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Inflatable Restraints Installed on Some Transport Aircraft

In some types of seats, an inflatable bag mounted on a seat belt improves head protection for the passenger. Airlines also have begun to install these devices to increase seating capacity and to introduce new seating configurations.

FSF Editorial Staff

The technology of supplemental restraint systems (SRS) based on inflatable airbags, which became standard safety equipment in U.S. automobiles in the late 1980s, has been adapted to the first inflatable-restraint systems to be certified and installed in some passenger seats of transport aircraft cabins in several countries. The new restraints are called "inflatable lap belts" by some aviation regulators.

The basic principle is similar to that in automobiles: When a mechanism senses the powerful, sudden deceleration that is experienced in most accidents, it deploys a rapidly expanding, gas-filled bag in front of the passenger. Within a few thousandths of a second, the bag then occupies space in front of the passenger to cushion against the uncontrollable forward body articulation (bending) caused by sudden deceleration and to prevent the head from striking solid objects (such as the seat or floor) or the passenger's own legs. Cabin safety engineers consider the inflatable lap belt an "active system" that must be reliable enough to activate properly when required.

Amsafe Aviation, based in Phoenix, Arizona, U.S., which supplies conventional seat belts for airline, corporate, general aviation and helicopter aircraft, manufactures an inflatable lap-belt system called the Amsafe Aviation Inflatable Restraint (AAIR). The U.S. Federal Aviation Administration (FAA) and the European Joint Aviation Authorities (JAA) have certified this inflatable lap belt for use on several types of transport category aircraft according to existing regulations and special conditions developed to judge the safety of these systems.

"The AAIR is designed specifically to keep a passenger conscious during a crash event," said Larry Williams, Amsafe vice president, business development.[1] Rather than being released from a fixed stowage space in front of the occupant, as in an automobile, it is folded inside a sheath on the nonadjustable section of a conventional passenger seat belt (photo, page 2). The bag inflates away from the passenger rather than toward the passenger.

Other differences are that shoulder harnesses (upper-torso restraints) are used in the automobile SRS but not the inflatable lap belt, and the automobile SRS airbag typically is concealed behind a plastic cover that reduces the wear and tear and the exposure to tampering.

This inflatable lap belt is the first active/inflatable restraint system to be certified for air carrier operations in jet transports, and the FAA Transport Airplane Directorate said that the system represents a unique "addition to acceptable means for protecting individual occupants during a dynamic event."[2]

The sheath attached to one end of the seat belt contains an inflatable nylon bag, connected to the inflator (the cylindrical object in the center). When installed, the inflator is out of view under the passenger seat. (Amsafe Aviation photo)

Williams said that the impetus for the development of this system was U.S. Federal Aviation Regulations (FARs)/Joint Airworthiness Requirements (JARs) Part 25.562, known in the industry as the "16-g rule," which went into effect in 1998. The regulation, which applies to newly certified airplanes, specifies dynamic tests that must be conducted, using an anthropomorphic test dummy, to ensure that seat restraints are adequate to protect an occupant from longitudinal (along a forward-aft axis) deceleration forces up to 16 times the force of gravity, or 16 g.

Among the performance specifications tested is the head-injury criterion (HIC). The HIC, based on an algebraic formula involving distance and acceleration of a head strike, assigns numerical values to the degree of injury to a passenger's head in a 16-g deceleration. To meet the FARs/JARs requirements, a restraint system must be designed for a HIC of no more than 1,000, which is considered the maximum that the passenger can experience without being killed, seriously injured or rendered unconscious.

The rationale for the 16-g rule is to help aircraft occupants survive the initial impact of an accident and evacuate the aircraft quickly to avoid smoke and fire. Although some passengers believe that most aircraft accidents are not survivable, accident data indicate otherwise. A report by the U.S. National Transportation Safety Board (NTSB) on an analysis of accidents between 1983 and 2000 involving FARs Part 121 operations said that during the period, 95.7 percent of passengers involved in an accident survived.[3]

"The use of an inflatable lap belt is novel for commercial aviation," FAA said. "From the standpoint of a passenger-safety system, the inflatable lap belt is unique in that it is both an active and entirely autonomous device.

"The inflatable lap belt has two potential advantages over other means of head-impact protection. First, it can provide significantly greater protection [against head injury and head entrapment] than would be expected with energy-absorbing pads [such as the seat back in front of a passenger's head], and second, it can provide essentially equivalent protection for occupants of all statures. These are significant advantages from a safety standpoint, because such devices will likely provide a level of safety that exceeds the minimum standards of the regulations."

The inflatable lap belt was introduced into service in 2001, when BAE Systems installed it on about 100 of its Jetstream 41 regional airliners. Currently, the system is installed in some aircraft in the fleets operated by Air Canada, Cathay Pacific and Virgin Atlantic, as well as Atlantic Coast Airlines and other regional carriers.

The manufacturer estimates that by the end of 2003, 18 airlines will be flying with about 2,600 seats equipped with the inflatable lap belt. Aircraft types will include the Airbus A319-112, A320-214, A321-211, A320-214, A330-200, A340-500 and A340-600; the Boeing 747 and 777; and the Bombardier Canadair CRJ700, as well as the BAE J41.

Nevertheless, the HIC for some seat positions has presented a difficult challenge, said Thomas Barth, Amsafe technical director for Europe.[4]

HIC compliance for seats in rows behind other seats has been based on developing energy-absorbing seat backs. Although this strategy has enabled manufacturers to meet the HIC of 1,000 or less for most seats, it does not represent the maximum protection that is possible with current restraint technology, Barth said.

"Tests with modifications to material shape and stiffness are conducted until the HIC value passes, rarely lower than 800 or 900," Barth said. "A HIC of 900 may not satisfy the ultimate objective of successful aircraft evacuation."

Design engineers have faced a different problem in meeting the 16-g rule for seats that are not behind another row of seats. Williams estimated that 5 percent of airline seats are in this category, which includes seats facing bulkheads for galleys, lavatories, life raft pods and cabin-class dividers. Another problem category is "offset rows," necessitated by the tapering of a wide-body airplane's fuselage in the aft part of the cabin.

Passengers in an offset row, rather than being directly behind other seats, sit behind the armrests of the forward-row seats.

Unable to comply with the HIC of 1,000 or less for bulkhead-facing rows, airlines chose an alternative method of compliance that has been permitted under the 16-g rule.[5] Providing enough extra space in front of the rows ensured that there would be no head impact against the bulkhead or offset-seat armrest in a 16-g event, based on tests and calculations, and therefore no HIC was required to be measured. Accordingly, large airliners or seating configurations certified since 1988 have rows set well back from bulkheads.[6]

Nevertheless, the solution fails to address another hazard, Williams said. The striking force — and susceptibility to injury — of a human body in motion is proportionate to the acceleration distance. When an airline moves a seat row back to prevent head strikes against a forward bulkhead, "we've actually made the situation worse," said Williams. "Because instead of moving forward and hitting the seat in front of you or hitting a wall, when you articulate forward, you've got much greater distance to travel. So your head is going to hit your own legs, the bottom of the seat or sometimes even the floor. And the HIC numbers we get in that test scenario are very, very high. We've measured HIC values in the six-thousands."

The same problem may occur in connection with the relatively large seat pitch (the distance between a specified point on one seat and the equivalent point on the seat in the next row) in first-class cabins and in business-class cabins.

Furthermore, although passengers in bulkhead-facing rows may appreciate the ample space, for airlines the space lowers seating capacity with a consequent loss of revenue.

The inflatable lap belt was designed, in part, as an alternative means of meeting the HIC and enabling airlines to safely increase seating capacity, Williams said. For example, on one configuration of the Airbus A340-600, 18 additional seats could be installed by using inflatable lap belts, he said.

In smaller aircraft such as the J41, where a set-back row would eliminate a significant percentage of usable cabin space, FAA/JAA granted waivers from the 16-g rule, Williams said. The waivers included an expiration date, however, to allow for the possibility that a technological solution to meet the 16-g rule would be developed. Williams said that since the first certification of seats with the inflatable lap belt installed, the authorities have considered that to be an approved solution, and waivers are no longer granted.[7]

The AAIR system includes the following components:

- **Electronic module assembly (EMA)**. A rectangular box about 16 cubic inches (262 cubic centimeters) mounted out of sight on the seat frame under the seat row (one EMA can control deployment for as many as three seat positions), the EMA senses, beginning one millisecond after the deceleration event, the specific crash pulse (rates of deceleration over time) that is interpreted by electronic circuits as a severe impact in progress. In such an event, the EMA sends a battery-powered electronic signal through a cable to actuate a valve in the next component, the stored-gas inflator. Being self-powered, the EMA does not rely on power generated by the aircraft, which might be interrupted by an impact, and no battery power is consumed until the mechanical sensor detects a deceleration force of 8 g.

Williams said that the installation does not interfere with access to life vests stowed under seats equipped with the inflatable lap belt system.

- **Inflator**. When the inflator (photo, page 2) receives the signal from the EMA, it releases compressed helium gas from a small steel cylinder. ("Airbag" is a misnomer — helium, not air, causes the bag to inflate. But the term has become standard for inflatable-restraint systems. Helium is nonflammable as well as lighter than air.) The inflator does not use a chemical reaction and no heat is generated, so there is no possibility of thermal injury by contact with the bag. The helium travels through a release manifold, through a hose and into the bag. Full bag inflation occurs in 45 milliseconds at normal cabin temperature.

- **Bag**. The nylon bag is folded precisely and packed in the soft-cover sheath on the outward-facing side of the nonadjustable section of the seat belt. As helium fills the bag, the bag deploys from the sheath, expanding in front of and away from the passenger.

When the bag deploys (photo, page 4), it acts as a pillow, absorbing in milliseconds the energy of the passenger's mass as body movement begins. Because the bag is mounted on a flexible belt, there is considerable variability in the direction of its travel and its shape as bag surfaces expand. In effect, the bag wraps around the seat occupant, rather than exerting significant force against the occupant, whose position remains unchanged. Williams said that testing for certification has demonstrated that the effectiveness of the inflatable lap belt is not reduced if the bag deploys in an uncentered position. Regardless of the direction of the bag's outward deployment, the seat-belt-release tab's location is unaffected, so that the passenger unlatches the seat belt in the normal way.

After deployment, the bag deflates automatically in about 10 seconds, so that egress is not blocked in an emergency evacuation. The inflatable lap belt's performance is not affected by cabin-pressure changes, including sudden depressurization, Williams said.

The bag can be used only once. Williams said, "I tell airlines that if this thing goes off, they probably are going to be replacing the airplane."

In this sequential view, the inflated bag absorbs the energy of the anthropomorphic test dummy articulating forward in a simulated accident scenario. (Amsafe Aviation photo)

The EMA had to be designed to practically eliminate the possibility of inadvertent deployment as a result of nonaccident forces such as severe turbulence, an unusually hard landing or a child crawling under the seat and kicking the unit. The solution was to limit the EMA's activation to a very narrowly defined crash-pulse scenario that would not occur in normal flight, even under conditions of sudden deceleration. The EMA analyzes the aircraft's acceleration or deceleration, correlated with time, to identify a crash-pulse "signature." An event that could trigger deployment would have to meet a specification that is characteristic of aircraft collisions: a force threshold (about 8 g) combined with a duration signature. The EMA responds only to longitudinal forces, not vertical forces or downward-angled forces.

The designers considered the possibility of multiple aircraft decelerations — if, for example, a first impact caused the bag to be deployed and was followed by a second impact, perhaps with greater force than the first, after the bag had deflated. The manufacturer concluded from testing that even with the bag deflated, the head by then would have been pitched forward, and the second strike would be unlikely to cause a dangerous head velocity. Neither FAA nor JAA required that the system deploy more than one time in response to multiple impacts.

The bag is designed to protect the head and upper body of passengers of almost all sizes, from a two-year-old child to a 95th percentile male, and passengers in various positions, including the brace position. A person whose height and/or weight exceed a male larger than the 95th percentile of body size is, Williams said, "beyond the safety design limitations of the seat but we've tested the system up to a 99th percentile male and it worked." The bag of the inflatable lap belt will not deploy, however, when a seat-belt extender is added to accommodate a child-safety seat, an obese passenger or a pregnant passenger.

A child-safety seat that is held in place by the inflatable lap belt will be effective even though the inflator/bag components have been disabled by use of the seat belt extender, Williams said. A pregnant passenger who does not require a seat-belt extender will receive the same protection from the inflatable lap belt as other passengers within the standard range of occupant sizes. No operational limitations have been placed by JAA or FAA on use of a seat equipped with the inflatable lap belt by people using seat-belt extenders because these passengers otherwise exceed the design limitations of the standard seat for crashworthiness.

"We are able to show the regulatory authorities that for a pregnant woman, the system does not introduce any mechanics of injury or any more lethal potential than already exists in a standard seat," Williams said. "If the woman is not so big that she has to use a seat-belt extender, the bag will work up to the full extension of the seat belt. When a seat-belt extender is worn, the passenger's body mass occupies space and helps to prevent the head from articulating as far forward as the passengers who do not need the extender."

The manufacturer emphasizes that any child smaller than a two-year-old child should be placed in an approved child-safety seat to travel in an aircraft cabin and not carried in an adult's lap, he said. Otherwise, there is a high risk that a lap-held child would be propelled forward out of the adult's arms because 16-g deceleration forces exceed human strength.

"Our position is that an approved child-safety seat is the only way to ensure protection of an infant," he said.

A small child restrained in an adult's lap by a belt loop — a length of seat-belt webbing with two loops that is installed over a seat belt, approved in some European countries but not in the United States — will not prevent the inflatable lap belt from being effective for the adult. A child restrained by a seat-belt loop would be crushed when the adult articulates forward during a 16-g deceleration, he said.

"An adult cannot hold a child in a 16-g event, and the bag will not introduce any additional mechanisms of injury; the child would become a missile and the bag would not make any difference for the child," Williams said. "The regulatory authorities, therefore, said that we did not have to have an operational restriction for lap-held children. For a two-year-old child and older children wearing a standard two-point seat belt, the bag will provide much greater protection than the seat belt alone by preventing the child from striking the bottom of the seat, the legs or the floor. Smaller children can be placed in an approved child-safety seat with the belt extender."

In 2001, Goodrich Corp. and Schroth Safety Products Corp. announced a joint venture to develop a family of inflatable-restraint systems for transport category airplanes and other aircraft. Two technologies have been licensed to Schroth, which is refining, evaluating and testing the systems. One of those technologies, the Inflatabelt Restraint System, is also designed for passenger use. Test results for the Inflatabelt for transport category airplanes have not yet been submitted to FAA or JAA, the company said.[8] (In the aerospace industry, other manufacturers provide inflatable restraints to protect the crews of military helicopters.)

Certification of any restraint system is part of the larger process of certifying seats for a specific aircraft (in initial type certification or supplemental type certification). The restraint system is considered an integral part of the seat. Certification from FAA and JAA must be obtained for each new aircraft type and each different seating configuration on that type, as well as new seating configurations on existing types, Williams said.

Before airlines can provide seats with inflatable lap belts, the specific airplane type must be in compliance with applicable regulations and special conditions issued by FAA or JAA. The special conditions identify safety issues in addition to those that have been considered in current regulations.

"Since no [specific] requirements are in existence for these new design features [in Joint Aviation Requirements JAR–25, *Large Aeroplanes*], special conditions needed to be developed [in cooperation with FAA] to certify these new systems," JAA said. "Certain aspects can be covered by the current JAR–25 requirements. To be an effective safety system, the inflatable lap belt must function properly and must not introduce any additional hazards to the occupants as a result of its functioning. Special conditions have been issued for each applicable project and these are, in effect, JAA requirements. JAA has approved the inflatable restraint for some airplane types, and currently no applications for similar systems have been received."[9]

FAA said that the special conditions overall can be characterized as addressing either the safety performance of the system or the system's integrity against inadvertent activation. Neither FAA nor JAA conduct the dynamic testing that is required for certification of inflatable lap belts. JAA said that mutual acceptance of an applicant's dynamic-test results by JAA and FAA, upon acceptance by either regulator, is the normal practice.

The FAA Civil Aviation Medical Institute (CAMI) has not participated directly in the type-certification testing of inflatable lap belts. Nevertheless, based on its crash-sled tests of other inflatable restraints from various manufacturers to assess their viability and performance as a potential safety system for civil aviation, CAMI has contributed valuable insights for identifying possible safety issues in using inflatable lap belts, FAA said.

"It is the applicant's responsibility to perform all required certification testing," FAA said. "These certification tests are witnessed by FAA personnel or designees of the FAA. All applicants are required to submit certification plans, test plans and test reports as needed. These documents must be approved by the FAA as part of the type-certificate [approval processes] and supplemental-type-certificate approval processes. The seat and the restraint system can be considered as the basic elements of the seat system. In terms of the dynamic-testing requirements, both elements are considered critical for the success of the system."

The following special conditions exemplify those for which FAA and JAA have required compliance as part of their supplemental type certificate approvals for installation of the inflatable lap belt:[11]

- "It must be shown that the inflatable lap belt will deploy and provide protection under crash conditions where it is necessary to prevent serious head injury or head entrapment. The means of protection must take into consideration a range of stature from a two-year-old child to a 95th-percentile male. The inflatable lap belt must provide a consistent approach to energy absorption throughout that range. In addition, the following situations must be considered: the seat occupant is holding an infant; the seat occupant is a child in a child-restraint device; the seat occupant is a child not using a child-restraint device; [and] the seat occupant is a pregnant woman;

- "The inflatable lap belt must provide adequate protection for each occupant regardless of the number of occupants of the seat assembly, considering that unoccupied seats may have active seatbelts;

- "The design must prevent the inflatable lap belt from being either incorrectly buckled or incorrectly installed such that the inflatable lap belt would not properly deploy. Alternatively, it must be shown that such deployment is not hazardous to the occupant, and will provide the required head-injury protection;

- "It must be shown that the inflatable lap-belt system is not susceptible to inadvertent deployment as a result of 'wear and tear,' or inertial loads resulting from in-flight or ground maneuvers (including gusts and hard landings), likely to be experienced in service [FAA required that such activation be an extremely improbable occurrence — i.e., a probability of one inadvertent deployment in 1 billion flight hours — and required appropriate inspection intervals and self-test capability];

- "Deployment of the inflatable lap belt must not introduce injury mechanisms to the seated occupant, or result in injuries that could impede rapid egress. This assessment should include consideration of an occupant who is in the brace position when it deploys and an occupant whose belt is loosely fastened;

- "It must be shown that an inadvertent deployment, that could cause injury to a standing or sitting person, is improbable;

- "It must be shown that inadvertent deployment of the inflatable lap belt, during the most critical part of the flight [i.e., the takeoff phase and the landing phase], will either not cause a hazard to the airplane or is extremely improbable;

- "It must be shown that the inflatable lap belt will not impede rapid egress of occupants 10 seconds after its deployment. [FAA said, 'Ten seconds has been chosen as a reasonable time since this corresponds to the maximum time allowed for an exit to be openable. In actuality, it is unlikely that an exit would be prepared this quickly in an accident severe enough to warrant deployment of the inflatable lap belt, and the inflatable lap belt will likely deflate in much less than 10 seconds.'];

- "The system must be protected from lightning and [high intensity radiomagnetic fields (HIRF)]. The threats specified in [FAA] Special Condition no. 25–ANM–23 are incorporated by reference for the purpose of measuring lightning [protection] and HIRF protection. For the purposes of complying with HIRF requirements, the inflatable lap belt system is considered a 'critical system' if its deployment could have a hazardous effect on the airplane; otherwise it is considered an 'essential' system;

- "The inflatable lap belt must function properly after loss of normal aircraft electrical power, and after a transverse separation of the fuselage at the most critical location. A separation at the location of the lap belt does not have to be considered;

- "It must be shown that the inflatable lap belt will not release hazardous quantities of gas or particulate matter into the cabin;

- "The inflatable lap belt installation [including any pyrotechnic squib] must be protected from the effects of fire such that no hazard to occupants will result; [and,]

- "There must be a means for a crewmember to verify the integrity of the inflatable lap-belt-activation system prior to each flight or it must be demonstrated to reliably operate between inspection intervals."

JAA said that all of the stages of certification are required for all applicants seeking a type certificate or a supplemental type certificate.

"This has led to specific special conditions to cover all possible scenarios, and certain aspects might need to be addressed by limitations — such as the prohibition of carrying lap-held children," JAA said. (JAA did not require an operational limitation on carrying lap-held children, however, Williams said.)

Because the passenger fastens and unfastens the inflatable lap belt in the same manner as a standard seat belt, no changes to the passenger-information card or the preflight briefing typically have been required by regulators … .

The manufacturer complied with the special conditions by various proprietary methods as part of the certification process for each aircraft type, FAA said. FAA provided a few examples of safety issues that were addressed.

"The design was required to prevent the inflatable lap belt from being either incorrectly buckled or incorrectly installed such that the inflatable lap belt would not properly deploy," FAA said. "Alternatively, it had to be shown that such deployment was not hazardous to the occupant, and would still provide the required head-injury protection. Additionally, they were required to run dynamic tests to verify the effectiveness of the system and its interaction with the seat, demonstrating installation compatibility."

For each aircraft modified with the inflatable lap belt, the manufacturer prepared a training manual for flight attendants. The device has the standard buckle and is fastened and unfastened in the usual way. Because the passenger fastens and unfastens the inflatable lap belt in the same manner as a standard seat belt, no changes to the passenger-information card or the preflight briefing typically have been required by regulators, he said.

Prevention of incorrect fastening and incorrect installation in the aircraft were addressed by design and engineering solutions. A key-like feature in the buckle prevents accidental fastening with one end of the belt twisted 180 degrees from the correct orientation, which would disable the system.

Another safety issue also had to be addressed: After fastening the inflatable lap belt, a passenger could deliberately or inadvertently twist the belt and sheath to an upside-down position (i.e., bag beneath the seat belt). The buckle cannot be unfastened from this position, and if the system were to deploy with the sheath upside down, constraint of the inflating bag under the belt and directly against the passenger's body would cause serious soft-tissue injuries, Williams said.

"That is not how the device was designed to be used," he said. "The probability of upside-down deployment happening is fairly low because the person physically would have to first put on and buckle the device in the correct position and then turn the device upside down, which would be counterintuitive even for a very young passenger or someone who is not familiar with flying. We convinced the certification authorities that this is not a big factor in the overall safety considerations."

The countermeasures basically comprise training flight attendants to be aware of this safety issue, and providing obvious methods of recognizing/warning passengers and flight attendants that the device has been turned to an upside-down position.

The underside of the inflatable lap belt has a large yellow warning label that tells the passenger — and shows the cabin crew during standard seat-belt checks— that the inflatable lap belt is not being worn correctly, Williams said.

"The pictograms and the wording on labels are specific to each airline and to different languages," Williams said. "They are similar in saying 'Warning — Serious injury can occur by wearing this device upside down' and in telling the passenger that use of a belt extender disables the bag. Training for the cabin crew basically consists of how to recognize that the belt is upside down and how to answer passenger questions about why the seat belt appears to be thicker than other seat belts and what it will do. Flight attendants typically will explain that the passenger cannot unbuckle the seat belt if worn upside down. Airlines, JAA and FAA have not seen a need to have something specific mentioned about the orientation of the seat belt in the passenger briefing."

The visible sheath that encloses the bag is durable and resistant to liquid spills and ordinary wear and tear, although Williams said that the enclosure could be damaged by severe intentional abuse.

Airlines also familiarize their maintenance technicians with the components of the system and inspections, including checks for tears in the sheath, he said.

In addition to providing the required head protection, the inflatable lap belt enables airlines to reconsider seating configurations, such as installing more seats or using a larger seat pitch for the seats behind the front seat row, JAA said.

"The certification of the first inflatable-restraint device is significant from the JAA technical/safety standpoint [because] these systems provide for a different means of compliance with the HIC for front-row seats installed in front of a bulkhead," JAA said. "The system should be considered as an alternate means of compliance [compared with] the current [method] of introducing a large distance between the front row seats and the bulkhead to prevent head contact."

Head protection provided by the inflatable lap belt when used with various passenger seats is measured using separate crash-sled testing for each airplane type.

"We duplicate the interior configuration of the airplane and we use the anthropomorphic test dummy in the test sled in a 16-g crash simulation, and we take the HIC readings from the test dummy," Williams said. The data are provided to regulators as required by the approved certification plan.

The system has been designed for installation with minimal change to current seats. The belt section is mounted on the same anchors as a conventional seat belt, making retrofitting practical. The weight penalty of the latest model, designated version 1.5, is about two pounds (0.9 kilogram). Maintenance is scheduled for every 1,900 flight hours and consists of initiating and monitoring the EMA's self-diagnostic cycle using a test device. The system is rated for a seven-year service life before overhaul, which must be performed by the manufacturer. The time between overhauls is feasible because the battery has no power drainage unless the EMA is activated momentarily by sudden longitudinal force.

Based on tests conducted during research and development, the manufacturer believes that inflatable lap belts would increase passengers' ability to remain conscious in every seat on a transport airplane during a 16-g event, Williams said. Although regulatory certification has not been sought for every seat, recent certification has enabled one airline to safely position seats at angles up to 40 degrees from the longitudinal axis of a specific airplane type and to have the seat reclined during takeoff and landing, he said.♦

Notes

1. Williams, Larry. Interviews by Rosenkrans, Wayne. Alexandria, Virginia, U.S., May 22, 2003, and Aug. 8, 2003.

2. Transport Airplane Directorate, Aircraft Certification Service, U.S. Federal Aviation Administration. Email communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S. July 22, 2003. Flight Safety Foundation, Alexandria, Virginia, U.S.

3. U.S. National Transportation Safety Board (NTSB). "Survivability of Accidents Involving Part 121 U.S. Air Carrier Operations, 1983 Through 2000." Safety Report no. NTSB/SR-01/01. March 2001. Reprinted in FSF *Flight Safety Digest*, October 2001.

4. Barth, Thomas. "AAIR Passenger Airbag System for Transport Aircraft." Published on the Amsafe Aviation Internet site, <http://www.amsafe.com/tca.htm>.

5. U.S. Federal Aviation Regulations (FARs) Part 25.562(b)(5); U.S. Federal Aviation Administration Advisory Circular no. 25.562-1A,

Dynamic Evaluation of Seat Restraint Systems & Occupant Protection on Transport Airplanes, 13(d)(1). Jan. 19, 1996.

6. FAA said that FARs Part 25.785 requires that occupants be protected from head injury by either the elimination of any injurious object within the striking radius of the head, or by padding. "Traditionally, this has required a set back of 35 inches [89 centimeters] from any bulkhead, other rigid interior feature or, where that is not practical, specified types of padding," FAA said. "FARs 25.562 specifies that dynamic tests must be conducted for each seat type installed in the airplane. In particular, the regulations require that persons not suffer serious head injury under the conditions specified in the tests, and that a head-injury criteria (HIC) measurement of not more than 1,000 units be recorded, should contact with the cabin interior occur."

7. Williams, Larry. Telephone interview by Darby, Rick. Alexandria, Virginia, U.S., July 8, 2003. Flight Safety Foundation, Alexandria, Virginia, U.S.

8. Ebel, Wolf. Telephone interview by Darby, Rick. Alexandria, Virginia, U.S., Aug. 4, 2003. Flight Safety Foundation, Alexandria, Virginia, U.S.

9. Morier, Yves. Email communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S. July 25, 2003. Flight Safety Foundation, Alexandria, Virginia, U.S. Morier is regulation director of the European Joint Aviation Authorities (JAA).

10. U.S. Federal Aviation Administration (FAA). "Special Conditions: Airbus Model A319, A320 and A321 Series Airplane; Seats With Inflatable Lap Belts." *U.S. Federal Register,* Volume 67, Aug. 30, 2002, 55703–55706. The special conditions add requirements to FARs Part 25, *Airworthiness Standards: Transport Category Airplanes* for a specific applicant seeking a supplemental type certificate. The special conditions issued for these Airbus models generally are representative of those issued for several transport aircraft types certified in the United States and Europe, said FAA and JAA. Nevertheless, FAA said, "This action [notice of proposed special conditions] affects only certain novel or unusual design features on Airbus model A319, A320 and A321 series airplanes. It is not a rule of general applicability, and it affects only the applicant who applied to the FAA for approval of these features on the airplane. … Finally, it should be noted that the special conditions are applicable to the inflatable lap belt system as installed. The special conditions are not an installation approval."

11. FAA. "Special Conditions: Airbus Model A319, A320 and A321 Series Airplane; Seats With Inflatable Lap Belts."

Further Reading From FSF Publications

FSF Editorial Staff. "Report Recommends Jumping Onto Evacuation Slide as Best Egress Method for Adults Carrying Infants and Young Children." *Cabin Crew Safety* Volume 37 (May–June 2002).

Johnson, Daniel. "Studies Reveal Passenger Misconceptions About Brace Commands and Brace Positions." *Cabin Crew Safety* Volume 33 (May–June 1998).

Gowdy, Van; DeWeese, Richard. "FAA Tests Indicate Most Child Restraint Devices Inadequate in Airline Passenger-seat Use." *Cabin Crew Safety* Volume 29–30 (November 1994–February 1995).

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