] was required to fracture the test PSU outboard clamp. While the NTSB recognizes that this load far exceeds the FAA certification static test requirements of a 3 *g* side load, or 37.5 pounds,[18] it demonstrates that the forces imposed on the outboard clamps during these accident sequences were greater than the forces present during certification static testing and likely caused them to fail.

Based on this information, it was determined that when the (C) tie rods broke during the accident sequences, overhead bins (and attached bin rails) were allowed to articulate inboard from their upper attachment points to the fuselage, causing increasing separation between the aircraft rails and bin rails. As the bin rails and aircraft rails moved farther apart, the resulting load from the bins was passed on to the PSU outboard clamps causing them to fracture. As the released PSUs dropped, the maintenance lanyards separated from the PSUs during the fall.[19]

Examination of the Continental Airlines flight 1404 fuselage revealed a second failure mode for PSU detachment. In this accident, all the PSUs in the aft section after the fuselage

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[13] Ultem is a hard plastic (polyetherimide resin) material.

[14] Title 14 CFR 25.561, "Emergency Landing Conditions—General" specifies that airplane structure, seats, and items of mass must withstand static forward loads of 9 *g*, static downward loads of 6 *g*, and static upward loads of 3 *g*.

[15] The Boeing 737NG family includes -600, -700, -800, and -900 series airplanes.

[16] Representatives from the NTSB, the FAA, and Boeing participated in this examination.

[17] The loads applied during the field examination exceeded the 3 *g* side load required for certification. However, the testing method for the field examination used a loading condition and configuration outside of certification requirements.

[18] According to Boeing, the weight of the PSU used for static certification testing was 12.5 pounds.

[19] The maintenance lanyard and its point of attachment to the PSU are not intended or designed to withstand the momentum of a falling unit.

break became dislodged because the aircraft rails on both sides of the airplane, though themselves remaining intact, detached from the fuselage aft of row 18 while staying attached to the forward section of the airplane (see figure 4, which shows the detached aircraft rails). As the aft section of the fuselage separated, the relative motion of the outboard aircraft rails remaining with the forward section of the fuselage created high stresses in the PSU outboard clamps, resulting in their failure and release of the PSUs. For either failure mode, the relative motion of the outboard and inboard rails increases the stresses in the clamps well beyond the stresses that would be generated during tests using static forces.

Figure 4. Photographs showing failed aircraft rail on the left and right side of the aft section of Continental Airlines flight 1404.

In March 1992, as a result of the accident involving Scandinavian Airlines System (SAS) flight 751, a McDonnell Douglas MD-80,[20] the NTSB issued several recommendations to the FAA concerning the load testing requirements for overhead bins and component fixtures.[21] Safety Recommendations A-92-13 through -15 asked the FAA to do the following:

> Amend the appropriate subparts of 14 CFR 25.561 to establish and require dynamic testing standards for overhead stowage bins and all bin component fixtures. (A-92-13)
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> Require that transport-category airplanes manufactured after a certain date be equipped with overhead stowage bins and component fixtures that meet the requirements of dynamic test standards. (A-92-14)
>
> Develop a timetable that will require the modification of all bins and component fixtures currently in service on transport-category airplanes in order to meet the new dynamic tests standards as cited in A-92-13. (A-92-15)

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[20] The Swedish Board of Accident Investigation conducted the investigation for this accident. For more information, see *Air Traffic Accident on 27 December 1991 at Gottröra, AB County*, Report C 1993:57 (Stockholm, Sweden: Board of Accident Investigation, 1993), available at <http://www.havkom.se/virtupload/content/101/C1993_57e.pdf>.

[21] It is unclear from the investigative record whether "bin component fixtures" included PSUs.

Safety Recommendations A-92-13, -14 and -15 were classified "Closed—Unacceptable Action" on January 23, 1996, after the FAA responded that, "test results from additional testing conducted indicated that there is good correlation between dynamic and static test strengths. Consequently, the FAA does not believe that there is an advantage to establish and require dynamic testing standards for overhead stowage bins and all bin component fixtures. If necessary, the static load factors could be adjusted to account for any additional loading."

The currently required static load tests that PSUs are subjected to take for granted that the forces at PSU attachments are proportional to the static loads applied. Postaccident examinations and testing based on the recent accidents discussed show that, due to substantial relative motion, forces imposed on the PSU attachments during survivable accidents are much greater than those required to be demonstrated during certification testing. Although the NTSB notes that PSU attachment failures may occur in areas of an airplane where greater localized impact damage is experienced, the repeated occurrence of PSUs becoming separated from their attachments in fuselage locations without associated impact damage also indicates that current static load tests imposed on these attachments do not provide an adequate basis on which to evaluate their performance. Therefore, the NTSB recommends that the FAA modify the design and test requirements for the attachment points of PSUs to account for the higher localized loading that results from the relative motion of the attachment structure.

Because head injuries might also result from occupants hitting the seats in front of them during complex deceleration scenarios, it is difficult to specifically attribute the injuries sustained in the discussed accidents to the released PSUs. However, the occupiable space impingement resulting from a released PSU suggests that passenger contact with a dislodged unit during an accident sequence may be unavoidable. The characteristics of a PSU once released (sharp edges, corners, and protuberances) have the potential to cause serious injuries, in contrast to a seatback, which is relatively more protected. Additionally, in the accidents discussed, many of the PSUs above aisle seats that separated from their overhead bins were found in the cabin aisle. Such an obstruction in the rows and aisles, especially at overwing emergency exits, could delay emergency evacuation for passengers. Moreover, the dislodging of PSUs in these accidents is not consistent with the requirement for items of mass under 14 CFR 25.789(a), which states, in part, that "means must be provided to prevent each item of mass…in a passenger or crew compartment or galley from becoming a hazard by shifting under the…emergency landing conditions of § 25.561(b)."

Because these PSU attachment points cannot withstand the substantial forces created by the relative motion of the structure, an alternative approach is necessary to prevent injury caused by PSUs that become separated from their attachments. For example, fittings that can accommodate accident sequences with considerable relative motions of structure or mechanisms that provide for capture of a separated PSU, assuming that the unit could separate, may provide an adequate level of safety. Whatever approach is taken, designers should plan to prevent released PSUs from striking occupants in survivable accident scenarios. Therefore, the NTSB recommends that the FAA require that the installation design for overhead bins and PSUs manufactured by Boeing and installed in Boeing 737NG series airplanes be modified so that the PSUs remain attached to the bins or are captured in a safe manner during survivable accidents. Because other manufacturers may have similar overhead bin and PSU designs with the same potential for failure during survivable accidents, the NTSB also recommends that the FAA review the designs of manufacturers other than Boeing for overhead bins and PSUs to identify designs with deficiencies similar to those identified in Boeing's design, and require those manufacturers, as necessary, to eliminate the potential for PSUs to separate from their attachments during survivable accidents.

Failure of Negative-*g* Strap Attachment Brackets

As mentioned previously, the purpose of the negative-*g* strap in a five-point restraint system is to hold the lap belt in a proper position to comply with the dynamic testing requirements of 14 CFR 25.562, "Emergency Landing Dynamic Conditions."[22] Specifically, the strap is intended to prevent (1) the pelvis from rotating under the lap belt, thus increasing the loading on the spine and (2) the lap belt from rising into the soft tissue of the abdomen. In performing this function, the strap extends from the buckle to the seat, between the occupant's legs, and is secured by the attachment bracket, which is fixed to the seat. During the accident involving American Airlines flight 331, the captain's negative-*g* strap attachment bracket failed on the left side (the first officer's bracket remained intact);[23] both attachment brackets also failed on the left side for the captain and first officer of Continental Airlines flight 1404[24] (see figure 5). The three flight crewmembers suffered from either serious (compression fractures) or minor (pain) back injuries, which are consistent with, and possibly a result of, the occupants bouncing in their seats.

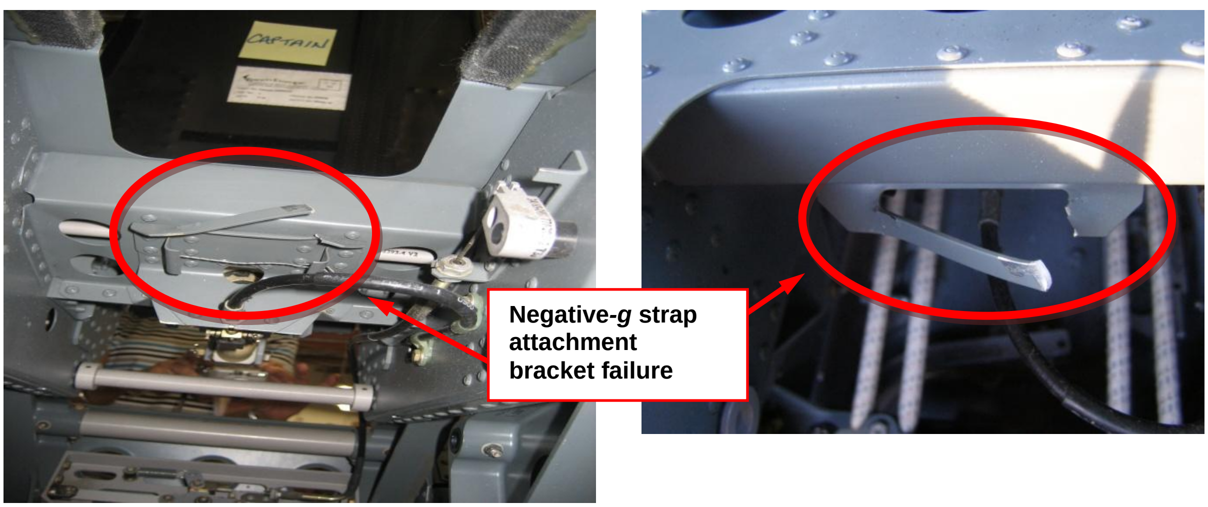

Figure 5. Photographs showing broken negative-*g* strap attachment bracket on American Airlines flight 331 captain's seat.

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[22] During testing to meet these requirements, seats and restraint systems are subjected to sled testing using an anthropomorphic test dummy (ATD).

[23] The captain's seat on flight 331 was a 16 *g* seat, meaning that the seat system was subjected to dynamic tests and minimum performance standards required by section 25.562. Among other requirements, the regulation states that during testing "peak floor deceleration must…reach a minimum of 16G."

[24] The captain and first officer seats on flight 1404 were 9 *g* seats. The 9 *g* designation indicates that the seat system met minimum performance standards contained in TSO-C39a, "Rotorcraft, Transport Airplane, and Normal and Utility Airplane Seating Systems," which specifies ultimate static loads of 9 *g* forward, 6 *g* downward, 3 *g* sideways, 3 *g* upward, and 1.5 *g* rearward.

Ipeco, Inc. designed, tested, and manufactured the seats that were installed at the captain and first officer positions in both airplanes; however, the negative-*g* attachment brackets were of two different manufacturer designs. One bracket, designed by Ipeco, consists of 0.063–inch thick sheet aluminum that is riveted to the seat. A loop stitched onto the strap is inserted through the bracket, and a rod is inserted through the loop behind the bracket to keep the strap in place. This design was installed at all three crew positions where the bracket failed. The other bracket, designed by AmSafe Aviation, consists of 0.093-inch thick aluminum that is bolted to the seat, and the strap is looped through the bracket then stitched. The thicker bracket, used on the first officer's seat on flight 331, did not fail.

As part of the investigation of the flight 331 accident, the strength of the negative-*g* attachment bracket was evaluated by the JCAA, NTSB, Ipeco, and a biomedical engineer from the FAA Civil Aerospace Medical Institute. The evaluation considered the captain's weight,[25] the occupant motion (an estimation of body contact points and relationship to injury causation, seated position, and seat belt loading),[26] and typical seat deformation observed during seat sled testing for certification purposes. During the evaluation, Ipeco determined that damage to the seat was comparable to damage observed for seats that passed the 16.7 *g* pulse used during sled testing. The evaluation determined, however, that the lateral loading to the occupant and seat, as well as multiple impacts during the accident sequence would likely induce additional loading into the bracket. As a result, the evaluation suggested that the forces imposed on the bracket during the accident were greater than demonstrated during certification testing, even though the overall loading to the seat appeared to be equivalent to the 16 *g* test requirements.

Title 14 CFR 25.785(g) states that "each seat at a flight deck station must have a restraint system consisting of a combined safety belt and shoulder harness with a single-point release." Currently, a negative-*g* strap is not a required part of a restraint system. However, at the manufacturer's discretion, a negative-*g* strap can be part of a system design to meet the testing requirements of section 25.562 for proper lap belt positioning. If a manufacturer determines the use of a five-point restraint is necessary to meet the certification criteria for the seat, all portions of five-point restraint system would be used during FAA certification testing under sections 25.561 and 25.562. Thus, negative-*g* straps are in place for section 25.562 dynamic sled testing that uses an anthropomorphic test dummy (ATD). As a seat attachment, the bracket is in place for static testing with ultimate loading conditions as outlined in section 25.561.

Performance criteria prescribed in the current dynamic testing standards for restraint systems include measures for torso tension loads, compressive loads of the pelvis and lumbar, maintenance of belt positioning, protection from serious head and leg injury, and maintenance of seat attachment points. Additionally, as defined in Advisory Circular 25.562-1B, "Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes," the pass/fail criteria for dynamic impact tests for seat systems require that the occupant restraint system remains attached at all attachment points. FAA certification of both the 9 *g* and 16 *g*

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[25] The captain's weight was 200 pounds, 30 pounds heavier than the 170-pound ATDs used during dynamic sled certification testing.

[26] It was assumed that 60 percent of the load was taken by the lap belt and 40 percent of the load was taken by the negative-*g* strap, which was then transferred into the bracket at the left end of the retention bar due to occupant motion.

Ipeco flight deck seats suggests that the negative-*g* strap assembly (the strap and attachment bracket) met the static and dynamic testing requirements outlined in sections 25.561 and 25.562, respectively; however, these tests are not necessarily designed to fully test the functionality and performance of these items.

Because the negative-*g* strap assembly is not a required component, there are no established standards by which to independently evaluate its performance. Current dynamic testing is conducted using best-case scenarios, with the ATD sitting perfectly upright and the lap belt tightly fastened around the pelvis of the ATD with one impact pulse in the vertical direction. However, the test standard does not provide an opportunity for the negative-*g* strap assembly to independently experience any loading or to incur multiple impacts with upward or large lateral components, such as likely occurred in the accidents where the attachment brackets failed.

In the accidents discussed, such loads were sufficient to cause the bracket to fail while the restraint system otherwise continued to perform as intended. When used in a restraint system, the negative-*g* strap serves a vital function by keeping the lap belt positioned properly and is essential to ensure that maximum compressive load between the pelvis and the lumbar column is kept to minimums prescribed in section 25.562. For occupants to derive the full safety benefit of the restraint systems, the attachment bracket should remain functional as long as the restraint system is providing protection. Flight crew injury or incapacitation during a survivable accident may delay the initiation of emergency evacuation procedures and could restrict crewmembers' ability to assist with passenger evacuation and to use cockpit exits if needed. The NTSB concludes that the lack of established test criteria and performance standards for negative-*g* strap assemblies when used as part of a five-point restraint system may compromise the full safety benefit of the restraint system. Therefore, the NTSB recommends that the FAA develop test criteria and performance measures for negative-*g* strap assemblies to better evaluate their real-world loading capability during accident sequences. Once test criteria and performance measures are established, the NTSB recommends that the FAA amend Part 25, as appropriate, to include the newly developed test criteria and performance measures for negative-*g* strap assemblies.

The NTSB recognizes that establishing the recommended test criteria and performance standards will take time. Given that three negative-*g* strap attachment brackets of the same design failed in two of the survivable accidents discussed, the NTSB is concerned that flight crew seats with the Ipeco-manufactured bracket remain on many in-service airplanes. Because of design considerations, Ipeco uses the thicker AmSafe bracket on new production seats; however, the NTSB believes that interim action is needed to address the thinner gauge brackets already in service. For survivable, multiple impact accidents such as those discussed, using a stronger bracket would likely provide a level of protection more consistent with that provided by the current seat designs. Therefore, the NTSB recommends that the FAA require that negative-*g* attachment brackets manufactured by Ipeco be retrofitted with stronger brackets.

Therefore, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Modify the design and test requirements for the attachment points of passenger service units to account for the higher localized loading that results from the relative motion of the attachment structure. (A-12-1)
>
> Require that the installation design for overhead bins and passenger service units (PSU) manufactured by Boeing and installed in Boeing 737NG series airplanes be modified so that the PSUs remain attached to the bins or are captured in a safe manner during survivable accidents. (A-12-2)
>
> Review the designs of manufacturers other than Boeing for overhead bins and passenger service units (PSU) to identify designs with deficiencies similar to those identified in Boeing's design, and require those manufacturers, as necessary, to eliminate the potential for PSUs to separate from their attachments during survivable accidents. (A-12-3)
>
> Develop test criteria and performance measures for negative-*g* strap assemblies to better evaluate their real-world loading capability during accident sequences. (A-12-4)
>
> Once test criteria and performance measures are established as recommended in Safety Recommendation A-12-4, amend 14 *Code of Federal Regulations* Part 25, as appropriate, to include the newly developed test criteria and performance measures for negative-*g* strap assemblies. (A-12-5)
>
> Require that negative-*g* strap attachment brackets manufactured by Ipeco be retrofitted with stronger brackets. (A-12-6)

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred in these recommendations.

[Original Signed]

By: Deborah A.P. Hersman
Chairman