# Heating Comparison of Radial and Bias-Ply Tires on a B-727 Aircraft

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16. Abstract


Aircraft taxi tests were conducted to compare the heating correlation of radial and bias-ply tires. The tires were tested on a Boeing 727-200QC, owned and operated by the Federal Aviation Administration (FAA) for the purpose of aircraft safety research. The aircraft was taxied at two different tire loads, at three different speeds, and for a given distance unless a threshold temperature of 250°F was reached. There was also a 14-mile roll test of 25 mph and a 31,000 pound tire load was conducted to make a comparison between the radial and bias-ply tire heating. The differences in temperature change (ΔT) between the radial and the bias-ply tires that were taxied the same distance and tire load were then compared.

In summary, the radial tire ran cooler in all scenarios of weight and taxi speed. Bead temperatures were from 5 to 20 percent less for the radial tire than for the bias-ply tire. Tire load had a significant affect on tire heating. A 24 percent increase in weight caused a 17 percent increase in tire temperature over a distance of 36,000 feet for the bias-ply tire and an 8.5 percent increase for the radial tire under the same conditions. Taxi speed affected the change in bead temperature but only after a certain distance was taxied.


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# TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS



## LIST OF TABLES

# EXECUTIVE SUMMARY

Aircraft taxi tests were conducted to compare the heating correlation of radial and bias-ply tires. The tires were tested on a Boeing 727-200QC, owned and operated by the Federal Aviation Administration (FAA) for the purpose of aircraft safety research. The aircraft was taxied at two different tire loads, at three different speeds, and for a given distance unless a threshold temperature of 250°F was reached. There was also a 14-mile roll test of 25 mph and a 31,000 pound tire load was conducted to make a comparison between the radial and bias-ply tire heating. The differences in temperature change (ΔT) between the radial and the bias-ply tires that were taxied the same distance and tire load were then compared.

In summary, the radial tire ran cooler in all scenarios of weight and taxi speed. Bead temperatures were from 5 to 20 percent less for the radial tire than for the bias-ply tire. Tire load had a significant affect on tire heating. A 24 percent increase in weight caused a 17 percent increase in tire temperature over a distance of 36,000 feet for the bias-ply tire and an 8.5 percent increase for the radial tire under the same conditions. Taxi speed affected the change in bead temperature but only after a certain distance was taxied.

# INTRODUCTION

Radial tires have been used for normal aircraft service as a substitute for conventional bias-ply type for several years. Recently, radial tires have become more prevalent with the introduction of new aircraft and landing gear. Tire heating due to taxiing and braking is an important safety concern when considering the operational envelope of an aircraft tire. Although it's generally accepted that radial tires are more durable and run cooler than conventional bias-ply tires, very little aircraft test data are available on the heating of tires. Radial and bias-ply tire heating have been correlated with testing programs on dynamometers, but temperature correlation data acquired from aircraft tests are essential for determining operational limits of radial tires.

This report presents the results of aircraft tests correlating radial and bias-ply tire heating on the main gear of a Boeing 727. The bead temperature of the tire was measured with distance taxied and other critical parameters in an attempt to determine the relationship between the heating of traditional bias-ply tires and radial tires.

# TESTING AND EQUIPMENT

## TIRES AND SENSORS.

One radial and one bias-ply tire were tested separately at the inboard left main gear position to allow for a temperature correlation. Table 1 gives the specifications of each tire. Each tire was instrumented with four thermocouples embedded in the tire bead at a specific location to measure the tire bead temperature. In addition, a small pressure transducer was adapted to fit on the end of the tire valve stem to measure tire pressure during testing. A close capacitance coupled telemetry system recorded the thermocouples and pressure transducer signals during the taxi tests. Two Wireless Data Corporation (WDC) microtransmitters were mounted to the test wheel, via a bracket, along with supporting hardware and a transmitting/receiving antenna ring. Figure 1 shows the telemetry system and the instrumented tire mounted on the aircraft wheel (Anderson, 1996).

TABLE 1. TIRE SPECIFICATIONS

| | Radial | Bias Ply |
|---|---|---|
| Size | 49 by 17 R20 | 49 by 17 |
| Ply Rating | 30 | 30 |
| Rated Load (lbs) | 48,145 | 46,700 |
| Rated Pressure (psi) | 200 | 195 |
| Rated Speed (mph) | 225 | 225 |

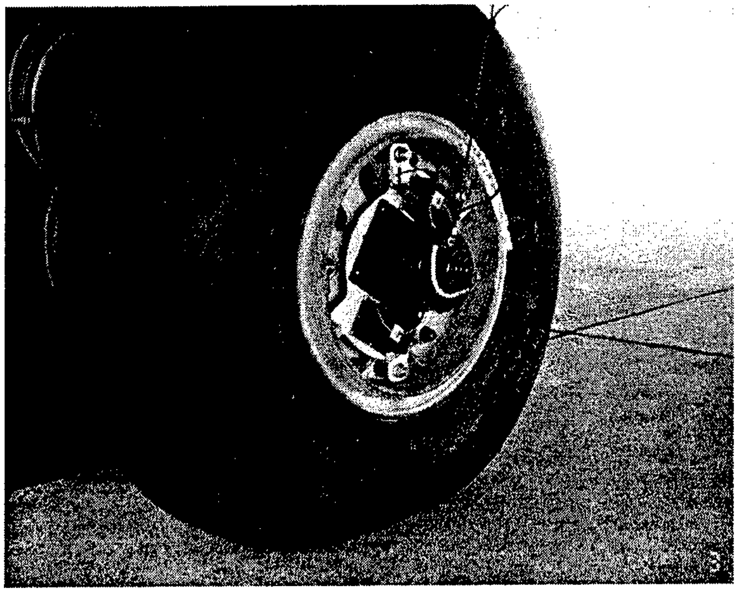

FIGURE 1. WHEEL WITH INSTRUMENTION AND TIRE MOUNTED

AIRCRAFT AND DATA ACQUISITION SYSTEM.

The tires were tested on a Boeing 727-200QC aircraft owned and operated by the FAA for the purpose of aircraft safety research (figure 2). The landing gear of the aircraft was instrumented with strain gages to measure axle shear (tire load) and side shear. The aircraft was also equipped with a velocity and distance sensor, made by Correvit, which gave ground speed and distance taxied. The aircraft was equipped with a data acquisition system (DAS) to acquire data during the testing. It used a Metraplex pulse code modulation (PCM) encoding DAS to accept signals from the strain gages, the speed/distance sensor, and the telemetry receiving unit and stored the data to a file on a supporting computer with an Eidel PCM decoder card (figure 3).

FIGURE 2. B-727-200QC AIRCRAFT OWNED BY FAA

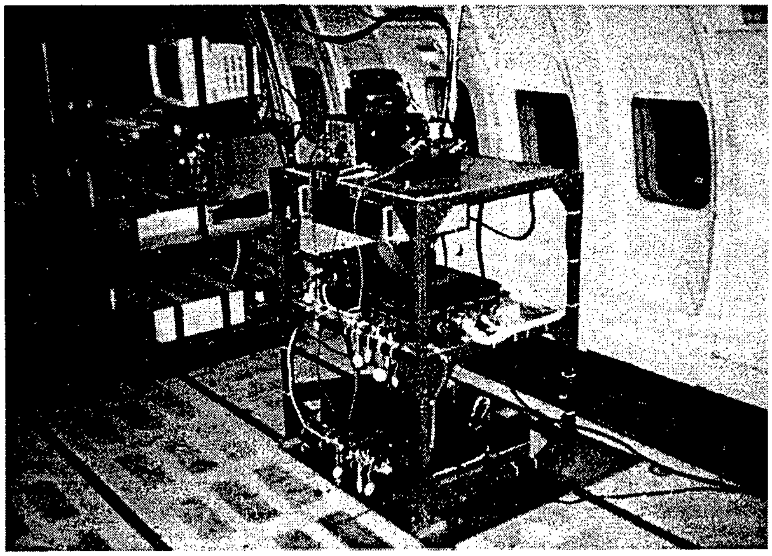

FIGURE 3. B-727 ONBOARD DATA ACQUISITION SYSTEM

TEST PROCEDURES.

The test plan called for taxiing the aircraft at two different tire loads, at three different speeds, and for a given distance unless a threshold temperature of 250°F was reached. The aircraft was taxied at 10-, 40-, and 70-miles per hour (mph). The two tire loads used were 24,000 and 30,000 pounds. The tests were not started until the tire bead temperature had dropped below 100°F. The aircraft was also taxied at 25 mph for a 14-mile roll test or until the threshold tire bead temperature of 250°F was reached. Due to a mistaken calculation, the bias-ply 14-mile roll test was run at a tire load of 31,000 pounds. The radial 14-mile roll test was then performed at the same weight to allow for a valid comparison. Some bias-ply tests were started at temperatures above 100°F due to the rapid initial heating of the bias-ply tire, which often had a 10°F increase in temperature while taxiing off of the ramp. The tests were repeated for both the radial and bias-ply tires to compare tire heating due to taxiing.

The aircraft weight was adjusted by adding or removing fuel to obtain different tire loads. Weight and balance data were used to calculate the tire load for each test. The fuel weight did change over the course of the test, but efforts were made to minimize this affect.

## DISCUSSION OF RESULTS

To compare the heating of the radial and bias-ply tires, we defined $\Delta T$ to be the difference between the start and finish temperatures ($\Delta T$ = temperature at end - temperature at start).

RADIAL AND BIAS-PLY DISTANCE COMPARISONS.

Figures 4 and 5 give radial and bias-ply tire temperature profiles as a function of distance taxied for the 24,000-pound tire load at taxi speeds of 10 and 40 mph, respectively. It is apparent that the radial tires tended to run cooler.

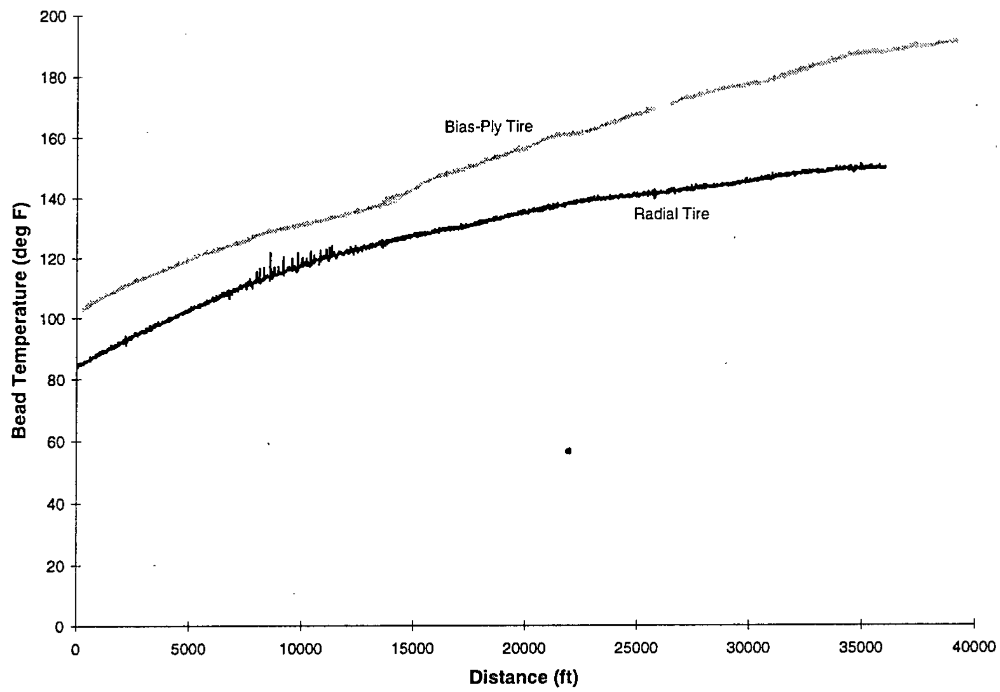


FIGURE 4. RADIAL AND BIAS-PLY TIRE HEATING DURING 10-MPH TAXI WITH 24,000-LB TIRE LOAD

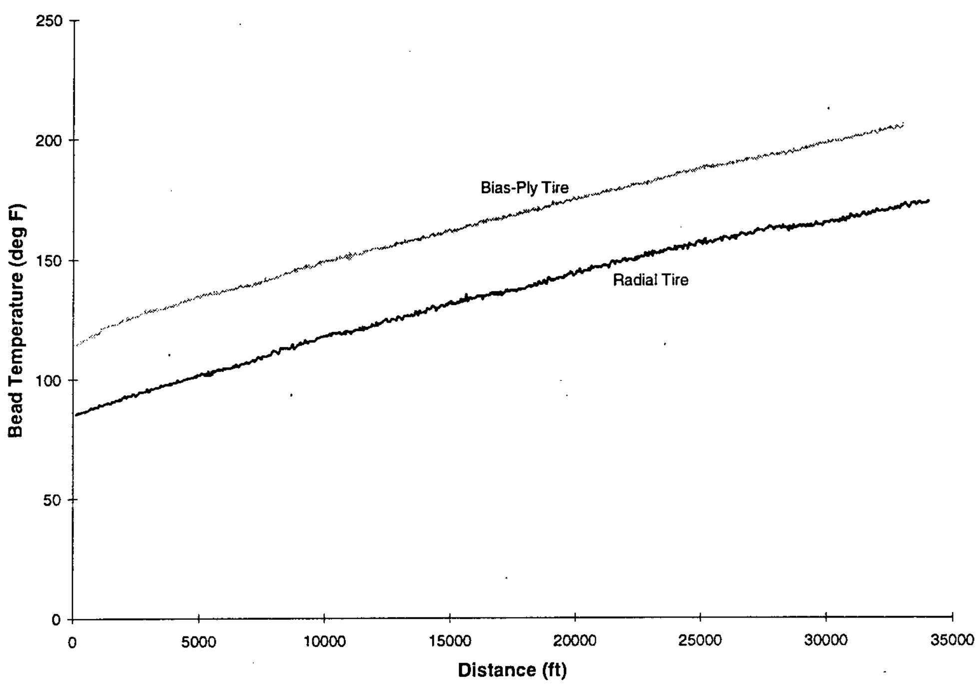


FIGURE 5. RADIAL AND BIAS-PLY TIRE HEATING DURING 40-MPH TAXI WITH 24,000-LB TIRE LOAD

Figures 6, 7, and 8 give radial and bias-ply tire temperature profiles with respect to distance taxied for the 30,000-pound tire load for taxi speeds of 10, 40, and 70 mph, respectively. The radial tire bead temperature was between 11 and 20 percent cooler than the bias-ply tire for taxi distances from 32,600 to 37,000 feet. Although a set taxi distance was initially established, most tests had different taxi lengths due to the point at which the 250°F temperature cutoff was reached. The higher tire load resulted in higher temperatures; however, it is obvious that the rate of increase for the radial tire tends to be equal or less than for the bias-ply tire while taxiing at the same speed for the same distance at the same weight.

Figure 9 compares the radial and bias-ply tire temperature profiles for the 14-mile roll test which had a taxi speed of 25 mph and a tire load of 31,000 lbs. The test was not run for the full 14 miles because the bias-ply tire reached the threshold temperature of 250°F after taxiing approximately 36,000 feet. The figure shows the plot for the additional 9000 feet that was required to return to the ramp. The radial tire had a bead temperature of 209°F after the same taxi distance, resulting in a 16.4 percent lower bead temperature for the radial tire compared to the bias-ply tire. Figure 9 illustrates that the radial tire heats slower and has a lower final temperature under what would be a typical taxi for a moderately loaded B727-100 taxiing a long distance at a large airport. Table 2 gives a summary of the ΔTs for each test discussed.

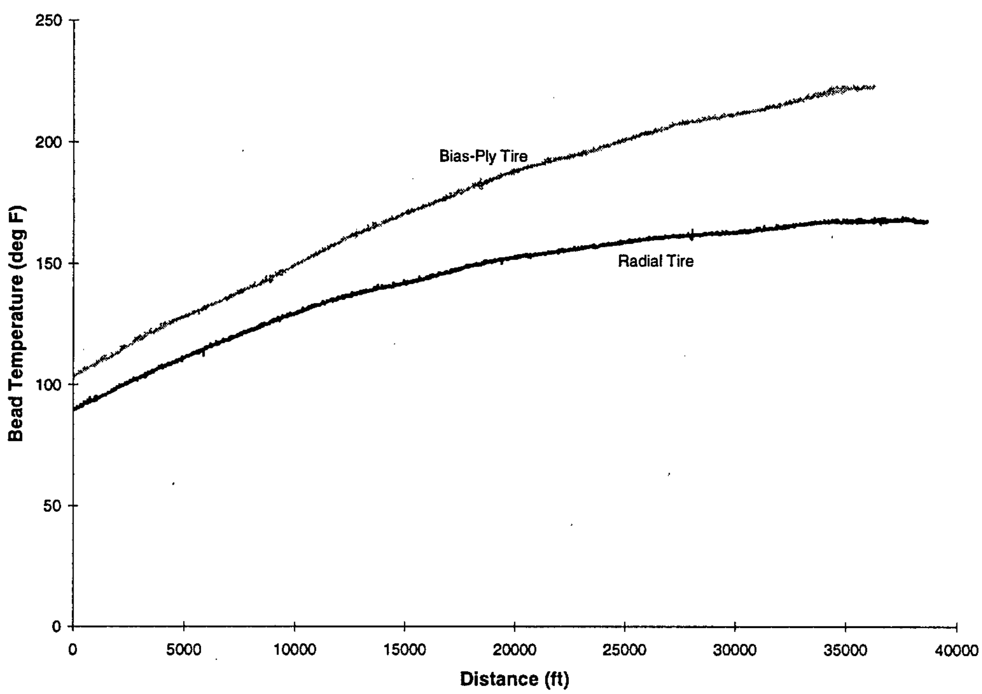


FIGURE 6. RADIAL AND BIAS-PLY TIRE HEATING DURING 10-MPH TAXI WITH 30,000-LB TIRE LOAD

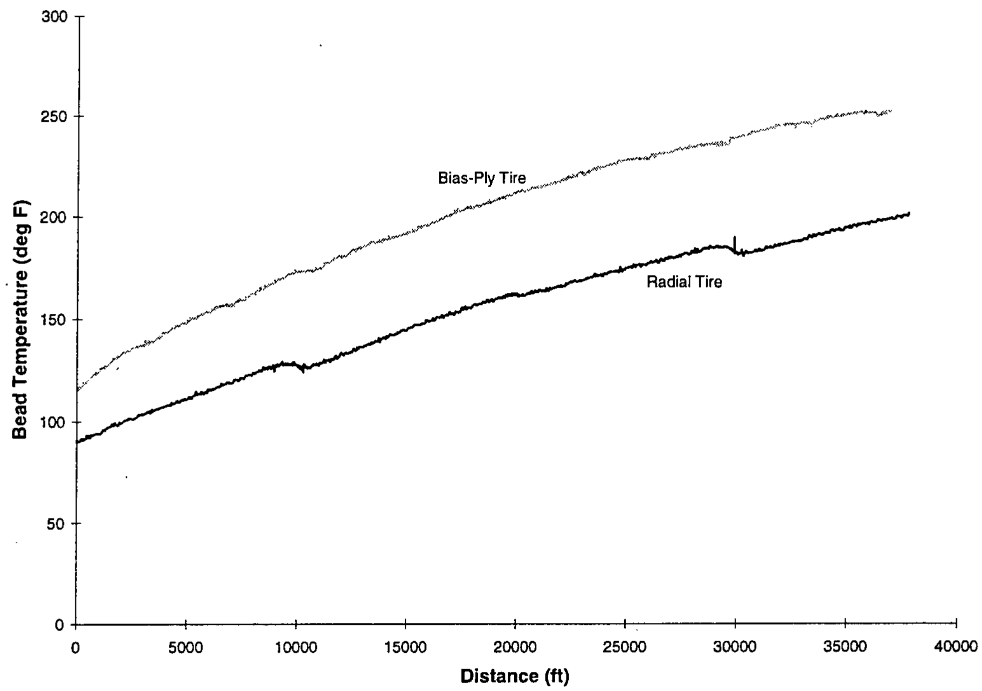


FIGURE 7. RADIAL AND BIAS-PLY TIRE HEATING DURING 40-MPH TAXI WITH 30,000-LB TIRE LOAD

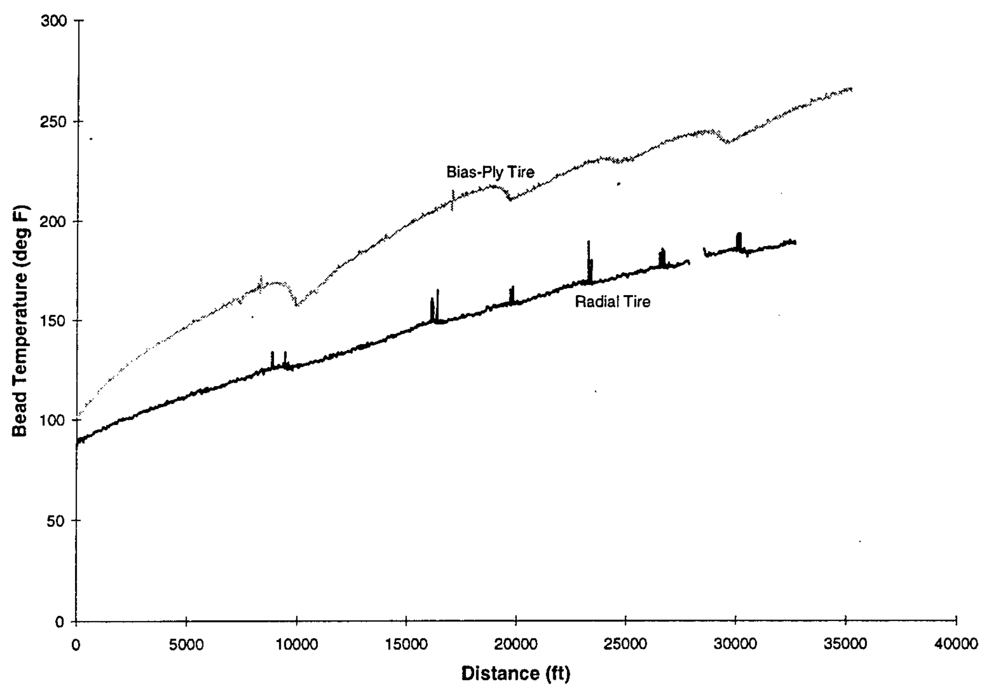


FIGURE 8. RADIAL AND BIAS-PLY TIRE HEATING DURING 70-MPH TAXI WITH 30,000-LB TIRE LOAD

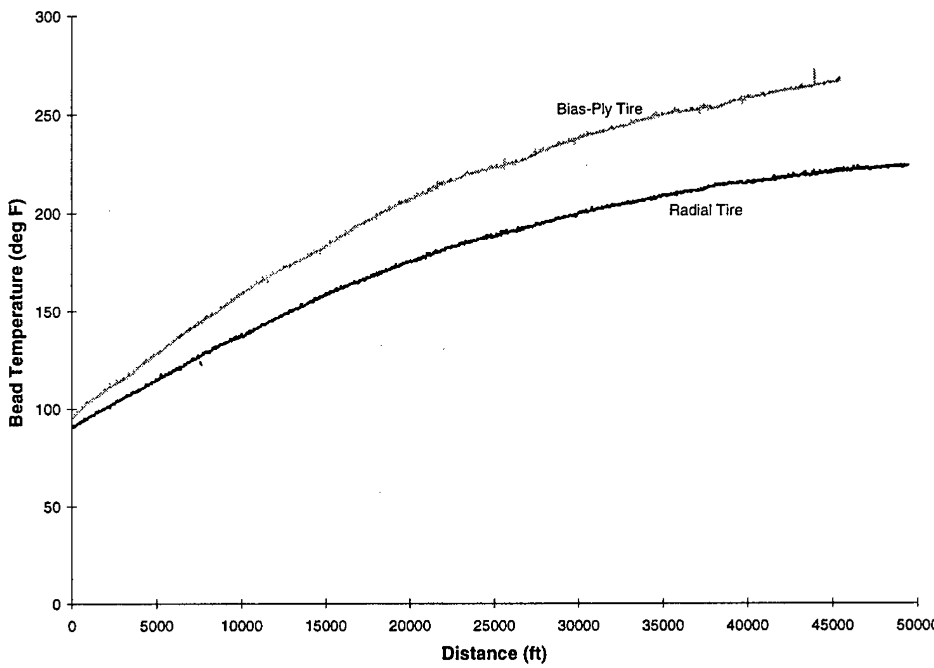


FIGURE 9. RADIAL AND BIAS-PLY TIRE HEATING DURING THE 25 MPH 14-MILE ROLL TEST WITH 31,000-LB TIRE LOAD

TABLE 2. SUMMARY OF RADIAL AND BIAS-PLY HEATING COMPARISON

| Test Description | Target Speed (mph) | Estimated Tire Load (lbs) | Distance Traveled (ft) | Temperature Difference (°F) |
|---|---|---|---|---|
| Lightweight Taxi Test | 10 | 24,000 | 36,000 | 19 |
| Lightweight Taxi Test | 40 | 24,000 | 33,000 | 5 |
| Lightweight Taxi Test | 70 | 24,000 | Data Not Available | Data Not Available |
| Medium Weight Taxi Test | 10 | 30,500 | 37,700 | 44 |
| Medium Weight Taxi Test | 40 | 30,500 | 35,500 | 29 |
| Medium Weight Taxi Test | 70 | 30,500 | 32,600 | 51 |
| 14-Mile Roll Test | 25 | 31,400 | 45,300 | 41 |

## TIRE LOAD COMPARISONS.

Figures 10 and 11 give 24,000- and 30,000-pound tire load temperature profiles as a function of distance taxied at 10 mph for the bias-ply and radial tires, respectively. These two graphs illustrate the effect of tire load on tire bead heating. For the bias-ply tire (figure 10), a 25 percent increase in tire load (6000 pounds) caused a 17 percent increase in bead temperature (33°F) over 36,000 feet of taxiing. For the radial tire, however, a 25 percent increase in tire load (6000 pounds) caused only an 8.5 percent increase in bead temperature (13°F) over 36,000 feet of taxiing. Although tire load highly affected the heating of tires, the radial tire still saw lower temperatures compared to the bias-ply tire.

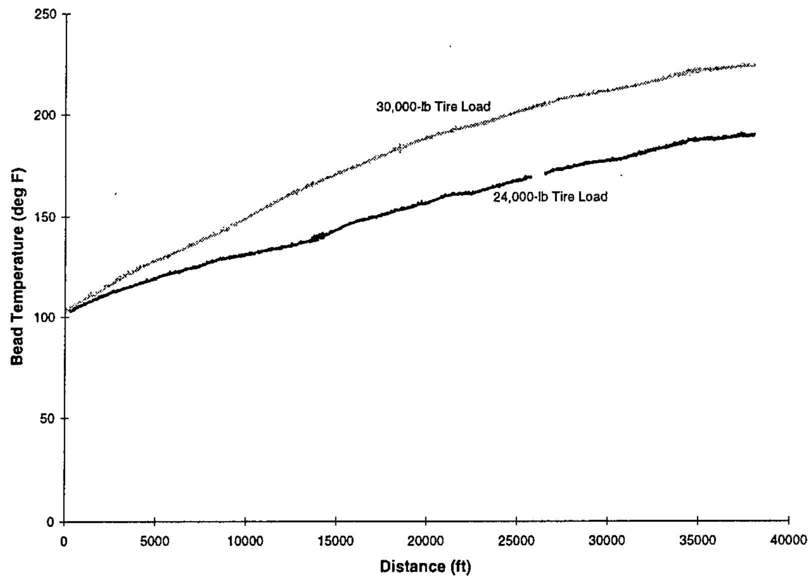


FIGURE 10. BIAS-PLY TIRE HEATING FOR DIFFERENT TIRE LOADS DURING 10-MPH TAXI SPEED

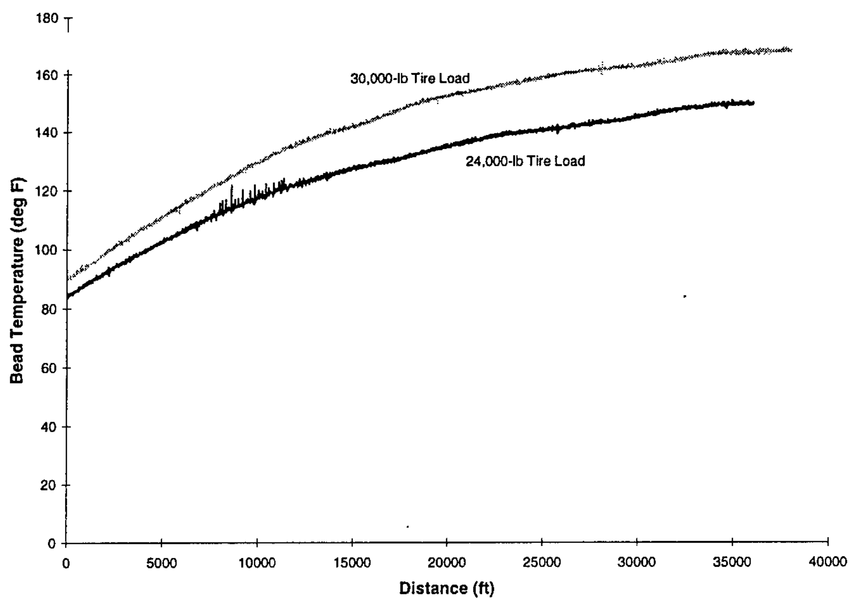


FIGURE 11. RADIAL TIRE HEATING FOR DIFFERENT TIRE LOADS DURING 10-MPH TAXI SPEED

Figures 12 and 13 give 24,000- and 30,000-pound tire load temperature profiles as a function of distance taxied at 40 mph for the bias-ply and radial tire, respectively. Similar results were obtained, as those shown in figures 10 and 11. Figure 13 illustrates short periods of temperature drops on the 30,000-lb tire load curve. These were due to the aircraft coming to a stop and turning around and continuing to taxi on the same surface (runway). In the other tests, the aircraft slowed down and turned onto the taxiway from the runway or onto the runway from the taxiway. In this maneuver there was additional heating from the lateral tire load. Also, bias-ply tires tended to lose heat more rapidly at higher temperatures, causing these cooling periods to be more noticeable.

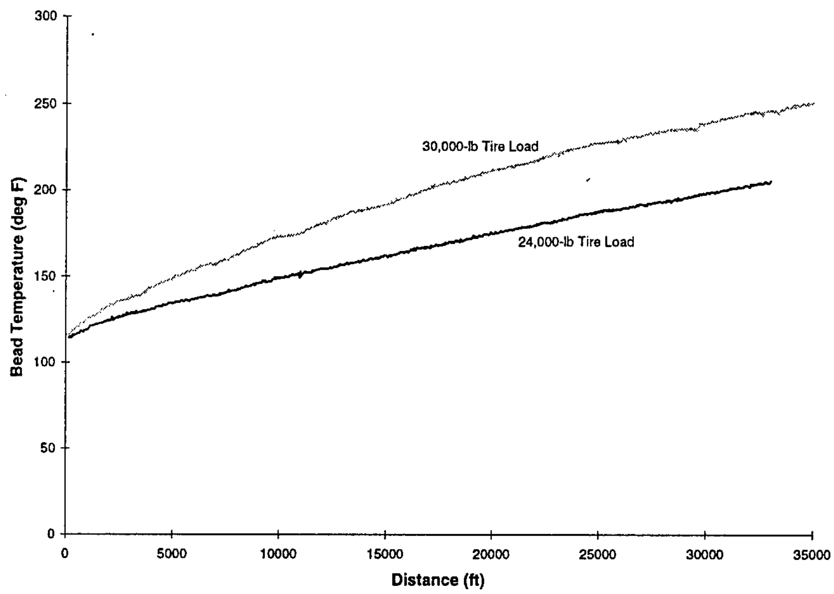


FIGURE 12. BIAS-PLY TIRE HEATING FOR DIFFERENT TIRE LOADS DURING 40-MPH TAXI SPEED

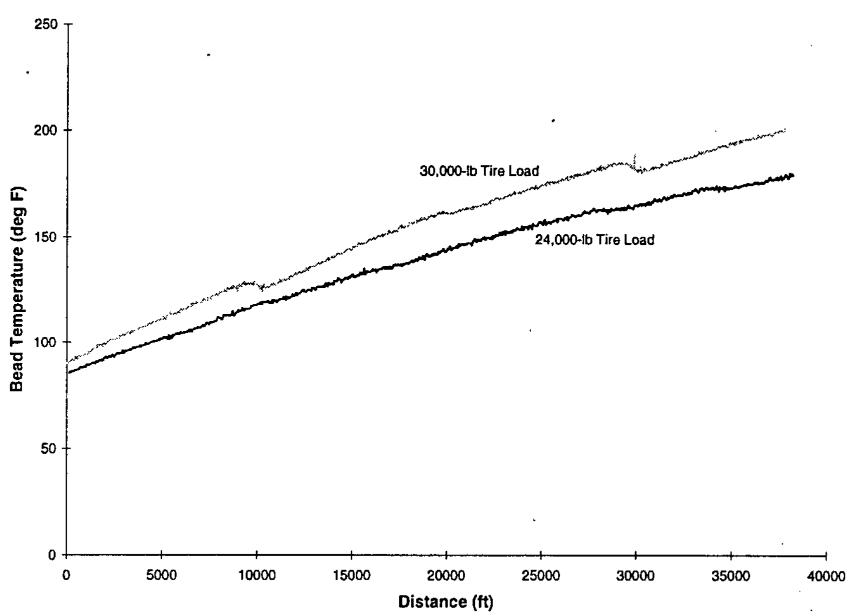


FIGURE 13. RADIAL TIRE HEATING FOR DIFFERENT TIRE LOADS DURING 40-MPH TAXI SPEED

TAXI SPEED COMPARISONS.

Figures 14 and 15 illustrate 10- and 40-mph taxi temperature profiles as a function of distance taxied for the 24,000-pound tire load for the radial and bias-ply tire, respectively.

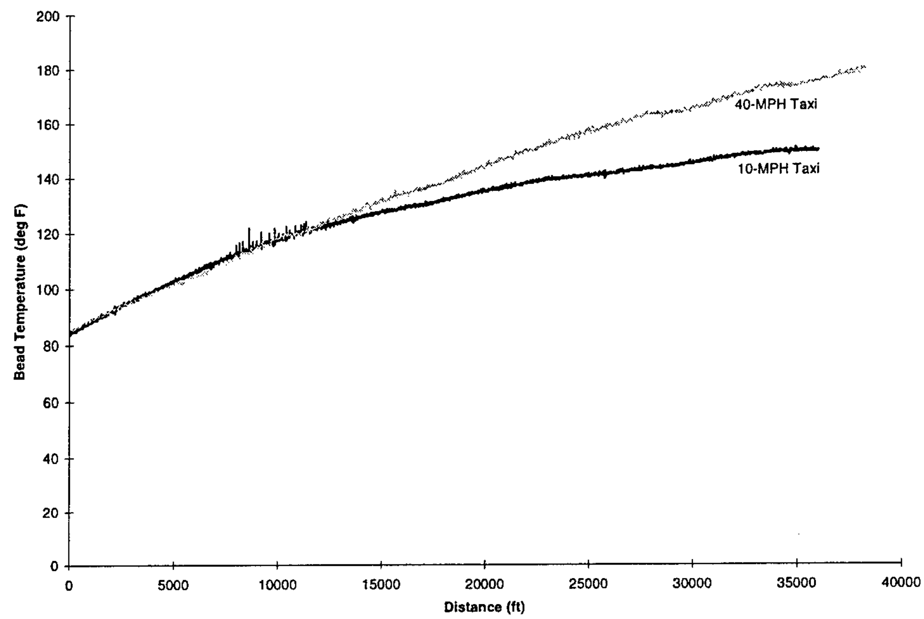


FIGURE 14. RADIAL TIRE HEATING AT DIFFERENT TAXI SPEEDS WITH 24,000-LB TIRE LOAD

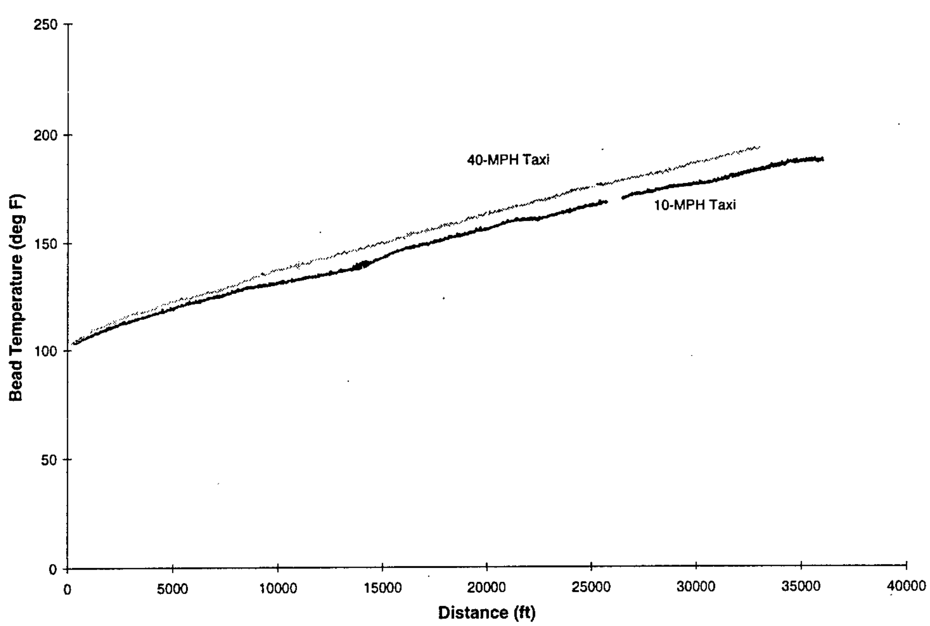


FIGURE 15. BIAS-PLY TIRE HEATING AT DIFFERENT TAXI SPEEDS WITH 24,000-LB TIRE LOAD

Figure 16 gives 10-, 40-, and 70-mph taxi temperature profiles as a function of distance taxied for the 30,000-pound tire load for the radial tire. A similar comparison for the bias-ply tire was not made due to irregularities in the data.

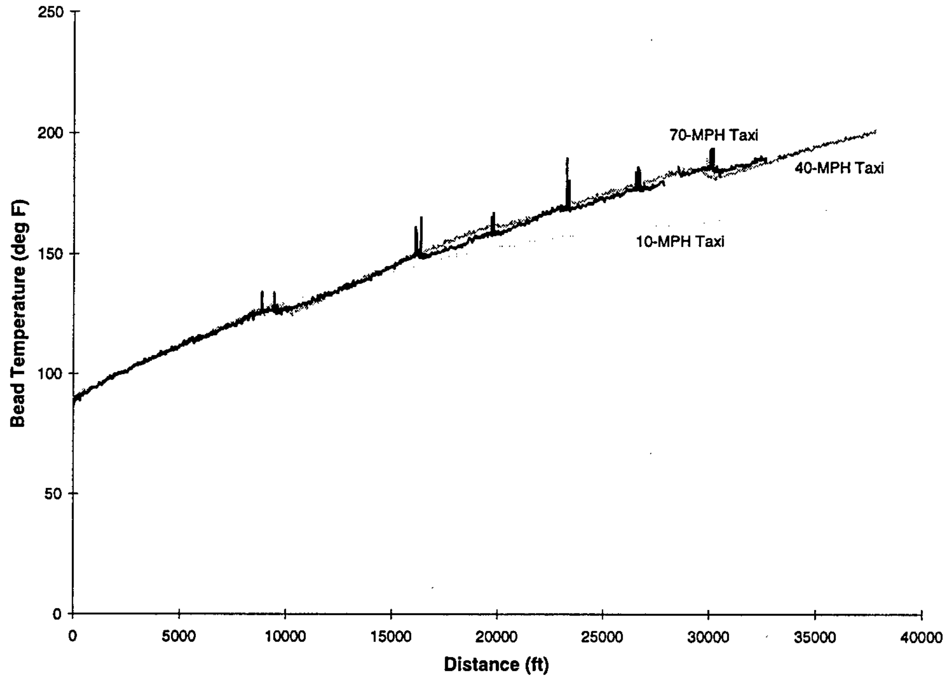


FIGURE 16. RADIAL TIRE HEATING AT DIFFERENT TAXI SPEEDS WITH 30,000-LB TIRE LOAD

## CONCLUDING REMARKS

In summary, the radial tire tended to run cooler in all scenarios of weight and taxi speed. Bead temperatures were from 5 to 20 percent less for the radial than for the bias-ply tires where taxied distances were from 32,500 to 37,000 feet. Tire load had a significant effect on tire heating in 36,000-foot taxi tests; a 24 percent increase in weight caused a 17 percent increase in bias-ply tire temperatures and an 8.5 percent increase in the radial tire temperatures. Taxi speed affected the change in bead temperature but only after taxiing some distance.

Although it is apparent that radial tires taxi at lower temperatures than the equivalent bias-ply tire, the effects of pavement temperature and ambient temperature are not fully understood and were not examined in the present work. More tests are needed to determine the effect of these parameters on the heating of commercial aircraft tires. Additional tests at greater weights would more thoroughly examine the effect of tire load on tire bead heating during taxi. Also, additional tests at taxi speeds between 10 and 40 mph and greater than 40 mph for longer distances would provide a better understanding of the effect of speed on tire bead heating during taxi.

## REFERENCE

Anderson, R., "Tire Test Correlation: Radial Versus Bias-Ply Tires," DOT/FAA/AR-TN95/97, FAA William J. Hughes Technical Center, Atlantic City International Airport, NJ, March 1996.