Overweight Landing? Fuel Jettison? What to Consider

THERE ARE IMPORTANT ISSUES WHEN DECIDING TO LAND OVERWEIGHT, BURN OFF FUEL, OR JETTISON FUEL.

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An overweight landing is defined as a landing made at a gross weight in excess of the maximum design (i.e., structural) landing weight for a particular model. A pilot may consider making an overweight landing when a situation arises that requires the airplane to return to the takeoff airport or divert to another airport soon after takeoff. In these cases, the airplane may arrive at the landing airport at a weight considerably above the maximum design landing weight. The pilot must then decide whether to reduce the weight prior to landing or land overweight. The weight can be reduced either by holding to burn off fuel or by jettisoning fuel. There are important issues to consider when a decision must be made to land overweight, burn off fuel, or jettison fuel.

Due to continuing increases in the cost of fuel, airlines want help deciding whether to land overweight, burn off fuel, or jettison fuel. Each choice has its own set of factors to consider. Holding to burn off fuel or jettisoning fuel prior to landing will result in increased fuel cost and time-related operational costs. Landing overweight requires an overweight landing inspection with its associated cost. Many airlines provide their flight crews with guidelines to enable the pilot to make an intelligent decision to burn off fuel, jettison fuel, or land overweight considering all relevant factors of any given situation.

This article provides general information and technical data on the structural and performance aspects of an overweight landing to assist airlines in determining which option is best suited to their operation and to a given situation. The article covers these facets of overweight landings and fuel jettisoning:

- Regulatory aspects.
- Safety and ecological aspects.
- Airplane structural capability.
- Airplane performance capability.
- Automatic landings.
- Overweight landing inspection requirements.

FLAP PLACARD SPEED MARGINS AT WEIGHTS UP TO MAXIMUM TAKEOFF WEIGHT
Boeing Models with Fuel Jettison Systems
Figure 1

Landing overweight and jettisoning fuel are both considered safe procedures.

REGULATORY ASPECTS

The primary Federal Aviation Administration (FAA) regulations involved in landing overweight and fuel jettison are:

- Federal Aviation Regulation (FAR) 25.1519 — Requires the maximum landing weight to be an operating limitation.
- FAR 91.9 — Requires compliance with operating limitations.
- FAR 121.557 and FAR 121.559 — Allow the pilot in command to deviate from prescribed procedures as required in an emergency situation in the interest of safety. In June 1972, the FAA issued Air Carrier Operations Bulletin No. 72-11 giving three examples of situations the FAA considered typical of those under which pilots may be expected to use their emergency authority in electing to land overweight:
  - Any malfunction that would render the airplane unairworthy.
  - Any condition or combination, thereof, mechanical or otherwise, in which an expeditious landing would reduce the exposure to the potential of additional problems which would result in a derogation or compromise of safety.
  - Serious illness of crew or passengers which would require immediate medical attention.
- FAR 25.1001 — Requires a fuel jettison system unless it can be shown that the airplane meets the climb requirements of FAR 25.119 and 25.121(d) at maximum takeoff weight, less the actual or computed weight of fuel necessary for a 15-minute flight comprising a takeoff, go-around, and landing at the airport of departure.

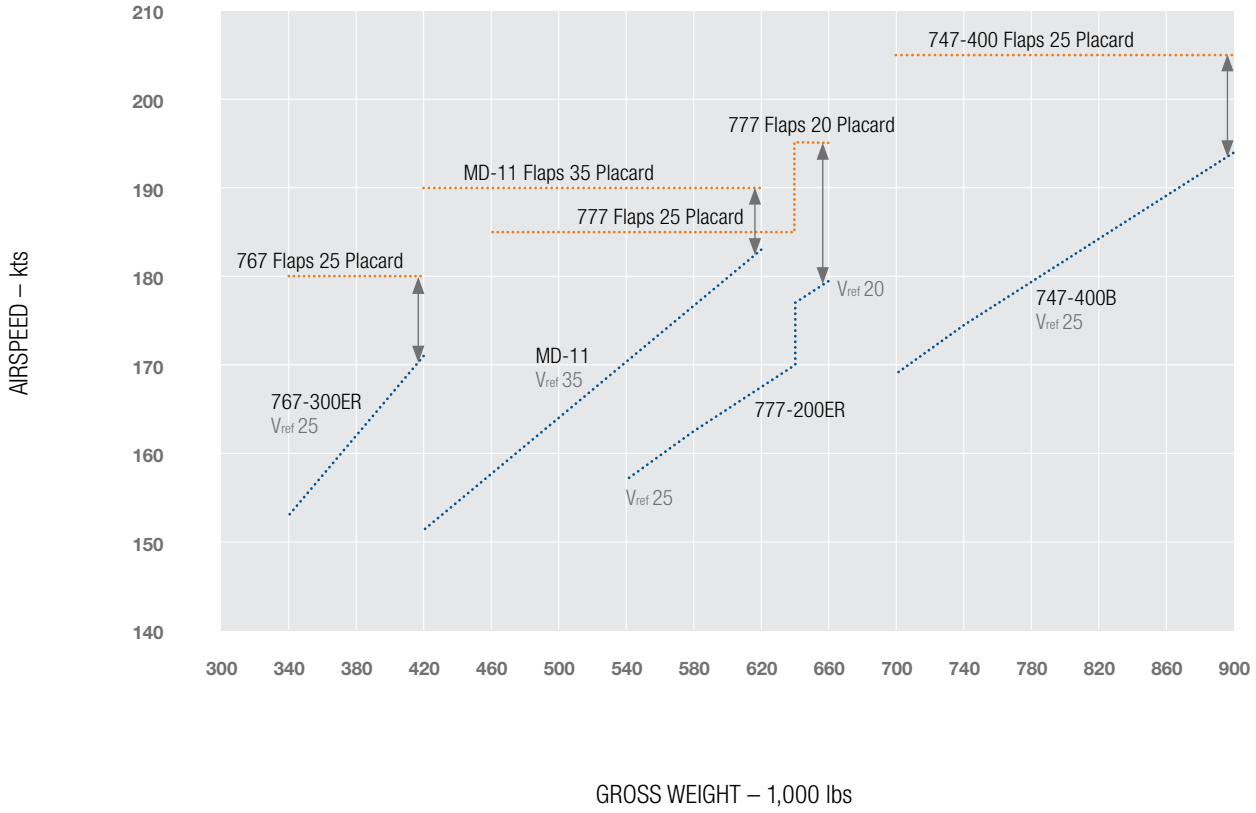
To comply with FAR 24.1001, the 747 and MD-11, for example, require a fuel jettison system. Some models, such as the 777 and some 767 airplanes have a fuel jettison system installed, but it is not required by FAR. Other models such as the DC-9, 717, 737, 757, and MD-80/90 do not require, or do not have, a fuel jettison system based on compliance with FAR Part 25.119 and 25.121(d).

SAFETY AND ECOLOGICAL ASPECTS

Landing overweight and fuel jettisoning are both considered safe procedures: There are no accidents on record attributed to either cause. In the preamble to Amendment 25-18 to FAR Part 25, relative to fuel jettison, the FAA stated, "There has been no adverse service experience with airplanes certificated under Part 25 involved in overweight landings." Furthermore, service experience indicates that damage due to overweight landing is extremely rare.

Obviously, landing at weights above the maximum design landing weight reduces the normal performance margins. An overweight landing with an engine inoperative or a system failure may be less desirable than landing below maximum landing weight. Yet, delaying the landing with a malfunctioning system or engine failure in order to reduce weight or jettison fuel may expose the airplane to additional system deterioration that can make the situation worse. The pilot in command is in the best position to assess all relevant factors and determine the best course of action.

Some operators have questioned whether fuel jettison is permissible when an engine or airframe fire exists. There is no restriction on fuel jettison during an in-flight fire, whether inside or outside the airplane. During airplane certification, Boeing demonstrates to the FAA in a variety of flight conditions that jettisoned fuel does not impinge or reattach to airplane surfaces. As fuel is jettisoned, it is rapidly broken up into small droplets, which then vaporize. Boeing does not recommend operator-improvised fuel jettison procedures, such as jettisoning fuel from only one side during an engine fire. Such procedures are not only



unnecessary but also can increase jettison time and crew workload.

The ecological aspects of fuel jettison have been most closely studied by the United States Air Force (USAF). These studies have shown that, in general, fuel jettisoned above 5,000 to 6,000 feet will completely vaporize before reaching the ground. Therefore, Boeing's general recommendation is to jettison fuel above 5,000 to 6,000 feet whenever possible, although there is no restriction on jettisoning at lower altitudes if considered necessary by the flight crew.

Fuel jettison studies have indicated that the most significant variables related to fuel vaporization are fuel type and outside air temperature. Some studies found that temperature can have a very significant effect on the altitude needed to completely vaporize fuel. For example, one USAF study found that a 36-degree Fahrenheit (20-degree Celsius) reduction in temperature can change the amount of liquid fuel reaching the ground by as much as a factor of 10. Other factors such as fuel jettison nozzle dispersion characteristics, airplane wake, and other atmospheric conditions can affect the amount of fuel that reaches the ground.

Even though fuel is vaporized, it is still suspended in the atmosphere. The odor can be pronounced, and the fuel will eventually reach the ground. Boeing is not aware of any ecological interest promoting a prohibition on fuel jettisoning. Because of the relatively small amount of fuel that is jettisoned, the infrequency of use, and the safety issues that may require a fuel jettison, such regulations are not likely to be promulgated.

AIRPLANE STRUCTURAL CAPABILITY

Overweight landings are safe because of the conservatism required in the design of transport category airplanes by FAR Part 25.

FAR criteria require that landing gear design be based on:

- A sink rate of 10 feet per second at the maximum design landing weight; and
- A sink rate of 6 feet per second at the maximum design takeoff weight.

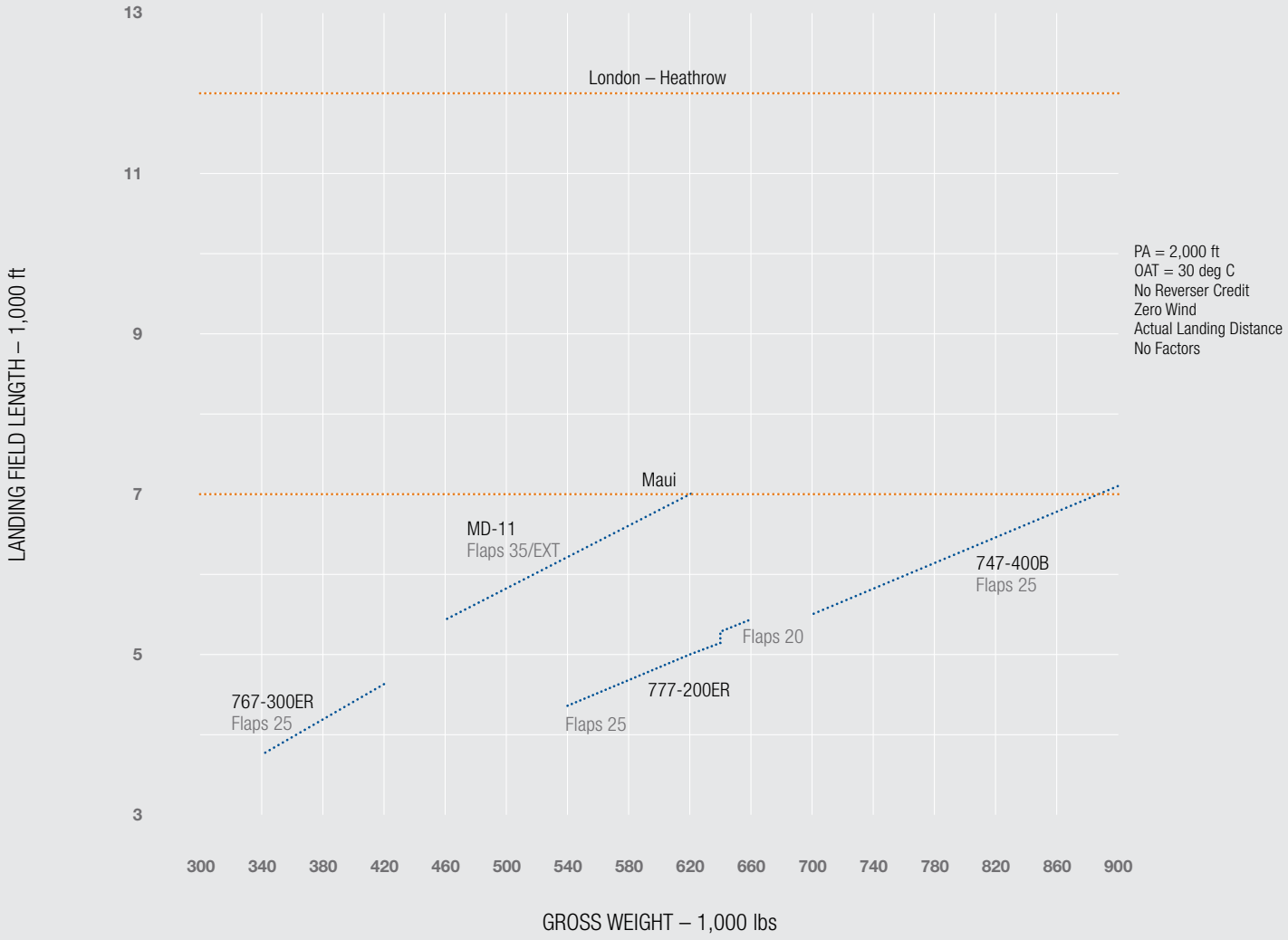
Typical sink rates at touchdown are on the order of 2 to 3 feet per second, and even a "hard" landing rarely exceeds 6 feet per second. Additionally, the landing loads are based on the worst possible landing attitudes resulting in high loading on individual gear. The 747-400 provides an excellent example. The 747-400 body gear, which are the most aft main gear, are designed to a 12-degree nose-up body attitude condition. In essence, the body gear can absorb the entire landing load. The wing gear criteria are similarly stringent: 8 degrees roll at 0 degrees pitch. Other models are also capable of landing at maximum design takeoff weight, even in unfavorable attitudes at sink rates up to 6 feet per second. This is amply demonstrated during certification testing, when many landings are performed within 1 percent of maximum design takeoff weight.

When landing near the maximum takeoff weight, flap placard speeds at landing flap positions must be observed. Due to the conservative criteria used in establishing flap placard speeds, Boeing models have ample approach speed margins at weights up to the maximum takeoff weight (see fig. 1).

In addition to specifying a maximum landing weight, the FAA-approved airplane flight manual (AFM) for some 747-400 and MD-11 airplanes includes a limitation on the maximum in-flight weight with landing flaps. This weight is conservatively established to comply with FAR 25.345, flaps down maneuvering to a load factor of 2.0. Compliance with FAR 25.345 is shown at a weight sufficiently above the maximum design landing weight to allow for flap extension and maneuvering prior to landing. Because the loads developed on the flaps are primarily a function of airspeed and are virtually independent of weight, the flaps will

LANDING FIELD LENGTH MARGIN AT WEIGHTS UP TO MAXIMUM TAKEOFF WEIGHT

Figure 2



Overweight automatic landings are not recommended. Autopilots on Boeing airplanes are not certified for automatic landing above the maximum design landing weight.

not be overstressed as long as airspeed does not exceed the flap placard speed.

If the maximum in-flight weight with landing flaps is exceeded, no special structural inspection is required unless the flap placard speed or the maximum landing weight is also exceeded. Generally, if the maximum in-flight weight with landing flaps is exceeded, the maximum design landing weight will also be exceeded and, by definition, an overweight landing inspection will be required.

Loading on the basic wing structure due to increased landing weight can be controlled by limiting the bank angle. To maintain reasonable structural margins, Boeing recommends that operating load factors be limited to those corresponding to a stabilized 30-degree banked turn.

All Boeing airplanes have adequate strength margins during overweight landings when normal operating procedures are used, bank angle does not exceed 30 degrees, and flap placard speeds are not exceeded.

AIRPLANE PERFORMANCE CAPABILITY

Increased gross weight can have a significant effect on airplane performance. Whenever possible, it is strongly recommended that normal FAR landing performance margins be maintained even during overweight landing. The AFM typically provides landing performance data at weights significantly above the maximum design landing weight and can be used in conjunction with landing analysis programs to calculate landing performance.

The landing field length capability of Boeing airplanes is such that, even ignoring reverse thrust, excess stopping margin is available at weights well above the maximum design landing weight (see fig. 2). The data in figure 2 are based on a dry runway with maximum manual braking. Wet and slippery runway field-length requirements, as well as autobrake performance, should be verified from the landing distance information in the performance section of the flight crew operations manual (FCOM) or quick reference handbook (QRH).

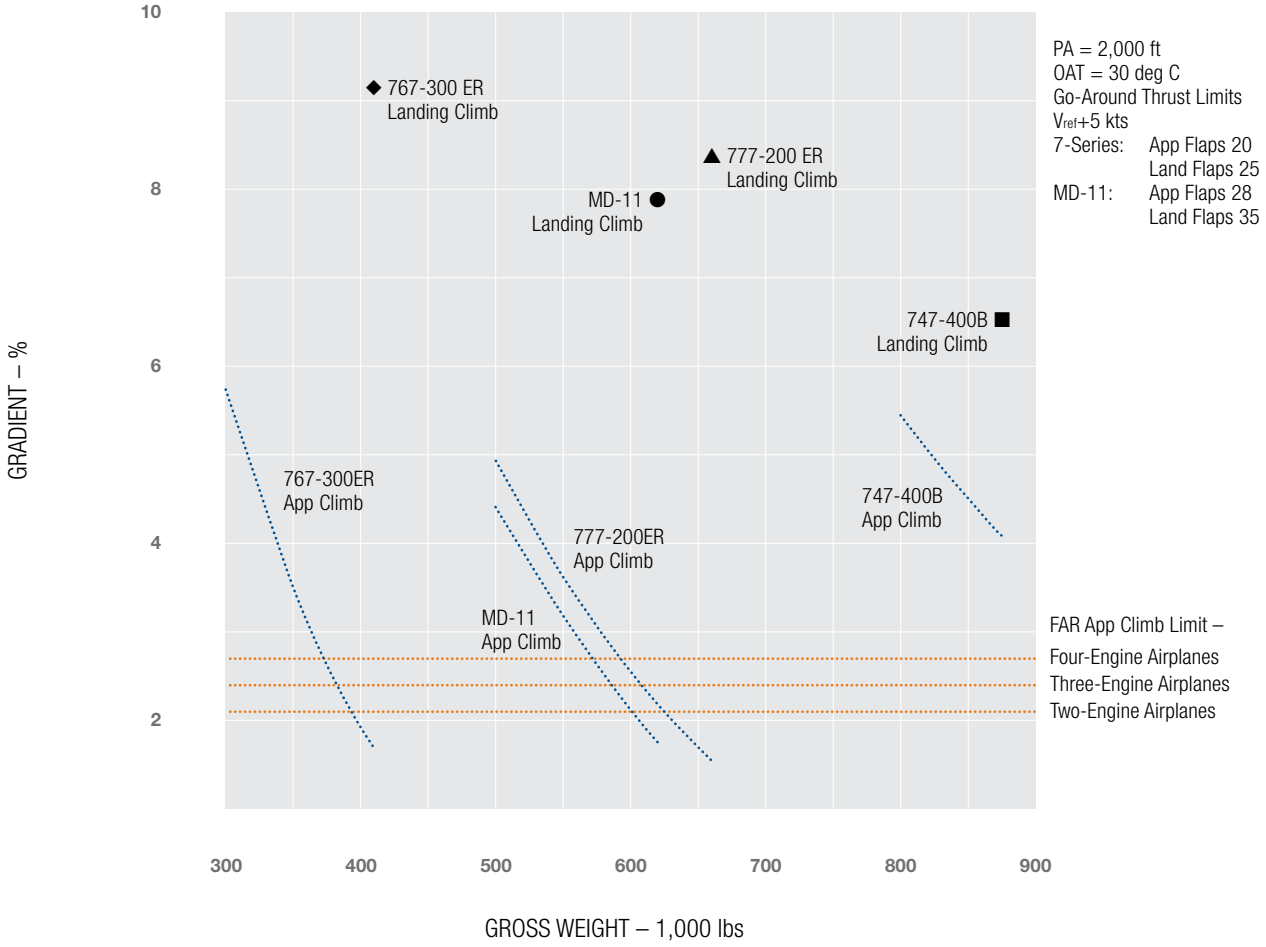
Climb performance exceeds the FAA landing climb gradient requirements (3.2% gradient with all engines operating, landing flaps and gear down), even at the maximum design takeoff weight as shown by the Landing Climb symbols in Figure 3. Climb performance generally meets the FAA approach gradient requirements (one engine inoperative with approach flaps and gear up) at weights well above maximum design landing weight as shown by the App Climb curves in figure 3, and a positive approach climb gradient is available with one engine inoperative even at the maximum design takeoff weight.

Normally, landing brake energy is not a problem for an overweight landing because the brakes are sized to handle a rejected takeoff at maximum takeoff weight. When using normal landing flaps, brake energy limits will not be exceeded at all gross weights. When landing at speeds associated with non-normal procedures with nonstandard flap settings, maximum effort stops may exceed the brake energy limits. In these cases, Boeing recommends maximizing use of the available runway for stopping. For Boeing 7-series models other than the 717, techniques for accomplishing this are provided in the overweight landing discussion in the “Landing” chapter of the Boeing flight crew training manuals (FCTM).

The stability and control aspects of overweight landings have been reviewed and found to be satisfactory. Stabilizer trim requirements during approach are unchanged provided normal V_{ref} speeds are flown. Speed stability, the control column force required to vary airspeed from the trimmed airspeed, is slightly improved. Pitch and roll response are unchanged or slightly improved as the increased airspeed more than compensates for increased mass and inertia effects.

Additional information on overweight landing techniques for Boeing 7-series models other than the 717 can be found in the “Landing” chapter of the FCTM.

CLIMB PERFORMANCE MARGINS AT WEIGHTS
UP TO MAXIMUM TAKEOFF WEIGHT
Figure 3



AUTOMATIC LANDINGS

Overweight automatic landings are not recommended. Autopilots on Boeing airplanes are not certified for automatic landing above the maximum design landing weight. At higher-than-normal speeds and weights, the performance of these systems may not be satisfactory and has not been thoroughly tested. An automatic approach may be attempted; however, the pilot should disengage the autopilot prior to flare height and accomplish a manual landing.

In an emergency, should the pilot determine that an overweight autoland is the safest course of action, the approach and landing should be closely monitored by the pilot and the following factors considered:

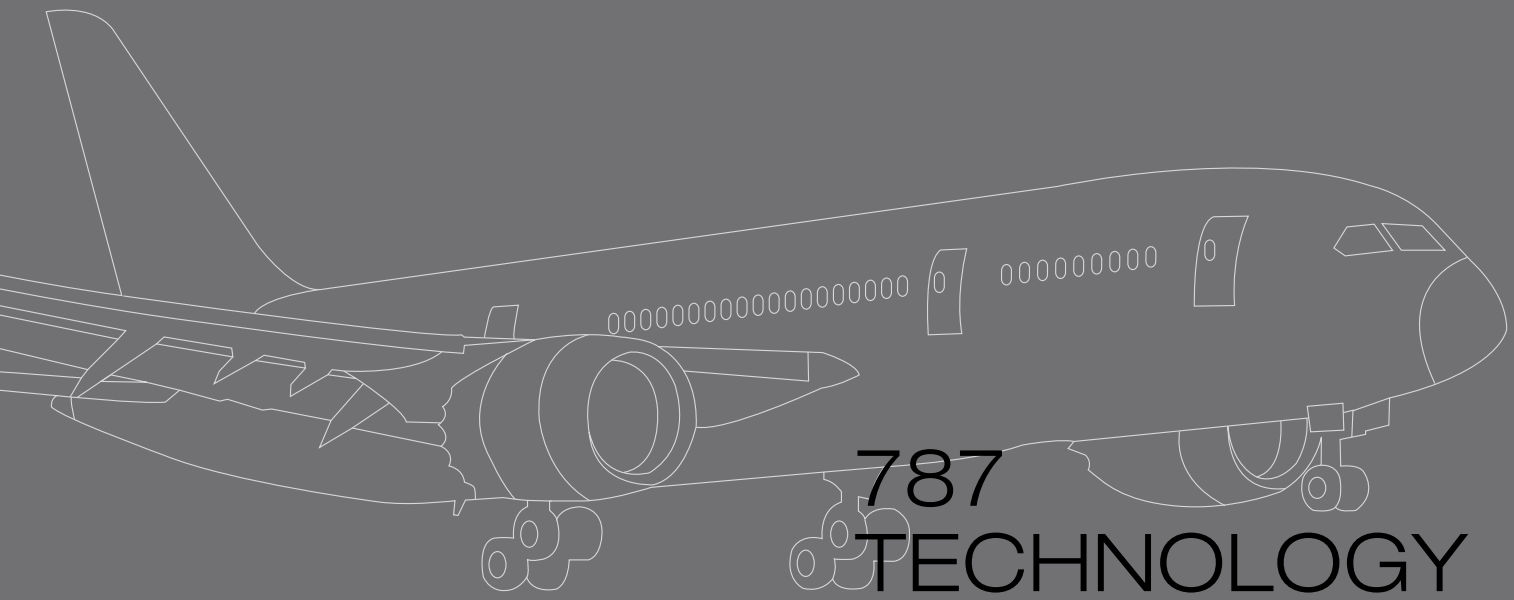
- Touchdown may be beyond the normal touchdown zone; allow for additional landing distance.
- Touchdown at higher-than-normal sink rates may result in exceeding structural limits.
- Plan for a go-around or manual landing if autoland performance is unsatisfactory; automatic go-around can be initiated until just prior to touchdown and can be continued even if the airplane touches down after initiation of the go-around.

OVERWEIGHT LANDING INSPECTION REQUIREMENTS

The Boeing airplane maintenance manual (AMM) provides a special inspection that is required any time an overweight landing occurs, regardless of how smooth the landing. The AMM inspection is provided in two parts. The Phase I (or A-check) conditional inspection looks for obvious signs of structural distress, such as wrinkled skin, popped fasteners, or bent components in areas which are readily accessible. If definite signs of overstressing are found, the Phase II (or B-check) inspection must be performed. This is a much more detailed inspection and requires opening access panels to examine critical structural components. The Phase I or A-check conditional inspection can typically be accomplished in two to four labor hours. This kind of inspection is generally not a problem because an airplane that has returned or diverted typically has a problem that takes longer to clear than the inspection itself.

SUMMARY

When circumstances force a pilot to choose between an overweight landing or jettisoning fuel, a number of factors must be considered. The information in this article is designed to facilitate these decisions. For more information, please contact Boeing Flight Operations Engineering at FlightOps.Engineering@boeing.com.



787 TECHNOLOGY HIGHLIGHT

The 787 design incorporates onboard structural health management technologies which will mitigate the operational impact and costs associated with structural inspections after an overweight or hard landing. This technology will greatly simplify the process of determining whether or not a landing has exceeded the capabilities of the airplane structure and will significantly reduce the inspection burden on the operator. This capability will reduce the overall downtime and maintenance costs associated with overweight and hard landing events without impacting flight crew workload or operational procedures. More information on this new technology will be covered in a future issue of *AERO*.