



TIRES - Performance and Maintenance

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In today's environment of high operating weights, long taxi distances, and short turnarounds, the performance and maintenance of the airplane tire are very significant. The 747 requires high-speed tires capable of carrying up to 53,400-pound tire loads. To reduce susceptibility to tire loss and possible aircraft damage, operators have been encouraged to examine their tire maintenance programs and to follow the Boeing recommendations which appear in the Maintenance Manual. Operators and tire retreaders have also emphasized closer control over retreads by better accountability and improved inspection techniques.

To further improve tire performance, the FAA has revised the federal regulations, which now call for increased tire load margin and more stringent testing. These revisions became effective on all new model aircraft on December 31, 1979. The effectivity on in-service models and the phaseout of older tires have not been established by the FAA. The intent of this article is to familiarize the reader with production, main-

tenance, and certification of tires and to summarize changes required by FAA regulations for the new series TSO C62c tire.

CLASSIFICATION AND CONSTRUCTION

Aircraft tires are classified in nine types by the United States Tire and Rim Association according to their type, size, ply rating, and whether tube type or tubeless. Type VII is the original commercial jet aircraft tire designed for extra high pressure and high load. These tires are designated by outside diameter and section widths. The New Design type tires, such as 49 x 19.0-20, are classified further by bead seat diameter.

Aircraft tires are designed for a deflection of 32 percent and must be strong enough to absorb touchdown loads and the stresses of high speed operation. For comparison, the automobile tire is designed only for a continued deflection of 12 to 14 percent. Typical construction and cross-section are shown in Figure 1.

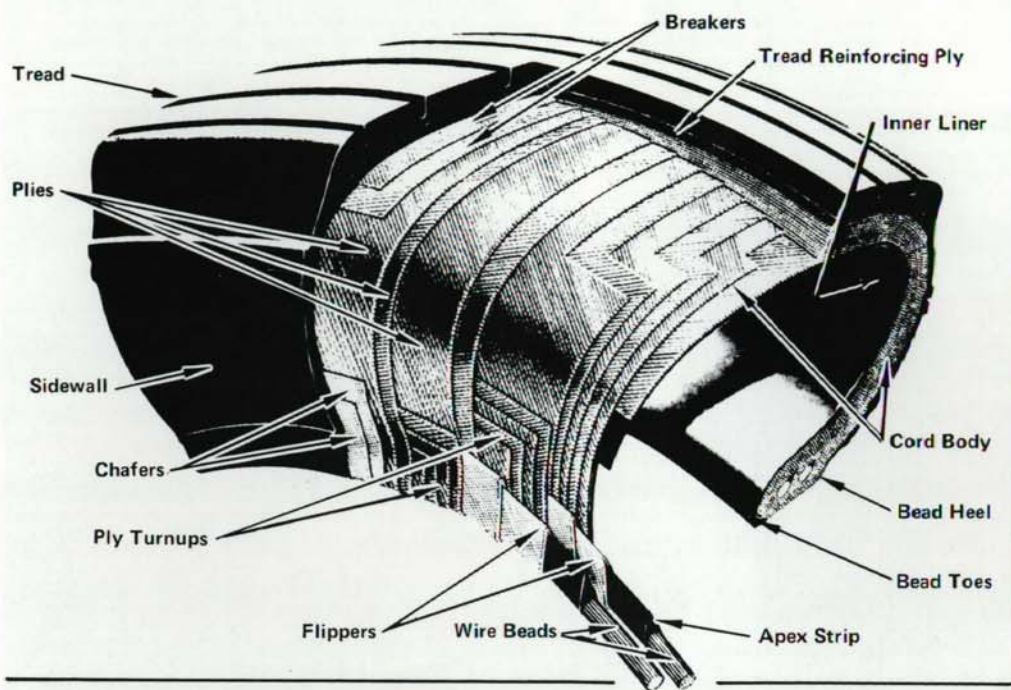


Figure 1— Construction of an Aircraft Tire

IMPORTANCE OF PROPER INFLATION

The greatest cause of damage to an aircraft tire is heat generated within the tire. As the tire rolls, the side walls flex and the rubber compound and body cords are exposed to bending and shear forces that cause internal friction and heat. Heat generated by normal deflection can be tolerated for a reasonable distance necessary for taxi and takeoff. The amount of deflection is determined by the air pressure which supports the weight of the airplane. For this reason inflation pressure is critical and should be checked daily or before each flight.

Over-inflation produces abnormal strain in the carcass and makes it more susceptible to cuts and bruises. It also causes centerline wear of the tread and makes the tire more susceptible to skidding.

While over-inflation is undesirable, under-inflation is worse. When a tire is under-inflated, it deflects more than the allowable 32 percent, breaks down the body cords, and causes the inner liner to crack. The excessive reversal of stresses in the tire body results in ply separation and weakens the carcass. However, the main damage resulting from under-inflation is the excess heat generated within the tires. If a tire is allowed to deflect as much as 45 percent, three times more heat builds up in the tire than it is designed to take and results in breakdown of the rubber compound, ply separation, and rupture of the plies. With damage of this type, the tire is weakened in a way that is not likely to be noticed until it fails in service.

The importance of proper inflation pressure in a tire makes frequent pressure checks imperative in tire preventive maintenance.

The Boeing Maintenance Manual recommends the inflation pressure for the main gear and nose gear tires on each model aircraft at the Maximum Taxi Gross Weight (MTGW). For example, a 747-200 with a MTGW of 778,000 pounds and 49x 17-32 ply rating tires has a recommended inflation pressure of 195 psi for the nose gear and the same for the main gear.

Operators who consistently fly at reduced gross weights may reduce main or nose gear tire pressures down to the minimum pressures provided on charts similar to that shown in Figure 2. The tire pressure for the nose gear is based on the most forward cg normally allowed at a particular airplane weight. The main gear tire pressures are based on the most aft cg normally allowed at a particular weight.

For example, if a 747-200 with a 778,000-pound maximum gross weight is always operated at 680,000 pounds or less, the main gear pressure can be reduced from 195 psi to as little as 180 psi and the nose gear tire pressure to as little as 168 psi.

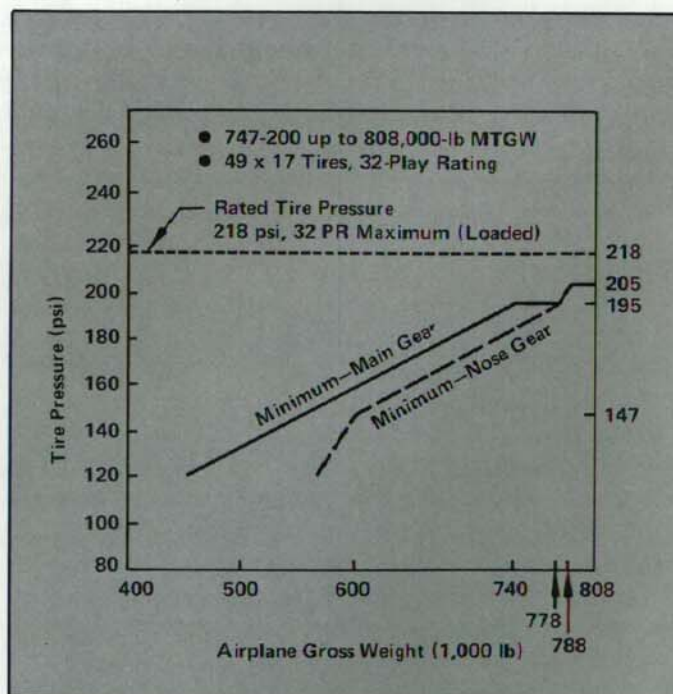


Figure 2— Tire Pressure Limits

The pressure specified in maintenance manuals is for the loaded tire; that is, for the tire that is supporting the weight of the aircraft. Under load, the tire is deflected and the volume of its air chamber will be decreased enough to raise the pressure by about four percent. Therefore, the inflation pressure of an unloaded tire should be four percent less than that specified in the Maintenance Manual. As a precaution, since the axle nut contributes to overall wheel strength, the unloaded tire is usually only partially pressurized until it is mounted on the aircraft.

If possible, inflation pressure should be measured when the tire is cold—at least two to three hours after a flight. If tires are hot, the reinflation or removal is based on criteria in the Maintenance Manual except the tire with the highest pressure on each truck should be used as the pressure standard. For example, on the 747, if the tires are hot at Positions 1, 2, 3, and 4 (left wing gear) and are 215, 205, 215, and 175 pounds, respectively, the No. 2 tire at 205 pounds should be inflated to 215 pounds and the No. 4 tire should be removed from service.

Inflation pressure of a tire will vary with the ambient temperature by about one percent for every 5°F or 3°C. For example, if a tire is inflated to 180 psi with the airplane inside a hangar at 70°F, and the airplane is then rolled outside where it remains overnight at zero degrees F, the pressure will be 14 percent low at 155 psi. Obviously, it will be seriously under-inflated and must be reinflated to the correct pressure before takeoff.

If the tires are properly inflated a few hours before takeoff, any subsequent minor change in ambient temperature will result in only a small change in tire pressure, which will have little effect on the load carrying capability of the tire. Any pressure reduction due to cold soak during long flights should not adversely affect tire capability because the airplane weight is reduced.



Figure 3— Direct-Reading Dial-type Tire Pressure Indicator

Temperature compensation is not included in the charts because tire inflation should be kept as near the correct value as possible. For instance, if the correct inflation pressure is 200 psi, the tire should be inflated to 200 psi prior to taxi-out whether the ambient temperature is 32°F (cold) or 95°F (hot).

GAGES USED TO CHECK INFLATION

Direct reading hand-held dial indicators are used to check tire pressure. The gages generally have 2 inch or larger dials that are calibrated to plus or minus 2 psi.

In the past three years, operators have been service evaluating and incorporating wheel-mounted, direct-reading dial indicators which are integral with the fill valve stem and are now available as an option on production airplanes. Typical gages have an accuracy of +0 -10 psi. Recent gage development has improved gage reliability. A typical indicator is shown in Figure 3.

The gages are used for walk-around inspections, but not for refill. Operator reports indicate that an occasional low tire is replaced or replenished by walk-around inspection.

A cockpit tire pressure monitoring system has been evaluated on the Boeing 747 test airplane using prototype hardware for pickups and cockpit display. One operator is also evaluating a similar system in service on another model airplane. The system continuously monitors the exact pressure in all tires and warns when the differential between adjacent tires is excessive or a single tire is below a preselected value. Crew concern is that the system be free from false warnings and be capable of detecting passive failures (i.e., a failure that would cause it not to indicate a low tire). Although the prototype system has worked reasonably well in the operator's service evaluation (one false warning in three months), maintainability of the system is not established. The system did, however, detect two low tires.

RETREADING

Before removal of a wheel nut, the tire should be deflated. After removal from the aircraft, a tire is routed to the tire shop. The tire is rejected if it is damaged excessively or is not suitable for retread because the tire was overloaded in service.

The tire is then subjected to an Air Needle test. The Air Needle test involves using a needle tool to inject air into the ply area of the carcass for 15-20 minutes at 100-125 psi. If any significant separations are present, the separated area will bulge. If the tire is removed due to overload or is a part of a batch being processed for the first time by the retreader, an additional check is usually made using Holography to detect smaller separations not visible in an Air Needle test. Casings previously retreaded and susceptible to failure in service are weeded out by the additional check. A typical process for retreading is described below:

- Relax the carcass by storing for 12 hours at 160°F.

- Buff to remove old tread.
- Coat the buffed area with an anti-oxidation agent.
- Add reinforcing ply.
- Apply tread by continuous overlapping of the 2-inch-wide rubber strip using an Orbitread machine.
- Balance tire before vulcanizing by adding short strips of rubber.
- Vulcanize tread.

At each step data is recorded on the permanent record card for the individual tire. Final inspection for ply or cord separation is made by Holographic Interferometry, when available.

RECENT INSPECTION TOOL DEVELOPMENT

Holographic Interferometry is a precise inspection method which uses the interference patterns of visible light as a measure of surface distortion. The two-stage photographic process uses a laser light to both expose and view the film. In the first stage, a double exposure is made of the inside tire surface; first at ambient pressure and then under a vacuum. In the second stage, the film is viewed and interpreted. Equipment used is shown below in Figure 4.

The tire is placed on the platform and spreaders are used to permit the camera to view the complete shoulder-to-shoulder area of the tire. After lowering the dome, the tire is rotated through four 90° segments to

obtain a double exposure in each position before and after vacuum is applied. The test record film strip of four frames is then viewed with a laser light source to create a hologram image. Superimposed on the surface of the inner liner are light and dark bands (interferometric fringes) which relate the movement of the tire surface between the first and second film exposures. Ply separation will show as closely-spaced fringe bands similar to a contour map of a mountain. Sensitivity with holography is in terms of micro inches surface deflection, permitting detection of very small separations.

As previously mentioned, in addition to normal inspection criteria for damage using Air Needle and Holographic inspections, tires removed are subject to rejection or inspection based on the conditions at removal as specified in the Boeing Maintenance Manual. In 1978, the Boeing manual was revised to include new criteria for removal of a paired tire, the addition of a 24-hour leak check for newly mounted tires, a reinflation method when tires are hot, and revised tire/wheel inspection criteria for melted or partially-melted wheel thermal fuse plugs. Current criteria are listed below:

- Inflation to the recommended pressure of maximum taxi gross weight (MTGW) per charts for each model aircraft.
- Reinflation without further check on a daily basis when tire is within 5% of recommended pressure.
- Removal of tire if tire pressure is 15% low.

- Removal of both paired tires if one is 30% low. (Good tire need not be changed if it can be shown that the pressure loss occurred after the airplane was parked and the tire was not rolled.)
- Leak check of newly-mounted tires for 24 hours allowing 8 psi drop in the first 12 hours and 5 psi drop in the second 12 hours.

After the tire is judged suitable for service it is identified by the number of retreads. Operators who place restrictions on the number of times a tire can be retreaded generally allow four to seven retreads. However, most operators limit retread only by the condition of the tire regardless of previous retreads. Some 747 operators have special restrictions limiting aft body gear tires to two to five retreads. One operator uses only new tires on the aft body gear.

STORAGE

Proper storage of any tire is important. Beside the normal precautions

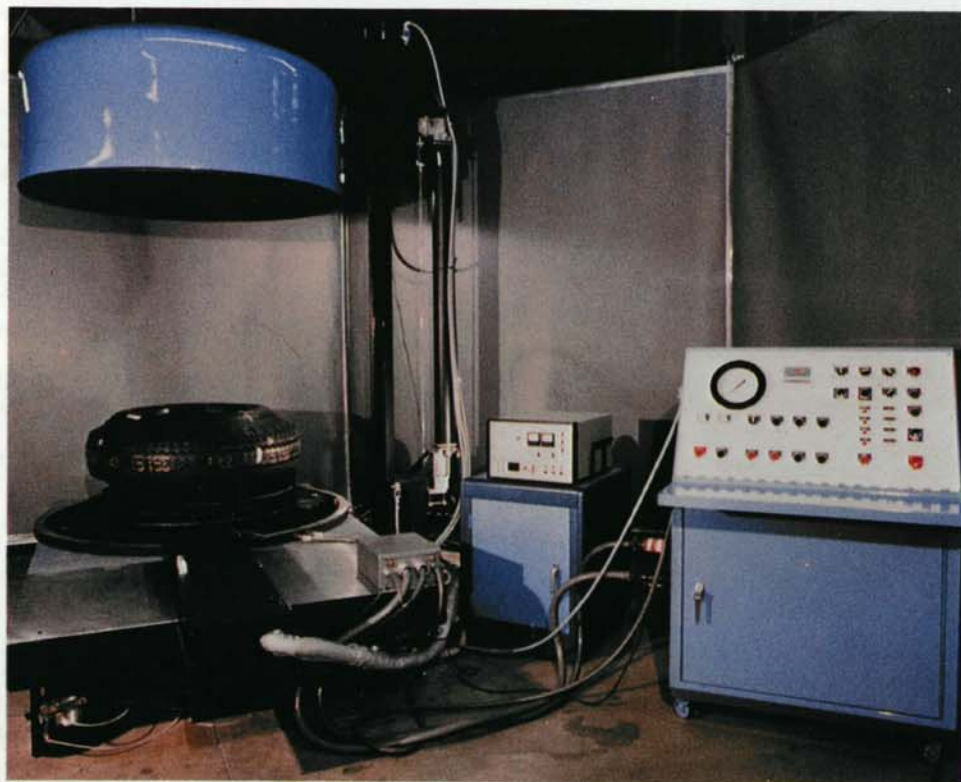


Figure 4— Holographic Tire Analyzer

of storing in a cool, dry area and away from sunlight, tires are normally stored vertically in racks with the tire supported on flat surfaces three to four inches wide.

If stacked horizontally, the bottom tires may be distorted enough to prevent seating of the tire bead onto the rim without the aid of a special tool. If 40- to 49-inch jet aircraft tires are stacked horizontally, the stack height is limited to four high.

TIRE QUALIFICATION AND CERTIFICATION

The FAA requires that each type of tire be qualified to a Technical Standard Order under FAR 37.167. The Technical Standard Order (TSO-C62) prescribes the minimum performance standards, marking requirements, and data requirements. The tire manufacturer is required to perform the required testing and submit the required data to the FAA for approval.

After December 31, 1982, all tires manufactured with speed ratings above 160 mph must conform to TSO-C62c. A brief summary of the TSO-C62c requirements follows (new or revised requirements appear in bold type):

- The tire must be permanently marked with: TSO-C62c, manufacturer, brand name, serial number, part number, speed rating, size, skid depth, and load rating. The ply rating is not required but will be marked on most tires.
- Data requirements include: rated inflation pressures, load radius at rated load and rated pressure, load deflection curve up to 1.5 load, tire weight, static unbalance, tolerance on nominal loaded radius.
- Performance (test) requirements include:
 - Withstand a pressure of 4.0 times the rated pressure for 3 seconds.
 - Dynamometer test cycles conducted on same tire: Fifty takeoff cycles with the initial load not less than the tire rated load per a chart such as Figure 5. Note: The applicable load-speed-time (L-S-T) data for tires used on 747 models are included in Boeing Specification 60B10058.
 - One overload cycle at 1.5 times the loads used through 50 cycle test.
 - Eight (was three) taxi cycles at 40 mph (was 35 mph) for 35,000 feet at rated load.
 - Two overload taxi cycles at 1.2 rated load at 40 mph for 35,000 feet.

Note: The 100-landing test per TSO-C62b is not required by TSO-C62c.

Obtaining FAA approval (certification) to use a tire on an airplane is accomplished by the airplane manufacturer. Generally, this is accomplished during airplane certification.

FAA Regulation Part 25, para. 25.733, has been changed to increase the margin between rated tire load and the load actually applied by the

Legend (Notation and Format Based on Figure 2 of TSO-C62c):

- L_0 = Tire Load (Rated) at Start of Takeoff Run (Minimum) (lb)
- L_A = L_0 = Tire Load at First Load Change (Minimum) (lb)
- L_1 = Tire Load at Rotation (Minimum) (lb)
- L_2 = Zero Tire Load (Liftoff)
- S_0 = Zero Tire Speed
- S_1 = Tire Speed at Rotation (Minimum) (mi/hr)
- S_2 = Tire Speed at Liftoff (Minimum) (mi/hr)
- T_0 = Zero Time at Start of Takeoff Run
- T_A = Time to First Load Change (Minimum) (sec)
- T_1 = Time to Rotation (Minimum) (sec)
- T_2 = Time to Liftoff (Minimum) (sec)
- RD_A = Roll Distance (Minimum) at T_A (ft)
- RD_2 = Roll Distance (Minimum) at T_2 (ft)

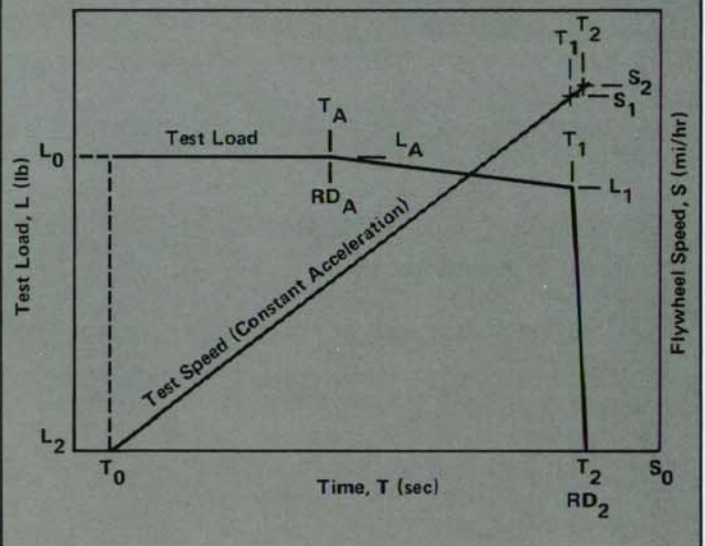


Figure 5— Load-Speed-Time Takeoff Cycle for Boeing 747 Airplane Tires

airplane, by an increment of 7%. Moreover, actual load is more specifically defined.

SUMMARY

- The change to TSO-C62c results in a tire with more actual strength and life for a given load rating.
- The change to FAR 25 results in a greater margin between tire rated load and actual applied load, which in some cases results in a larger tire size or higher load rating than on currently used tires.

CONCLUSIONS

With increased emphasis on proper maintenance, improved retread practices including holographic inspection, and the TSO-C62c tires, Boeing is confident that the frequency of tire loss will be appreciably reduced. Although this article is based directly on 747 experience, the new regulations affect all Boeing airplanes — the 707, 727, 737, and the future 757 and 767 models.