



AEROSPACE INFORMATION REPORT

AIR5487™**REV. B**

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Superseding AIR5487A

(R) Aircraft Tire History

RATIONALE

AIR5487B has been reaffirmed to comply with the SAE five-year review policy.

INTRODUCTION

The need for pneumatic tires has existed almost since the dawn of powered flight. Although the ability to operate from skids, skis and floats had been seen as methods of coping with unique situations, universal mobility demanded wheels with some sort of pneumatic tire for optimization. Information concerning aircraft tires, as an historical subject, has always existed in disconnected sources. It is hoped that, by collating from these sources and presenting them in the format of an AIR, we will have provided a more ready reference for those interested in this subject.

Background: This panel was formed within A-5C to utilize the archives of existing tire producers and users so as to provide as large an archival base as possible, while such documentation still exists.

Approach: The panel activity has concentrated on searches for relevant tables, drawings and photos that will augment the historical narrative.

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Full document details: SAE AIR5487B

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Documents

Document Sharing Hub

1. SCOPE

This SAE Aerospace Information Report (AIR), is intended to provide a continuum on historical development of aircraft tires.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of the other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

TSO-C62 Technical Standard Order – Tires

AC 145-4A Inspection, Retread, Repair, and Alterations of Aircraft Tires

2.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 3324-1 Aircraft Tyres and Rims – Part 1: Specifications

2.3 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-9495, <https://assist.daps.dla.mil/quicksearch/>.

MIL-PRF-5041 Performance Specification, Tires, Ribbed Tread, Pneumatic, Aircraft

MIL-PRF-7726 Performance Specification, Retread Tires, Ribbed Tread, Pneumatic Aircraft

2.4 Other Publications

The Tire and Rim Association (TRA) Aircraft Tire Year Book & Other Publications

The European Tyre and Rim Technical Organisation (ETRTO) Standards Manual

“The Aircraft Tire”, William R Woodall, 1/5/99

“Restoring Museum Aircraft”, Robert C. Mikesh

“The Story of Tire Beads and Tires (National-Standard Company”, Walter E. Burton (1955)

<http://ap.bridgestone.co.jp>

<http://www.dunlopaircrafttyres.com>

<http://www.goodyearaviation.com>

<http://www.airmichelin.com>

Also, certain artifacts residing in museums have been used for authentication.

3. HISTORICAL PERSPECTIVE

The aircraft tire was, and is, utilized as an efficient interface between the wheel rim and the supporting surface, an interface that provided flotation, traction, shock absorption, and torque transmission with a minimum of maintenance. Since the application of tires to aeronautical machines was preceded by their usage on various surface vehicles, the early airplane tire usually reflected what was "state of the art" for earthbound tires. As the product has matured, aircraft tires have occasionally led in this process. Due to the intermittent nature of their duty cycles, aircraft tires have acquired much higher load ratings and are operated at higher deflections than would be permitted for comparably sized surface vehicle tires, which require uninterrupted service.

4. TIRE TO RIM INTERFACES

The design of the surfaces where the tire and rim contact each other has always been of significant importance. The need to provide for reliable cooperation during service is obvious. These unions have produced some unique configurations. The aircraft tire and rim interface has been standardized by the Tire & Rim Association (TRA) and the European Tire & Rim Technical Organization (ETRTO). Further information on the TRA is supplied in Section 10.

4.1 Clincher Beaded Tires

This term describes the manner whereby the tire is attached to the rim. These tires have internal grooves molded into their lower sidewalls. The grooves match the "hook" shaped terminus of the inwardly curling rim flanges. The tire "bead" has no reinforcing steel wire. It relies on a core of hard rubber and fabric for anchoring purposes. The rim itself provides the primary resistance to the outward forces of inflation. These tires are subject to accidental dismounts from side loads, with the resultant blow out of the innertube. "Clinchers" began service with the earliest of airplanes and continued in use well into the 1920's. See Figure 1.

4.2 Straight Sided Tires

Tires so designated have one or more coils of rubber coated wire in each bead region. The beads also have interior conical faces designed to match similar conical regions of their specially designed rims. These rims are provided with vertical flanges, thereby entrapping the tire. Since the clincher and straight side equipment are not interchangeable, they were initially marked with the appropriate designation. See Figure 2.

4.3 Single Tube Tires

An early concept that avoided the use of a separate innertube was the "single tube". A complete innertube was built into the interior of these tires. Inflation caused the fabric carcass to expand in all directions. The downward force, reacting against the rim base, made beads unnecessary. Where concerns about torque (with the possibility of shearing the valve) existed, raised patterns were molded on the base of the tire where it would be in contact with the rim. Rims were manufactured with matching recesses. Single tube tires saw some application as low-pressure, tail wheel tires into the 1930's.

4.4 Bead Seat Angles

Rim bead seat angles for straight sided tires have usually been about 5 degrees, although some have utilized an angle of 15 degrees. The tire bead has been engineered to appropriately seat on its rim. Changes in tire constructions such as from tube type to tubeless, or bias to radial, may have changed the amount of bead seat interference that was required.

4.5 Rim Flange Heights

Flange diameters have usually been symmetrical and varied in height with the ply rating of the tire. Recently, however, many have been produced that are asymmetrical. The resulting height differences assist in meeting certain unusual wheel qualification and service requirements such as "roll-on-rim" requirements.

5. TIRE CONSTRUCTIONS

Beginning with the invention of the pneumatic bicycle tire, it has been a continuing practice to limit the growth of the elastic properties of rubber by imbedding textiles in the matrix. There have been several significant and distinct departures from past practices as the product has matured.

5.1 Tires Reinforced by Woven Fabric

The earliest of tires were made of rubber-coated woven cloth, and whether of the clincher, or straight sided variety, suffered from an inherent weakness that was basic. Because the weft and warp cords were in intimate contact with one another, the distortions associated with rolling under load produced a destructive shearing action. This resulted in carcass failures. Almost all early airplane tires shared this problem with the ground vehicle user.

5.2 Tire Chemistry

The tire has experienced evolving processes regarding its chemical make-up. In the early days, tires might have been manufactured so as to appear in differing shades of gray or white. This was before the discovery that carbon black provided an ideal reinforcement for rubber. Since those times, the dominant color has been black. Specific materials came to be compounded as coatings for the cord reinforcement, the flexible sidewalls, the wearing tread portion and any other zone that was seen to need special attention.

5.3 Bias Tires

This construction largely overcomes the problems associated with the woven tire. Here, discrete layers of rubber-coated cords are laid up as plies, which are positioned at alternate angles to the tire's circumferential center-line. This practice began in the aircraft tire arena prior to 1914, and eventually spread into all other areas of tire usage. When adapted to the straight side tire it provided an avenue for reducing costs and improving uniformity. By incorporating ever stronger cord materials, - cotton - rayon - nylon, bias tires have become the longest-lived "species" to date.

5.4 Radial Tires

The radial tire competes with the bias tire by providing a lighter weight, more efficient, cooler-operating carcass with a longer wearing tread surface. With its fewer body cords (displaced at approximately 90 degrees to the circumferential centerline), and its relatively inextensible belting (disposed more nearly parallel to the circumferential centerline), a radial tire, with its reduced hysteresis, is more tolerant of overloading conditions. In order to compensate for the reduction in vertical spring rate, radial tires are designed to match the static loaded radius of a bias tire of the same load rating. The result is that the inflated, unloaded dimensions of a radial tire are larger than are those of a bias tire. The "thrown and grown" dimensions of radials (due to their increased resistance to centrifugal growth) are designed to fall within the envelope provided for the matching bias tire. In general, the construction of radial tires make the tire more flexible, making lateral, fore & aft and torsional stiffnesses lower than their bias counterpart. Nylon was originally the fabric material of choice with Aramid and merged Nylon and Aramid fabric treatments being used in some tires.

6. TIRE PROFILES

Tires have been produced in a variety of contours. Each was expected to improve the performance of the aircraft to which it was attached. Efforts to reduce parasitic drag were clearly evident in the period when the landing gear was not retracted.

6.1 Tire Shapes

When aircraft tires began to address areas where system performance could be affected, they soon lost their original circular cross-sections. Although these will be treated in detail in Section 12, it might be noted that exterior contours have been offered that ran the gamut from narrow, elevated centers, to concavity.

7. TIRE USAGE IDENTIFIED BY APPLICATION

As the tail wheel replaced the tail skid, tires began to be catalogued as "main wheel" and "tail wheel" types. These represented one of the earliest attempts at design specialization. As "tricycle" landing gear configurations replaced "tail

draggers”, “nose” tires replaced “tail” tires. Coincidentally, main wheel designs became capable of transferring brake torque to the supporting surface as that requirement emerged. On some military aircraft, tires were placed near the wing tips and were designated “outrigger” tires.

8. STRENGTH RATINGS AND LOAD CAPACITY RATINGS

From the days of the base-line cotton reinforcement, tires have carried a marking either listing the actual number of structural layers (plies), or a number related to what would have been necessary had the earlier material continued in use. This system relates to the load carrying capacity of the tire and is called ply rating on aircraft tires.

From early in their conception, it has been thought that a safety factor of about “four” (burst strength/inflation pressure), should be required for new aircraft tires. This requirement has worked well. This remained a necessity as aircraft tires used Nylon fabric as its strength is reduced as tire temperatures increase. Also, it provided safety from foreign object damage to the fabric and the minor losses in fabric strength seen as the tire is used. It also allows for extensive retreading as further described in Section 19. The FAA set this safety factor of 4.0 as a minimum strength requirement within their Technical Standard Order TSO-C62 document on new aircraft tires. The FAA burst factor requirement for retreaded aircraft tires is a minimum of 3.0. New military tires typically use a safety factor of 3.5 to 4.0 as a minimum strength requirement based on whether land based or aircraft carrier based.

9. SIZE MARKINGS

Aircraft tire producers have left a unique history regarding the way tires have been size marked. Early size marking systems reflected the then current, surface-vehicle practice and involved specifying the outside diameter alone, the width of the cross-section (section width) and rim diameter together, or the outside diameter and section width together. These dimensions were expressed in inch or metric units. Most tires today show all three parameters in their size markings.

10. THE TIRE AND RIM ASSOCIATION

This voluntary organization was formed in 1903 to provide a forum, and the procedures for assurance that tire, rim, and valve manufacturers would produce designs that provided utility and interchangeability of product. This arrangement continues to benefit the participants as well as the users of these symbiotic systems. A similar organization in Europe is the European Tire & Rim Organization (ETRTO).

11. TIRES DEFINED BY PRESSURE

By 1939, The Tire and Rim Association was classifying some aircraft tires as “high pressure tires” such as the 32X8 which used 85 psi. By 1943, there was now a category known as “low pressure tires”. The 17.00-16 represented not only an example of this “naming”, but also exemplified the different method of “sizing”, which referred to the section width and the rim diameter (see Figures 5 and 6).

12. TIRES DEFINED BY “TYPE”

One unique program was once used to describe tires. The word “Type” followed by a marking in Roman numerals was molded on the sidewalls of most tires. It attempted to categorize tires by either usage or design philosophy. This military system began with “Type I” and eventually ended with “Type VIII”. After its adoption, it dominated the commercial arena as well.

12.1 Tires Marked With “Type” Designations

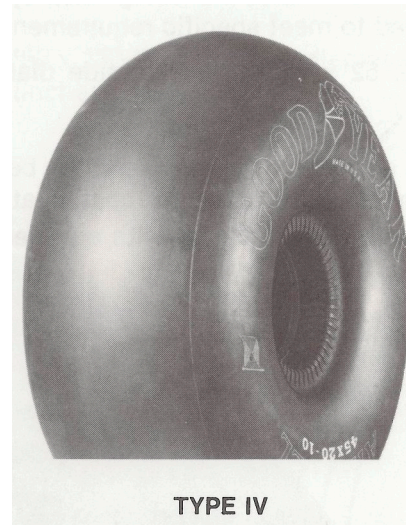
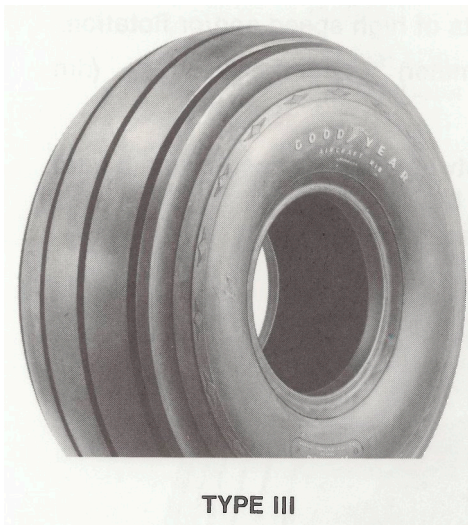
In 1945 a change was made in the way that tires would be classified. They would be sorted by “Type Markings”.

Type I collected the S.C. (smooth contour) tires. These tires displayed only their outside diameter as a size. (e.g., 56 inch). Their widest dimension would be equal at the rim flange. The aspect ratios were in the low 70% range; and the pressures ranged from 45 psi to 110 psi; the deflection was 35% (used on B-17 and B-24).



Type II tires replaced the former “high pressure tires” such as the 30X7. The numbers referred nominally to the outside diameter and the section width. The aspect ratio was about 85%, inflation pressures ranged from 55psi to 105 psi; and the deflections about 27.5% (used on SBD Dauntless).

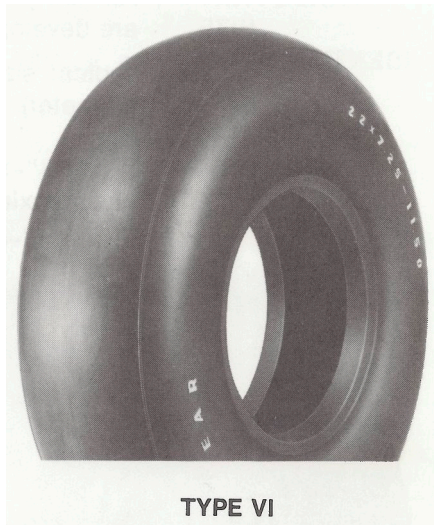
Type III replaced the “low pressure” category. The 17.00-16 was a representative size. The section widths and rim diameters were called out in the sizing. The aspect ratio was about 84%; pressures ranged from 18 psi to 105 psi; and the deflection was about 35% (used on the Douglas DC-3 [C-47/R4D]).



Type IV collected the “extra low pressure” tires which, in some cases had been called “airwheels”. An example would be the 12X5-3. The diameter was 12 inches; the section was 5 inches and the rim diameter was 3 inches; the aspect ratio was 90%; the deflection was 35%; and the inflation was 15 psi to 38 psi.

Type V catalogued what had been formerly called “Streamline” tires. These tires were identified by single dimension numbers such as 15.50 and 18.00. The aspect ratios were about 70%; and the deflection was 40% for mains, and 35% for tail wheels. The average inflation pressure was less than 45 psi.

Type VI, formerly called “low profile” tires, pioneered the nose wheel usage on such airplanes as the P-80, which used the 22X7.25-11.50. Here, the outside diameter, section width, and rim diameter were listed. Some tires were devoid of tread patterns. The aspect ratio was 72%. The deflection was 25% and the inflation pressure was 45 psi to 80 psi.



Type VII became the “extra high pressure” tires such as the 32X8.8, distinguishing themselves from the TYPE II by the decimal point and extra number in the section marking. The aspect ratio was 84%. The deflection was 32% and the inflation pressure was 75 psi to 225 psi on commercial sizes and up to 360 psi on military tires.

Type VIII was the last category to be identified as a type. They were considered to be “low profile – extra high pressure” tires. They used the three-part sizing of diameter, section width, and rim diameter as their identifier. The 41X15.0-18 would be representative. The aspect ratio was 77%. They had a similar inflation pressure range to Type VII tires.

Another type used was “British Type”. They were tires first developed in England and were standardized in ETRTO. An example of this was the 24x7.25-12 size. All former British-type tires have been incorporated into the 3-part size identification. Aspect ratios and inflation pressure ranges were similar to Type VII tires.

As the Type system lost relevance, the term “New Design” came into usage. These tires are any new tires being introduced today and they use the same three-part sizing as Type VIII tires.

As a footnote to the “Type” situation, it is interesting to find that many years after the relevancy of such markings, several are still perpetuated. This is in part due to the tremendous inertia that exists within the certification system. In order to re-license an aircraft, it may be necessary that all of the equipment retain the markings that were in place when the original type certificate was issued (although the meaning of the marking may have ceased to be known). As a result, several Type VII, Type III, and even a few Type I tires soldier on.

12.1.1 Tread Designs: In addition to the “Types”, unique tread designs were developed. Tread designs used were smooth, dimple, all-weather, rib all-weather, straight rib and channel tread. The smooth design, especially when used with the thin cross-section Type I tire, gave low drag characteristics on non-retractable landing gear. The all-weather tread design worked well on low speed tires for use on unimproved and grass runways. The rib all-weather tread design permitted higher speeds and provided for better water evacuation characteristics. The straight rib tread design provides for water evacuation and is best for high speed performance. It is the most common tread design and is used on most applications today. Channel treads were intended to reduce the shimmy tendencies of the landing gear by concentrating load paths on the shoulder ribs. They were made in the same sizes as the Type I, Type II, and Type VII. The inflation pressure was lower than in the standard application.



Additional Sub-Types: As specialization has necessarily increased, so have specialized tire categories. There was once a “Beaching Gear” genre that, when temporarily fitted, allowed “flying boat” aircraft to be winched or driven ashore (see Figure 12). “Chine” or deflector tires provide water dispersion for nose tires on aircraft with aft-mounted jet engines. Some military tires were designated “Ice Grip” and contained coil springs below the surface of their treads or shredded wire within the tread. (This is more successful as a concept than as a practical item.) Tires not designed in the U.S. were grouped by country of origin. “C” and “B” and “H” type tires represented different rim width to tire section width ratios, and the first two named utilized a 15 degree bead taper in place of the 5 degree bead taper used by all other aircraft tires.



12.1.2 Due to the aircraft load transfers that occur with brake applications on tricycle gear configurations, it has been accepted that nose wheel tires may be briefly loaded up to 50% more than the static rating that would have been assigned for main wheel application without adjustment of inflation pressure.

13. MULTIPLE WHEEL LAYOUTS

Even though some early airplanes were equipped with more than one tire per side, the philosophy to meet the demands of larger aircraft and higher loads was with ever larger single tires. Some of the applications reached levels where it was obvious that the loss of a tire would be catastrophic for the aircraft. The XB-36 and the XC-99 flew with single 110" Type 1 tires per side. Curiously, the major thrust behind the bogie systems that replaced them came from runway bearing strength considerations rather than other concerns (additional comments in Section 21).