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Information
Solutions for a
Competitive
Advantage

**Making
Composite
Repairs to the
787**

How to Determine
Hard and
Overweight
Landing Inspection
Requirements

Avoiding Airplane
Hazardous Energy

AERO

AERO

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AERO

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Information Solutions for a Competitive Advantage



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Boeing has developed tools, information, and training to help airlines repair the 787's composite structure and surfaces.

Making Composite Repairs to the 787

The 787 Dreamliner offers a number of operational benefits due to the airframe comprising approximately half (by weight) carbon fiber reinforced plastic and other composites. As airlines add the 787 to their fleets, they are increasingly interested in repair methods for the airplane's composite structure. Boeing offers information to enable airlines to make effective repairs to many different types of damage — often without taking the airplane out of service.

By **Arne Lewis**, Associate Technical Fellow, Commercial Aviation Services, 787 Service Engineering

The 787's composite structure has airframe maintenance costs that are 30 percent lower than any comparable airplane. This is largely due to its absence of corrosion and fatigue, the two primary drivers for repair and maintenance of the airplane structure. The 787 also weighs, on average, less than more conventional aluminum designs, resulting in greater fuel efficiency. The combination of these two factors made the choice for a composite airframe very appealing to designers and airlines.

This article will help the reader understand why composites were chosen for the 787 and what Boeing is doing to help the repair community transition to repairing composites.

THE EVOLUTION OF COMPOSITES IN COMMERCIAL AVIATION

Aluminum structures have been a mainstay in commercial airplane design for many years. While the evolution of aluminum designs has improved the strength-to-weight ratio, the industry has been seeking double-digit performance improvements in fuel efficiency for new airplanes. Composites, combined with system improvements, have helped provide the path to such improvements.

A composite is a combination of two or more materials (reinforcing elements, fillers, and composite matrix binder) differing in

form or composition on a macro scale. The constituents retain their identities: While they act in concert, they do not dissolve or merge completely into one another.

Composites also offer strength-to-weight ratios that enable lighter weight structures that allow the airplane design to feature items such as larger windows and lower altitude pressures in the cabin. In addition, a composite airplane structure has inherent resistance to fatigue damage and corrosion.

Composites are not new to commercial aviation. In fact, composites have been used in airframe structures since the 1950s, and their use has been increasing

Figure 1: The aftbody sections of the 787 Dreamliner are created using an advanced carbon fiber placement technology

As pictured here, an automated fiber placement (AFP) machine in Boeing's South Carolina facility lays carbon fiber tape using precise patterns and layers to maximize the strength of the barrel.



steadily over the last 45 years. Composite structures on commercial airplanes (see fig. 1) can be all fiberglass layers, all carbon layers, a mixture of the two (often referred to as hybrid parts), or cured with honeycomb core (see fig. 2). Over time, tougher composite materials and enhanced, robust designs have been developed and are being used for primary structure on both the 777 and the 787.

USE OF COMPOSITES ON THE BOEING DREAMLINER

In developing the 787, Boeing determined the most effective use of composites by evaluating every element of the airplane's

structure for function, load carrying capability, and durability. This evaluation resulted in composite materials being used extensively on the 787 airframe, making these materials dominant in areas that are traditionally aluminum (see fig. 3).

Many studies, tests, and demonstrations were performed to validate the strength and impact resistance of the composite material, particularly in comparison to aluminum structures. Additionally, in conjunction with airline partners, many damage scenarios were reviewed and the time and effort required to repair each type of damage were evaluated.

The damage scenarios and impact testing provided necessary information to assure areas prone to damage were

strengthened and designed to enable repairs if damaged.

Due to its use of toughened carbon materials, solid laminate composite structure is inherently very durable. Tests have shown the 787 fuselage can resist damage that would easily occur in an aluminum fuselage.

MAINTAINABILITY: A KEY 787 DESIGN REQUIREMENT

The ability of airlines to maintain the 787 was a key consideration during its development. The airplane's structure was designed for robustness in an in-service environment. Maintenance and repair

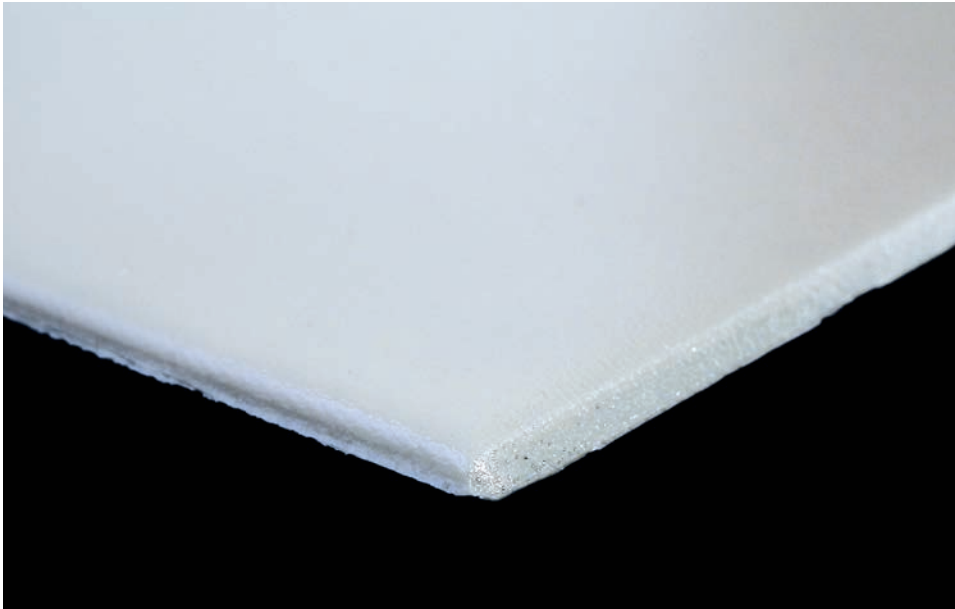


Figure 2: Types of composites

Composites on commercial airplanes include fiberglass solid laminates (top), carbon solid laminates (center), or cured with a honeycomb core (bottom).

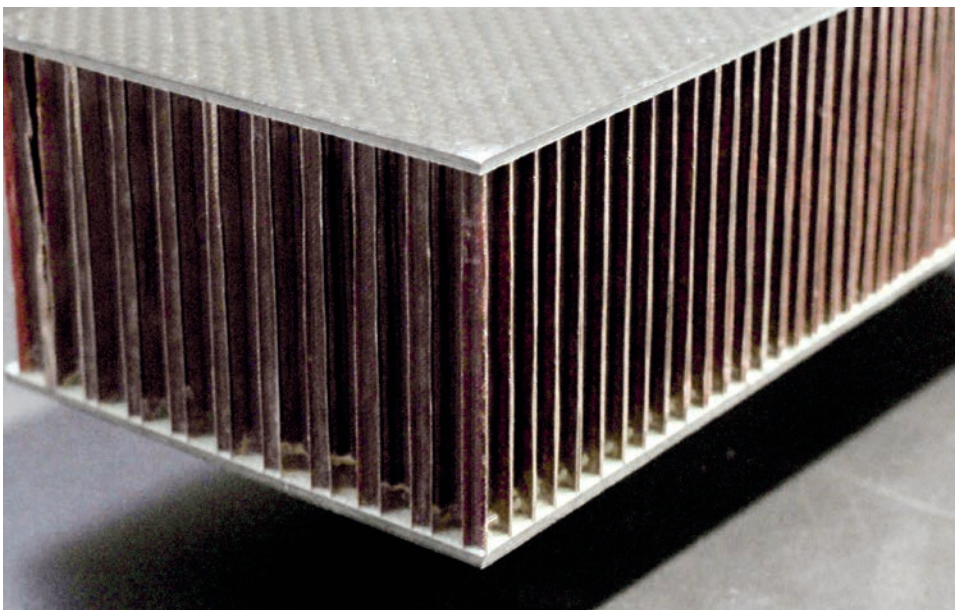
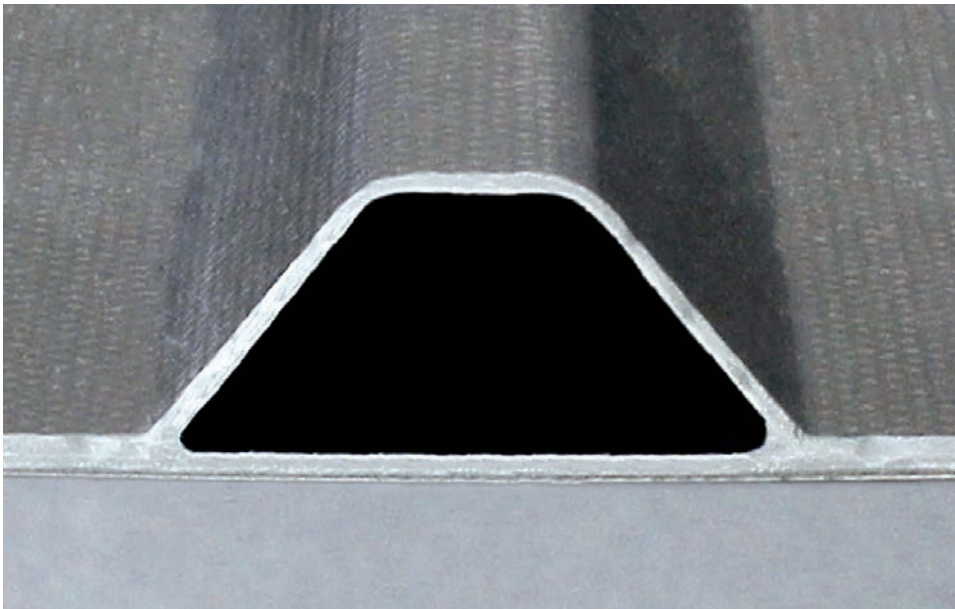


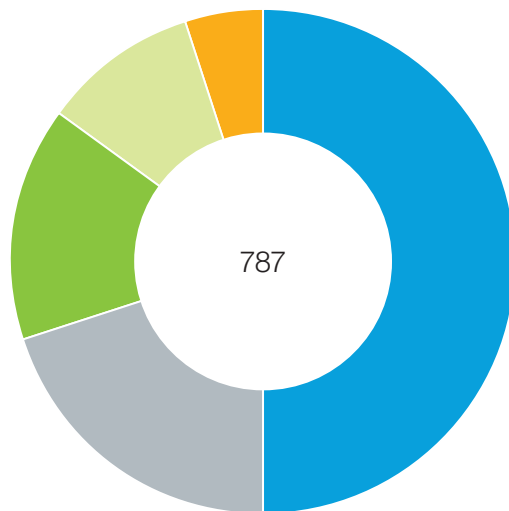
Figure 3: Composites on the 787

Composites comprise more than 50 percent of the 787 airframe.



Materials

Carbon laminate Carbon sandwich Other composites Aluminum Titanium Titanium/Steel/Aluminum

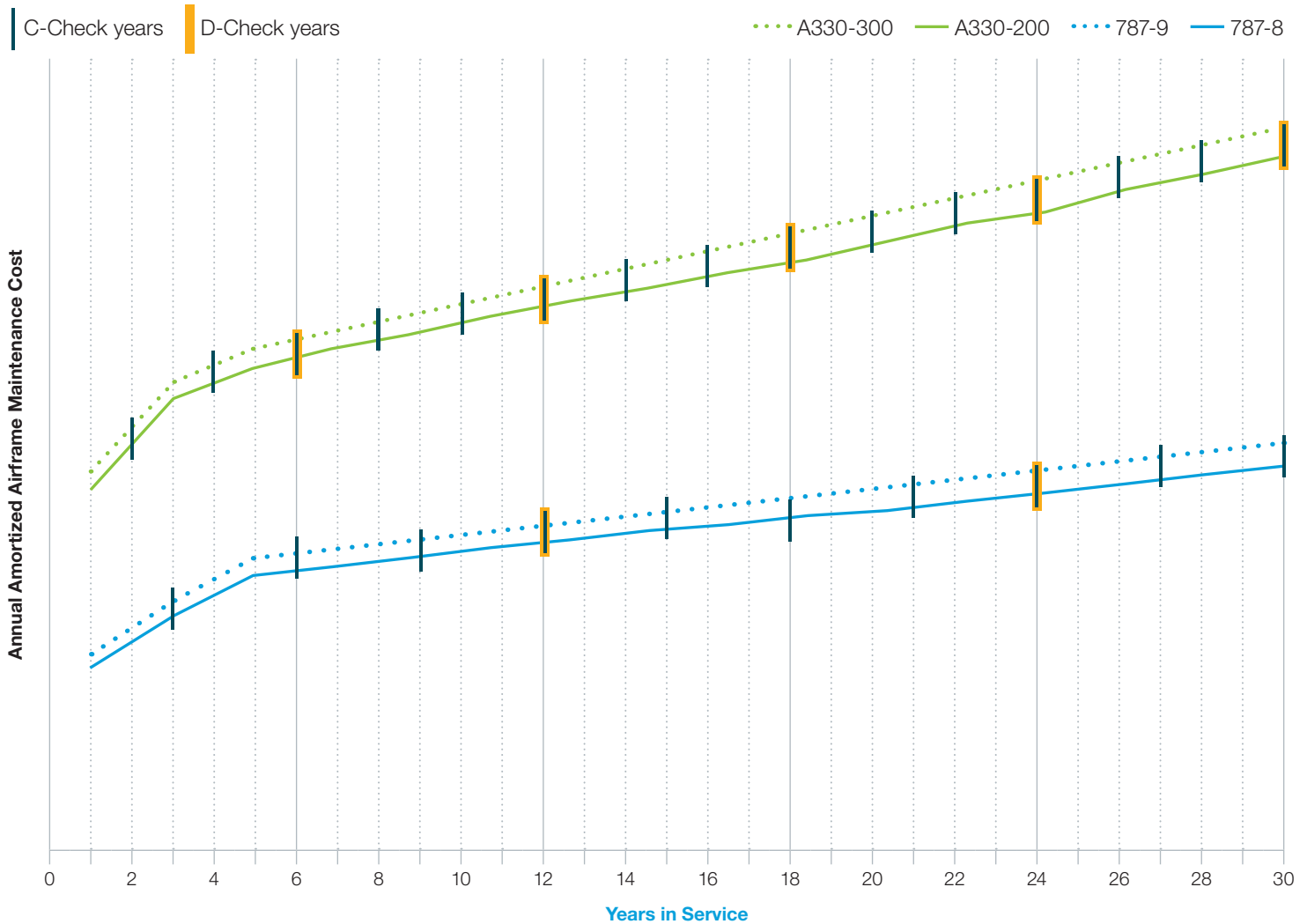


Materials by weight

Composite Aluminum Titanium Steel Miscellaneous

Figure 4: 787 maintenance cost reductions

In addition to longer intervals between scheduled maintenance checks, the 787 reduces labor hours by approximately 20 percent on a per-check basis. Total scheduled labor hours are reduced by approximately 60 percent over the life of the airplane. These reductions in required scheduled maintenance are a significant contributor to the 787's overall 30 percent airframe and systems maintenance cost reduction target.



considerations were inherent in the design. Boeing developed inspection equipment and techniques to support unplanned maintenance, such as airplane-on-ground events.

The 787 program had a maintenance cost reduction target of approximately 30 percent (see fig. 4). More than 100 design requirements and objectives were related to repair and maintenance.

Operators' in-service experience has demonstrated the robustness of the 787's composite structure. For example, one operator reported that hangar scaffolding came in contact with one of its 787s. The discrepant area was inspected fully and found not to have any type of delaminations or damage. The airline also reported that

this type of force applied to an aluminum fuselage would have caused damage that would have taken the airplane out of service for several days.

NEW REPAIR INSTRUCTIONS IN THE 787 STRUCTURAL REPAIR MANUAL (SRM)

Successful repairs to composite structure require the repair technician to strictly follow detailed and accurate repair instructions. For quality enhancement, the 787 SRM builds upon the established composite repair techniques and materials that Boeing successfully developed for the 777. Since the 787 has extensive composite structure, more than 20 new sections were added to

787 SRM chapter 51 to explain repair processes and procedures for:

- Pre-impregnated repairs (both original cure temperature and reduced temperature cure) use material that has been frozen, thawed, and then cured with heat.
- Wet layup repairs use dry fabric that is impregnated with resin.
- Bolted repairs for common architecture elements, including the skin-stringer, frame, and shear tie. This repair uses sheet metal (aluminum, titanium, or steel/corrosion-resistant stainless steel) bolted onto the structure. The repair can be flush with the airplane skin or, in

Figure 5: New inspection techniques

Maintenance personnel can first use a ramp damage checker (left and center) and, if necessary, the wheel probe (right) to quickly assess the condition of laminate and sandwich structures on the 787.



some cases, might protrude into the airstream.

- Quick composite repairs (see “Special kit enables airlines to make quick composite repairs” on page 12).

The new sections in the SRM address clean environments for bonding repairs on the airplane, better ply compaction methods to reduce porosity, drying solid laminate, and performing heat surveys to assure proper heat distribution during the repair cure. Most of the repairs in the 787 SRM use tools and equipment that have been used to repair legacy airplane composite components and have been available on the market for many years. One exception is the use of a double

vacuum bag debulk (DVD) system, a newer process that is implemented for several 787 repairs. The 787 SRM describes how technicians can construct a DVD box from simple lumber materials.

ASSESSING DAMAGE ON THE 787

Damage to composite structure can manifest itself differently than in aluminum structures. Because aluminum usually dents or tears, damage is typically visible. In contrast, composites will show rub marks or a small dent. If there is enough energy transferred, a delamination of plies may occur. When the delamination is critical, it will be visible on the exterior side

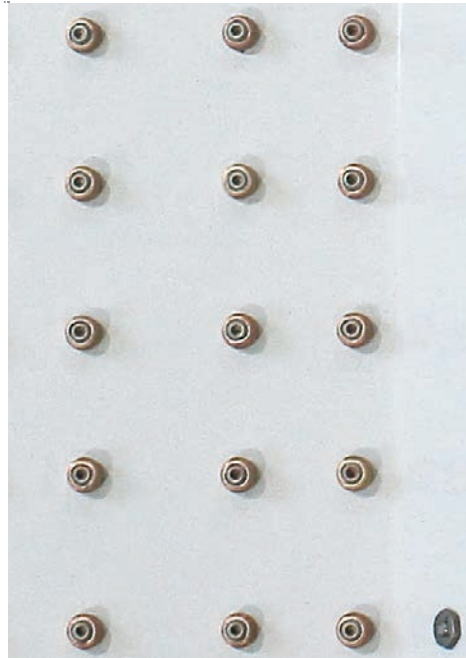
and/or on the interior side of the fuselage. Because of this different manifestation of damage, the aircraft maintenance manual (AMM) addresses specific conditions and inspections that need to be accomplished.

The development of the 787 also included the creation of a simplified inspection device to aid maintenance personnel in assessing the extent of damage. The inspection device, called the ramp damage checker, was developed specifically for the ramp technician. For additional damage characterization and more in-depth inspections, a wheel probe was developed to speed and simplify the assessment of laminate and sandwich structures (see fig. 5). Heat damage can be detected using instrumented inspection

Figure 6: Repair method considerations

Airlines have the option of bolted or bonded repairs. Each approach has its advantages.

	BOLTED REPAIR	BONDED REPAIR
Benefits	<ul style="list-style-type: none"> ■ Faster processing time. ■ No risk of heat damage. ■ Repair material not sensitive. 	<ul style="list-style-type: none"> ■ No protruding parts. ■ Lightweight. ■ Category A (permanent repair).
Other Considerations	<ul style="list-style-type: none"> ■ Heavier. ■ Hole drilling must be done with care and caution. ■ Repairs may be Category B (require inspections). 	<ul style="list-style-type: none"> ■ Slower processing time. ■ Risk of heat damage and porosity. ■ Material is time, temperature, and moisture sensitive.



methods as outlined in the nondestructive inspection manual.

Please note that any significant impact or damage needs to be inspected per the instructions in the 787 SRM and/or the 787 AMM, chapter 5.

ADVANCED REPAIR TECHNOLOGIES

Boeing has extensive experience supporting composite structures in service. In addition, Boeing participates actively in forums such as the SAE-sponsored Commercial Aircraft Composite Repair Committee to gain and share knowledge about composite repairs.

The repair technologies Boeing has developed for the 787 build upon the success of 777 composite repairs. Numerous repair tests were made based on repairs described in the SRM to validate repair capabilities. Repair tests included static and fatigue (including accidental damage and environment effects), tension, compression, and combined loads.

Boeing's research and in-service experience have demonstrated repairs for all areas of composite structures using bonded repairs, bolted repairs, or a hybrid comprising bonding with a bolted substructure (see fig. 6). There are various factors an airline needs to consider when choosing which type of repair to make. The SRM only allows you to choose the repair

method that restores ultimate load carrying capabilities and meets the operational needs of the airline. The airline needs to factor in:

- Which repair method will get the airplane back into revenue service the soonest.
- Repair environment (weather condition, hangar availability).
- Repair material availability.
- How much weight will be added to the airplane.
- How much aerodynamic drag will be added to the airplane.

When damage is determined to be minor, quick repairs to the composite surface can be accomplished in about an hour using a prepackaged time-limited

Special kit enables airlines to make quick composite repairs

Because ramp rash and other minor mishaps are a fact of life for a commercial airplane, Boeing has developed a quick way to repair composite materials. Previously, the most common way to fix composite skin damage involved moving the airplane to a maintenance hangar and using sophisticated cure controllers and heater mats to cure epoxy resins and adhesives in place. In contrast, the 787 Quick Composite Repair (QCR) kit allows

minor damage to be repaired at the gate, quickly and with no electricity.

To create the kit, Boeing's research team narrowed 150 candidate adhesives down to 10, evaluating them in laboratory tests during a four-year period. The adhesives were subjected to extreme hot and cold thermal conditions and tested for their shelf life, curing temperatures, and bond strength, among other parameters.

The QCR kit includes sanding disks, gloves, lint-free wipes, vacuum bag film, structural patches, anti-caul foil patches, heat pack, and adhesives.

The areas of the airplane where Quick Composite Repairs can be used and application instructions are provided in the 787-8 and 787-9 SRMs. QCR kits can be obtained through Boeing Material Services.

composite repair kit. (See "Special kit enables airlines to make quick composite repairs" above.)

Regardless of which method is selected, all 787 SRM repairs are structurally acceptable when applied as directed in the SRM.

SPECIAL DAMAGE CASES

Because of the uniqueness of the 787 composite structure, many repair questions from operators have centered on two specific types of damage: lightning strikes and large area damage.

Lightning strikes. Studies have shown that the airplane surface shapes are the determining factor for lightning strike attachment. (See *AERO*, second-quarter 2012.) While lightning strike damage can occur to composite structures, the damage is often minimal and repairable with a time-limited repair. The damage must first be inspected for size and depth. Once the size and depth are known, the airline will need to review the SRM for allowable damage limits and decide on the proper course of action. There have been many instances where the lightning damage can be sealed with resin or aluminum foil tape as a temporary repair

and service can resume immediately until the airplane can be put into maintenance at a more convenient time. If the damage is larger than allowable damage limits, most damage can be repaired using wet layup methods that have been used in the aviation industry for many years.

Large area damage. This type of damage is generally considered to be an area of approximately 3 feet by 3 feet (1 meter by 1 meter) or larger. Damage of that size and larger is repaired using a pre-cured panel bolted in place with splicing straps and doublers. This method has been successfully performed in-service on 787 fuselage

It is important that airlines receiving 787s review their capabilities, knowledge, repair processes, repair materials, and training to ensure they are prepared for repair. Because of the increased use of composites on the 787, Boeing has developed a suite of composite structure repair classes specifically for the 787.

structures. In cases where the fuselage was damaged through the thickness, the Boeing airplane-on-ground team was dispatched and successfully performed permanent bonded and bolted repairs.

BOEING STRUCTURES REPAIR TRAINING

It is important that airlines receiving 787s review their capabilities, knowledge, repair processes, repair materials, and training to ensure they are prepared for repair. Because of the increased use of composites on the 787, Boeing has

developed a suite of composite structure repair classes specifically for the 787. These classes include:

- [Line and Base Mechanics course](#). Standard Air Transport Association (ATA) 104 level 3 course.
- [Technicians course](#). Designed for mechanics who perform composite repairs on a daily basis.
- [Engineers course](#). For engineers who design the repairs for the technicians.
- [Inspectors course](#). Designed for line, base, and back shop inspections.

SUMMARY

Boeing has developed unique tools, information, and training to help airlines make repairs to the 787's composite structure and surfaces. These tools enable airlines to make effective repairs to many different types of damage, in many cases without leaving the gate. [A](#)



Revised inspection procedures for reported hard and overweight landings help maintenance determine the appropriate level of inspection.

How to Determine Hard and Overweight Landing Inspection Requirements

Boeing has developed a new inspection procedure that maintenance personnel can use immediately after the flight crew reports a hard or overweight landing to determine the appropriate level of inspection. This new procedure will reduce maintenance costs for airlines by reducing unnecessary inspections.

By Michael Harrison, Maintenance Engineer, Structures and Mechanical Systems;
Jack Hagelin, Loads and Dynamics Technical Fellow; and
Gary Bartz, Chief Design Engineer, DC-9/MD-80/MD-90/717

Boeing airplanes are designed to withstand touchdown rates well above typical touchdown rates seen during daily operations. Even a perceived hard landing is usually well below these design criteria. Boeing policy is that a pilot report is the only factor that consistently identifies a hard landing. If the pilot believes that a hard landing may have occurred, it should be reported. A maintenance inspection will determine if further maintenance action is needed.

Procedures contained in aircraft maintenance manuals (AMMs) for hard landing inspections include a single vertical load factor (VLF) value, in Gs, to assist operators in determining whether a hard landing was experienced.

Boeing is revising the AMM hard and overweight landing inspection procedures for all commercial models to provide an option for operators to utilize flight recorded data to determine the level of inspection required based on landing weight, VLF, and roll angle. The level of inspection may be

reduced if the data shows that these parameters are within prescribed limits.

AMMs prescribe a special maintenance inspection whenever a hard or overweight landing has been reported by the flight crew. A review of both hard and overweight landing inspection procedures indicated that the airplane items recommended to be checked were similar. As a result, Boeing has combined both inspections into one procedure for some models, and intends to expand this to most other models.

Figure 1: AMM hard/overweight landing inspection label

The new AMM hard and overweight landing inspection procedures split the Phase I inspection into two parts using the nomenclature below.

7-Series Inspections	MD Models and 717
Phase IA	A-1 Check
Phase IB	A-2 Check
Phase II	B Check



The revised procedures specify limits for VLF and roll angle for landing weights at and above the maximum certified landing weight. In addition, the Phase I inspection is split into two parts: Phase IA and Phase IB (see fig. 1). This article provides background about the new procedures and how operators can implement them.

CHANGING THE HARD AND OVERWEIGHT LANDING INSPECTION PROCEDURE

A coordinated effort within Boeing, combined with feedback from several operators, has resulted in a change to the hard and overweight landing inspection procedures for all Boeing airplane models. This new standardized procedure is found in AMM Section 05-51.

In some prior AMM procedures, a complete Phase I inspection has been required whenever a hard or overweight landing is reported by the flight crew, even if the flight recorded data shows that the landing was within normal landing limits. The flight crew report resulted in a Phase I inspection that involved pulling the airplane out of service and into a hangar for several hours for inspections. Experience has shown that most landings that are called “hard” by the flight crew are in fact within the structural design limits.

The revised procedure allows the operator to waive some of the Phase I inspections if the airplane’s flight recorded data of VLF and roll angle from the Flight Data Recorder (FDR), or other equivalent recording device, indicate that the landing was within specified limits. The new inspection procedure allows a shortened

inspection of less than an hour without removing the airplane from flight operations if the relevant data (i.e., roll angle, peak VLF, and landing weight) show the landing was below prescribed limits. This new procedure will reduce service disruptions and maintenance costs while maintaining the same level of airplane integrity.

INSPECTION PROCEDURE FOR LANDINGS REPORTED AS HARD

Currently the inspection procedure on some models is divided into Phase I and Phase II inspections. The new standardized procedure splits the Phase I inspection into two parts: IA and IB (see the left side of fig. 2). Phase IA is a visual inspection, while Phase IB may include inspections requiring removal of parts. Phase IA is required if the

Figure 2: Revised hard/overweight landing inspection flow chart

Previous hard landing procedures dictated a lengthy inspection whenever the flight crew reported a hard landing. The revised procedures use flight recorded data to help maintenance crews determine the level of inspection required.

(Airplane Model)
Aircraft Maintenance Manual
Landing Inspection Flow Chart

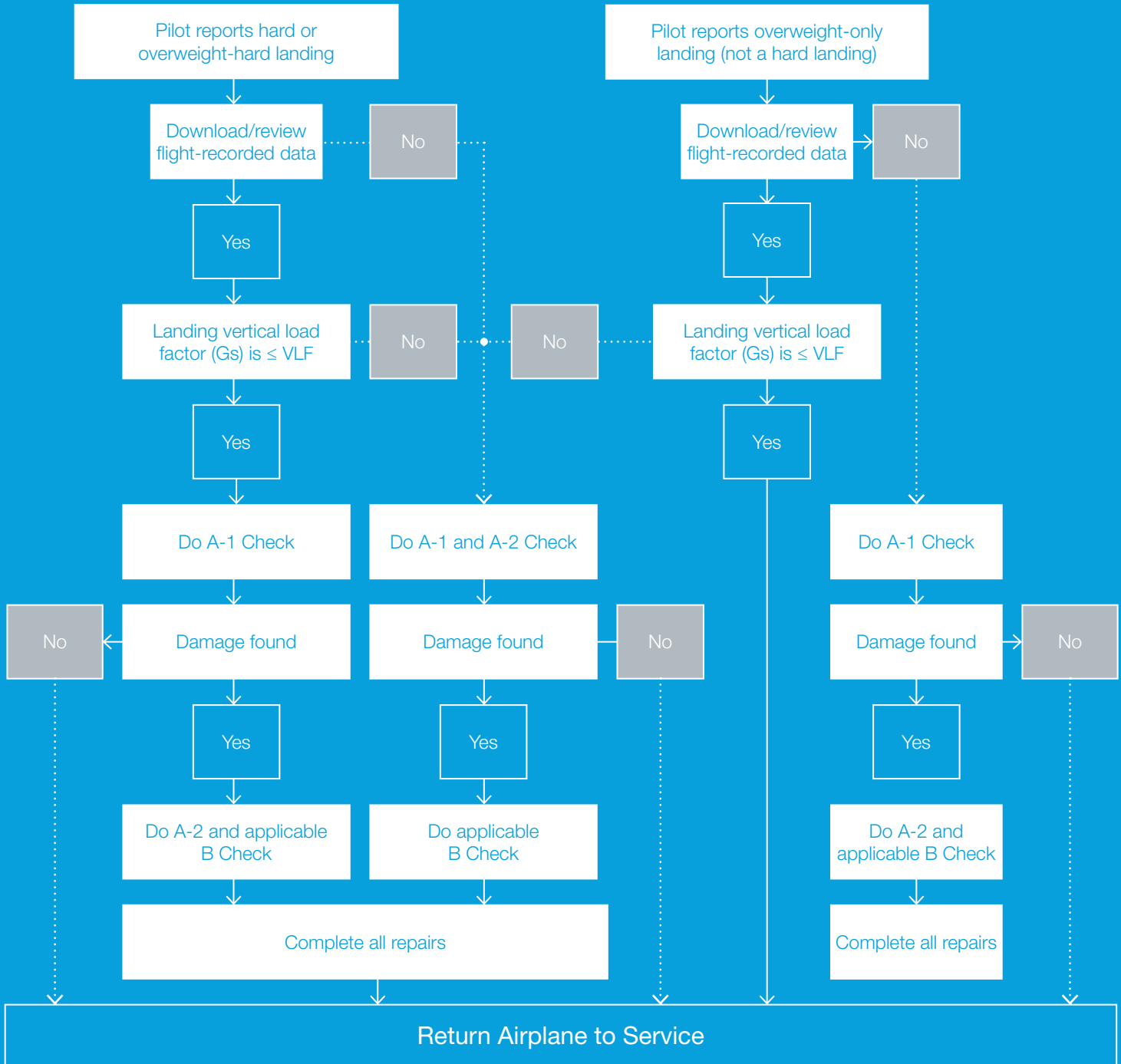
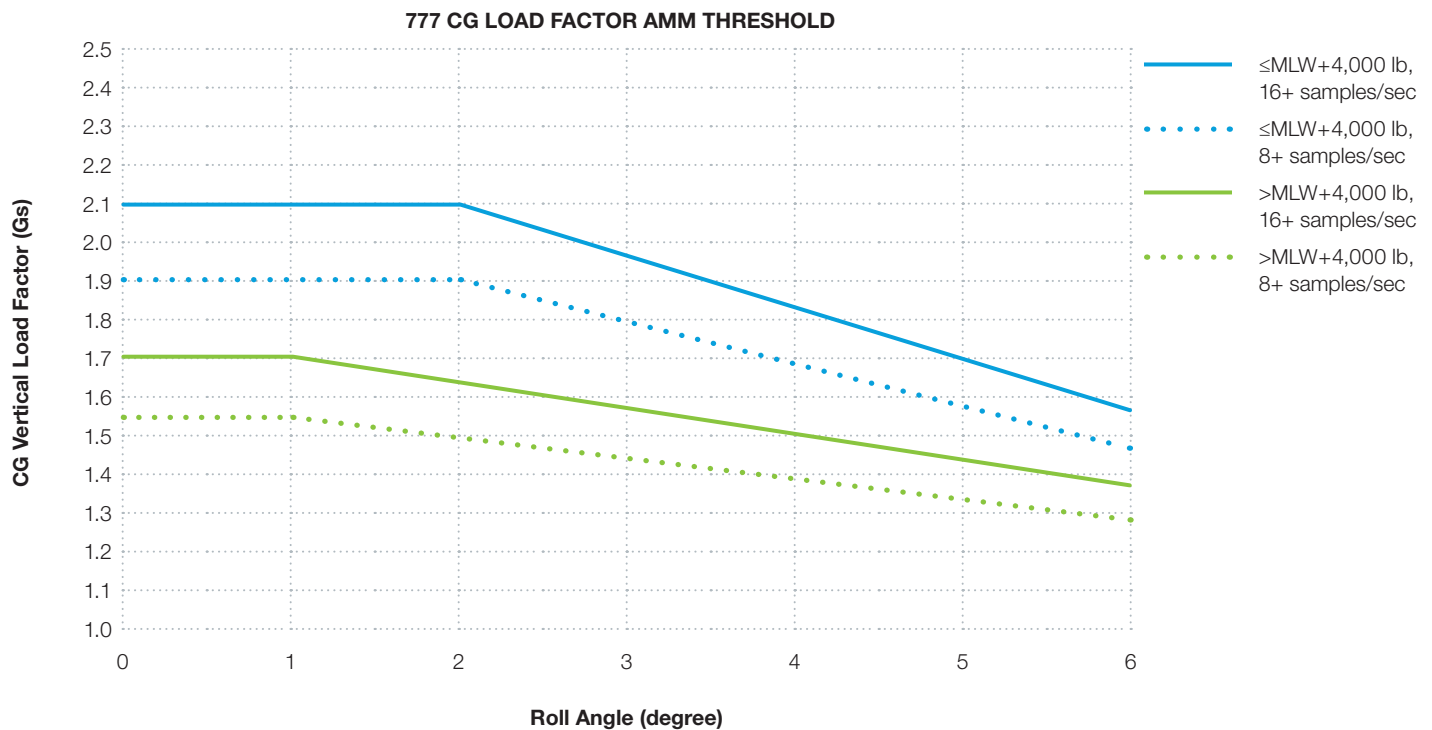


Figure 3: Revised landing vertical load factor (VLF) inspection limits

A Phase IB inspection can be waived if the touchdown peak VLF is less than the prescribed limit, which is now a function of roll angle.



flight crew reports a hard landing. Phase IB can be waived if:

- No damage was found in the Phase IA inspection.
- The touchdown peak VLF was less than the prescribed limit, which is now a function of roll angle and landing weight (see fig. 3).
- The roll angle was less than 6 degrees.
- It was not a bounced landing.
- It was not a hard nose-gear landing. (The flight crew must specify whether the hard landing was on the main or nose gear because the VLF limit is only applicable to main gear landings.)

The Phase II inspection remains unchanged in this new procedure. (For 767 and 777 models, some main gear fuse pin inspections have been moved from Phase IB to Phase II to further reduce inspection time.)

INSPECTION PROCEDURE FOR OVERWEIGHT LANDINGS

Overweight landing inspections can now also use flight recorded landing data to determine the level of inspection required. The Phase IA inspection, at a minimum, will be required for overweight landings that are also reported as hard by the flight crew. For overweight landings that are not reported as hard, the inspection is waived, provided the flight recorded data of VLF and roll angle from the FDR or other equivalent recording device are below the specified limits (see the right side of fig. 2). In addition, the definition of an overweight landing (for the purpose of the structural inspection) is changed to any landing that is above the maximum certified design landing weight plus a small weight tolerance. This weight tolerance represents about 1 percent of the design landing weight and is added in recognition of the potential for landing slightly above the

design landing weight due to unanticipated winds and other factors.

NEW HARD/OVERWEIGHT LANDING INSPECTION LIMITS

As part of the new hard/overweight landing inspection procedure, the landing VLF limits in the AMM are revised as follows (see fig. 3 as an example based on the 777):

- The range of VLF limits is expanded from 0 degrees to 6 degrees of roll angle.
- A VLF limit line for landing weights above the maximum landing weight (MLW), including a small weight tolerance, is added, enabling this chart to be used for overweight landings.
- The VLF limits are based on at least eight samples per second recording rate.
- The roll angle values are based on at least four samples per second recording rate.

Flight recorded data

Using these new and optional inspection procedures (flight recorded data to determine the level of inspection) depends on how quickly the relevant parameters (landing weight, vertical load factor [VLF], and roll angle) can be obtained after a reported event. Thus, download time for retrieving the relevant parameters from flight recorded data for analyzing hard or overweight landings will vary depending on the vintage of the airplane model and the type of recording equipment installed. For example, airplanes produced earlier than the mid-1980s have flight data recorders (FDRs) and analog flight data acquisition units flight recording systems that would record VLF and roll angle parameters but with inadequate sampling intervals for accurate landing analysis. However, data from any vintage airplane model can be downloaded by bringing the FDR into a lab and using FDR data reduction equipment, such as an Avionica ruggedized service

unit, Honeywell Hand Held Download Unit, or other similar units.

Airplanes with more modern digital subsystems are equipped with digital flight data recorders (DFDRs) and digital flight data acquisition units (DFDAUs). DFDAUs are frequently, but not always, combined with an Aircraft Condition Monitoring System (ACMS) with easier and quicker access to flight recorder data needed for flight performance and engine trending analysis, as well as hard/overweight landing analysis. ACMS application software processes selected parameter data through a dedicated processor, separate from the mandatory FDR processor. The ACMS data can then be recorded using an optical quick access recorder or transmitted to a ground station using an Aircraft Communications And Reporting System (ACARS) without the need to remove and download the DFDR.

Data from airplanes having these easier and quicker recording systems with access to flight recorder data can be considered to be equivalent data from data downloaded from the DFDR/FDR—provided the operator develops a means to validate equivalency. The means of determining this equivalency is dependent on meeting certain criteria, such as sampling rate, data validation, and configuration control if it is airline or non-OEM modifiable software, to determine the level of inspection required. One means, but not the only means, to do this would be to download data from a landing and compare the applicable FDR parameters (known good data) and the corresponding parameters from the equivalent recording device (i.e., validation of data and sampling rate for a common reference time period), along with the airline procedures that control the user-modifiable software for these parameters.

787 HARD/OVERWEIGHT LANDING INSPECTION LIMITS

The 787 AMM inspection procedure for hard/overweight landings currently makes use of a hard landing maintenance page that is available immediately after touchdown and is therefore not being revised. However, the advanced systems and recording equipment on the 787 enables the AMM inspection procedure to include additional parameters beyond the peak VLF. The airplane sink rate, pitch attitude, crab angle, roll angle, roll rate, and pitch rate are also used to determine if an inspection is required following a hard or overweight landing. If all parameters fall within the limits specified in the AMM, no inspections are required. While more advanced, this approach of using airplane recorded data is similar to what is/will be used on other models.

The capability to identify a hard nose-gear landing is also available on the 787 by using the body pitch rate just prior to nose-gear touchdown. This new capability is available only on the 787.


The 787 inspection procedure is divided into Phase I and Phase II inspections. However, the Phase I inspection is not split into two parts as with other models. The procedure contains tables of parameter values that maintenance personnel can compare to the actual landing values obtained from the airplane.

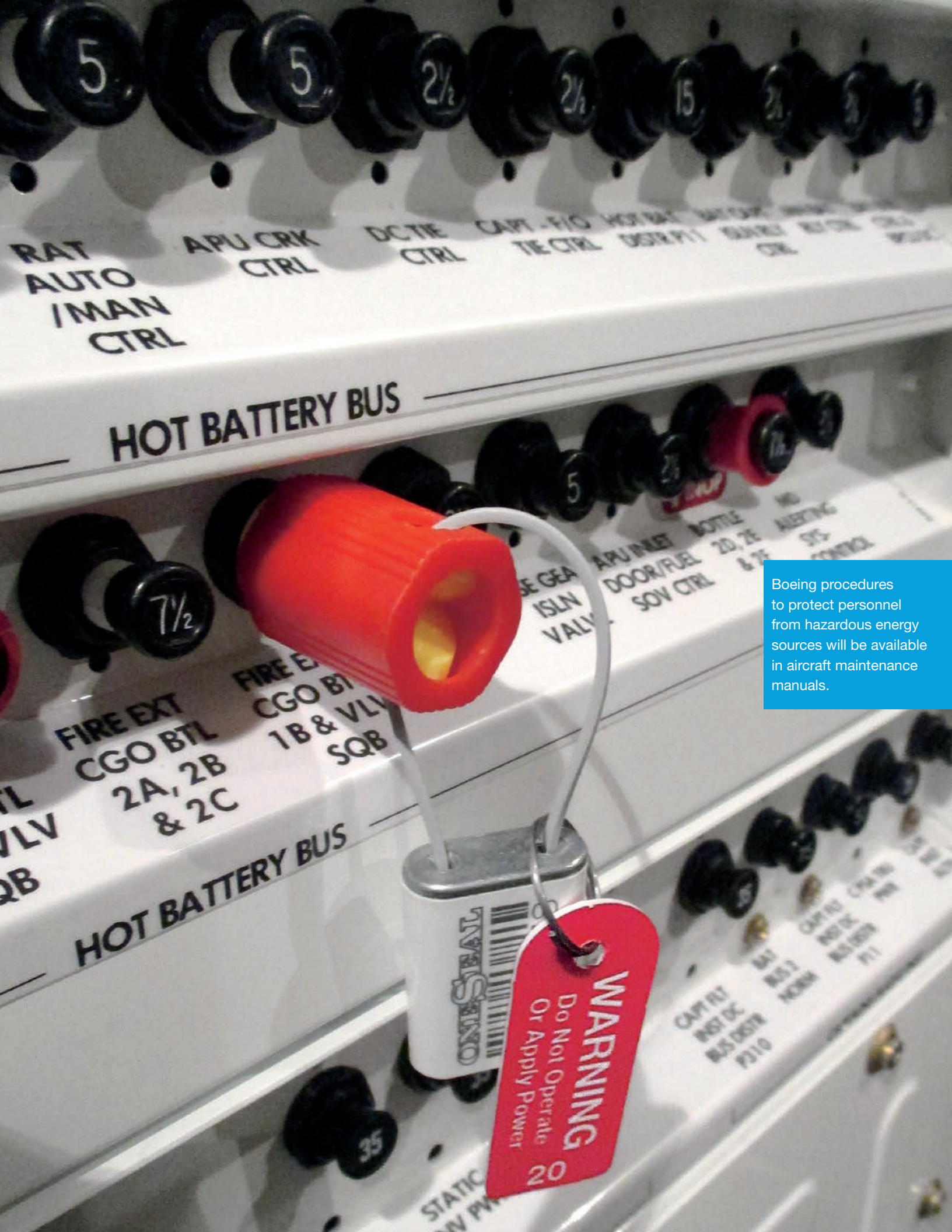
The values of the relevant parameters can be found by accessing the Air Transport Association (ATA) 51 Landing Conditions maintenance page from the 787 flight deck using the multifunction display or a maintenance laptop. After selecting the appropriate AMM table based on landing weight, maintenance personnel can then compare the values from the ATA 51 Landing Conditions maintenance page to the values in the AMM table. If all of the values are within the limits specified in the AMM table, no inspection is required. If any value is outside the limits, the full Phase I inspection is necessary.

Starting in 2015, some models of the 777 will also incorporate a hard landing display page similar to the 787.

SUMMARY

Revised AMM inspection procedures for reported hard and overweight landings use flight recorded data of VLF and roll angle from the FDR or other equivalent recording devices to help maintenance personnel determine the appropriate level of airplane inspection. This revision will result in maintenance cost savings to operators by way of fewer inspections and shorter down times when inspections are needed. These improved AMM inspection procedures have already been released for some models and are being planned for most models of Boeing airplanes.

For more information, contact designofficegroup@boeing.com. 



Boeing procedures to protect personnel from hazardous energy sources will be available in aircraft maintenance manuals.

Avoiding Airplane Hazardous Energy

Exposure to energized airplane systems can result in serious injury to maintenance technicians if proper controls are not followed. Hazardous energy controls are required when technicians could be exposed to unexpected energization, startup, or release of hazardous energy during service or maintenance activities. Boeing has made internal process improvements to control airplane hazardous energy within Boeing factories and on Boeing flight lines and is making these improvements available to the aviation industry through updates to the aircraft maintenance manual (AMM).

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Airplane hazardous energy can present safety risks for maintenance technicians when working on airplanes. This is true both when an individual technician is performing service and maintenance, and also when multiple teams are working independent of each other on the airplane. In some cases, one team's work may interfere with that of another team and introduce an unsafe condition. For example, one team may finish its job early and reenergize the airplane system, endangering another team that is still working on the airplane. Airplane hazardous energy also can be a problem when technicians are unfamiliar with the high level of automation in an airplane system. For example, on fly-by-wire airplanes, the flight

controls are computer-controlled and can move unexpectedly in response to fault detection.

This article describes some of the key sources of hazardous energy and how airlines can minimize the risk to technicians working around them.

POTENTIAL SOURCES OF HAZARDOUS ENERGY


Boeing has identified a number of potential sources of hazardous energy relating to airplane production, most of which also apply to maintenance operations, including the following:

- **Electrical**, such as primary external power at 115 volts (V) alternating current (AC) buses, auxiliary-power-unit (APU) generator power at 115 VAC buses, and integrated-drive generator power at 115 VAC buses.
- **Thermal**, including pitot probe, angle-of-attack sensor, wing anti-ice, window heat, heated drain mast, nitrogen-generating system exhaust, and cabin air compressor system.
- **Pneumatic**.
- **Hydraulic**, such as the airplane's pressurized hydraulics.
- **Mechanical**, including flight-control surfaces, jackscrews, torque tubes,

Figure 1: Changes to AMM task titles

AMM task titles are being changed to better identify hazardous energy AMM tasks.

Existing AMM Task Title


777
AIRCRAFT MAINTENANCE MANUAL

TASK 24-22-805
2. **Supply Electrical Power**

A. Location Zones
Zone _____ Area _____
211 _____ Flight Compartment, Left

B. Procedure
SUBTASK 24-22-00-860-800
(1) Do one of these tasks to supply electrical power to the plane:
(a) Do this task: **Supply** Primary External Power, TASK 24-22-00-860-801
(b) Do this task: **Supply** Secondary External Power, TASK 24-22-00-860-802
(c) Do this task: **Supply** APU Generator Power, TASK 24-22-00-860-803
(d) Do this task: **Supply** IDG Power, TASK 24-22-00-860-804

————— **END OF TASK** —————


TASK 24-22-806
3. **Remove Electrical Power**

A. Location Zones
Zone _____ Area _____
211 _____ Flight Compartment, Left

B. Procedure
SUBTASK 24-22-00-860-800
(1) Do one of these tasks to supply electrical power to the plane:
(a) Do this task: **Remove** Primary External Power, TASK 24-22-00-860-807
(b) Do this task: **Remove** Secondary External Power, TASK 24-22-00-860-808
(c) Do this task: **Remove** APU Generator Power, TASK 24-22-00-860-809
(d) Do this task: **Remove** IDG Power, TASK 24-22-00-860-810

————— **END OF TASK** —————

New AMM Task Title


777
AIRCRAFT MAINTENANCE MANUAL

TASK 24-22-805
2. **Electrical Power Activation**

A. Location Zones
Zone _____ Area _____
211 _____ Flight Compartment, Left

B. Procedure
SUBTASK 24-22-00-860-800
(1) Do one of these tasks to supply electrical power to the plane:
(a) Do this task: **Activate** Primary External Power, TASK 24-22-00-860-801
(b) Do this task: **Activate** Secondary External Power, TASK 24-22-00-860-802
(c) Do this task: **Activate** APU Generator Power, TASK 24-22-00-860-803
(d) Do this task: **Activate** IDG Power, TASK 24-22-00-860-804

————— **END OF TASK** —————

TASK 24-22-806
3. **Electrical Power Deactivation**

A. Location Zones
Zone _____ Area _____
211 _____ Flight Compartment, Left

B. Procedure
SUBTASK 24-22-00-860-800
(1) Do one of these tasks to supply electrical power to the plane:
(a) Do this task: **Deactivate** Primary External Power, TASK 24-22-00-860-807
(b) Do this task: **Deactivate** Secondary External Power, TASK 24-22-00-860-808
(c) Do this task: **Deactivate** APU Generator Power, TASK 24-22-00-860-809
(d) Do this task: **Deactivate** IDG Power, TASK 24-22-00-860-810

————— **END OF TASK** —————

push rods, linkages, control cables, powered doors, escape slides, powered seats, landing gear, thrust reversers, fan cowls, fan blades, springs, gears, and ram air turbines.

HAZARDOUS ENERGY AWARENESS

In general, technicians must be aware of factors such as residual pressure (sometimes referred to as “stored energy”), backup systems, latched faults, and unexpected movement when working on airplane systems containing hazardous energy. On fly-by-wire airplanes, a maintenance action may generate an unintended consequence on the airplane. Situations involving hazardous energy include:

- **Residual pressure.** In the deactivation procedures for hydraulic, pneumatic, or pressurized airplane systems, the residual pressure must be dissipated and the zero energy state must be verified. Residual pressure is often

released by opening a relief valve or cycling the system. Maintenance personnel must be aware of the potential for residual pressure to remain in the airplane system and follow the steps in the maintenance procedure to dissipate it prior to starting work.

- **Backup systems.** Some airplane systems have automated backup systems, and in many cases, these systems must be disabled in order to properly address sources of hazardous energy. Maintenance personnel should be aware of the way systems are integrated and that automated battery backup systems can reenergize airplane systems.
- **Unexpected movement.** Airlines should ensure that maintenance personnel are warned of the potential for unexpected movement of airplane components (e.g., flight control surfaces and hydraulic actuators) and cleared from the area prior to reenergizing.

- **Latched faults.** On fly-by-wire airplanes, disconnecting electrical connectors to a monitored component may generate latched faults, requiring numerous hours of work to clear the latched faults. Maintenance personnel must understand these latched faults must be cleared prior to reenergizing in order to prevent unexpected flight movement of flight controls. Maintenance personnel should be mindful of the possibility of excessive fault generation when removing an electrical connector.

IMPLEMENTING HAZARDOUS ENERGY CONTROL PROCEDURES IN THE AMM

Boeing is enhancing the AMM to better align with the hazardous energy control procedures (HECP) implemented as part of the safety program implemented in the company’s factory.

Boeing periodically reviews the HECPs created for use by Boeing factory personnel and on the flight lines to determine whether

Figure 2: The lockout, tagout, and tryout (LOTO) system

The lockout, tagout, and tryout system is designed to clearly communicate about potential energy hazards to maintenance personnel. Lockout (left) involves placing a lockout device on the airplane system. Tagout (center) places a warning tag on the airplane system. Tryout (right) is verification that the airplane system is in a zero-energy state.

Lockout



Tagout



Tryout



they can be applied with AMM procedures to better address hazardous energy. Applicable hazardous energy AMM tasks are revised by integrating relevant content from the HECs. To retain the effectiveness of current air-carrier maintenance procedures, only AMM tasks directly used to control hazardous energy are updated. The updates to hazardous energy AMM procedures are scheduled to begin in late 2014.

IDENTIFYING HAZARDOUS ENERGY PROCEDURES IN THE AMM

To help technicians distinguish the hazardous energy AMM procedures from other types of maintenance procedures (e.g., servicing, component removal, inspection, and test procedures), Boeing is enhancing the AMM to clearly identify AMM tasks directly related to hazardous energy.

For existing hazardous energy AMM tasks, the AMM task title is changing to include the terms “Deactivation” or “Activation” (see fig. 1). Additionally, all airplane systems will be reviewed to determine whether new standalone “Deactivation” or “Activation” procedures need to be added to the AMM.

COMMUNICATING TO MAINTENANCE PERSONNEL ABOUT POTENTIAL HAZARDS

Boeing recommends that airlines implement a system in their maintenance procedures that clearly communicates to maintenance personnel the potential risks associated with hazardous energy and the importance of compliance with AMM procedures. One such system is lockout, tagout, and tryout (LOTO) (see fig. 2), which establishes a safe level of protection before the technician performs maintenance on the airplane. The safety approach for

lockout and tagout draws upon U.S. Occupational Safety and Health Administration (OSHA) regulations (Title 29 of the Code of Federal Regulations [CFR], Part 1910.147).

Lockout is the placement of a lockout device on the energy control device(s) of an airplane system to ensure that the airplane system cannot be operated until after the lockout device has been removed.

Tagout is the placement of a warning tag on the energy control device(s) of an airplane system to indicate that the airplane system must not be operated until after the warning tag is removed.

Tryout is verification that an airplane system is in a zero-energy state and that residual energy has been released. Tryout requires that lockout devices and warning tags cannot be violated to perform the tryout method. Tryout confirms that the airplane system is in a safe condition prior to the

Figure 3: Clarifying tryout requirements in the AMM

The AMM updates identify tryout steps to hazardous energy AMM tasks for confirmation of zero energy state prior to performing maintenance.

(1) **Hydraulic System-Tryout**

Note: This tryout is to make sure the hydraulic system is in a zero energy state.

(a) Make sure that the hydraulic Systems 1, 2, 3, and 4 are all below 100 psig on EICAS.

(b) Make sure that the FLT CONTROL SHUTOFF TAIL and FLT CONTROL HYD SHUTOFF WING valves are in the closed position on EICAS.

■ Tryout heading

■ Note explaining the purpose of the tryout

■ Tryout steps

technician performing maintenance on the airplane system. Tryout methods include:

- **Operating the airplane system** to confirm that the airplane is in a safe state.
- **Using the airplane instruments** to confirm that the airplane is in a zero energy state. These instruments include the central-maintenance-computer maintenance page and multifunction display.
- **Using test equipment** to confirm that the airplane is in a zero-energy state. Test equipment includes voltmeters, multimeters, ammeters, pressure gauges, and test sets.
- **Performing a visual inspection** to confirm that lockout devices and tags are installed and that energy control devices are in the safe position. Lockout devices can include devices such as actuator collars, actuator locks, circuit breaker collars, or locking pins. Energy control devices include circuit breakers, control handles, and control levers.

LOTO IN THE AMM

The safety principles of LOTO are currently employed in the AMM. The tryout requirement in a hazardous energy AMM procedure enhances safety because it provides confirmation that the airplane system is in a safe condition for technicians prior to beginning maintenance activities. Tryout steps will be clearly identified in the enhanced AMM.

For example, in a 30-step deactivation procedure in the AMM, Boeing is enhancing the AMM to clearly identify the tryout requirements in the deactivation procedure (see fig. 3). The AMM updates maintain a continued focus on ensuring air carrier maintenance requirements for efficiency.

PROCEDURES WHEN PERFORMING AIRPLANE TESTING

Hazardous energy control must be implemented on the airplane system before the technician performs maintenance on

that airplane system. Further, for operational testing, functional testing, and system testing, the airplane system must be energized in order to perform the testing. In some cases, this testing will require use of LOTO, while in others the testing is done using airplane systems and airplane displays and therefore does not require control of hazardous energy. Where LOTO is needed during airplane testing, the AMM test procedure will specify that LOTO is required. Personnel must be cleared from the area prior to energization and testing.

SUMMARY

An airplane has many hazardous energy sources that must be controlled before technicians can perform maintenance activities. Boeing has developed procedures to protect factory personnel from hazardous energy sources. These procedures will be reviewed and relevant information used to update the AMM in order to enhance hazardous energy control. [A](#)

