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A STUDY OF THE FEASIBILITY OF REQUIRING THE FEDERAL GOVERNMENT TO USE RETREADED TIRES

SMITHERS SCIENTIFIC SERVICE, INCORPORATED

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A STUDY OF THE FEASIBILITY OF REQUIRING THE FEDERAL GOVERNMENT TO USE RETREADED TIRES

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Tires, which represent only 1.5 percent of municipal solid waste, pose a special solid waste problem because tires are difficult to dispose of by conventional methods. A partial solution to this problem can be achieved through the reduction of tire waste. One waste reduction option suitable for this is retreading.

This report reviews the topic areas pertinent to retreading including the mechanics of tire retreading, the performance of retreaded tires, improving retreadability, and the economics of retreading. Based on these topics the report evaluates the feasibility of requiring the Federal Government to use retreaded passenger tires. The report also examines the solid waste and energy benefits that would be derived by both the Federal Government and the general public through the use of retreaded passenger tires.

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INTRODUCTION

More than five billion pounds of discarded tires end up as solid municipal waste every year. This represents about 1.5 percent of the total municipal solid waste disposed of annually, but it is an especially troublesome part of the solid waste disposal problem. These 180 million tires are extremely difficult to dispose of by conventional methods such as incineration or landfills.

It is estimated that about 45 million tires per year are recycled by means of retreading. Retreaded passenger tires currently represent less than 20 percent of the total of new and retreaded tires sold as replacements. For truck and bus tires the percentage is over 30 percent. Obviously, one way to reduce this solid waste problem is to increase the percentage of tires being retreaded.

A second benefit to be derived from the increased recycling of tires by retreading, will be a reduction in petroleum consumption. Industry sources have estimated that it requires seven gallons of crude oil to make the average passenger tire. Five gallons as raw material feed stock, and two gallons to supply the required energy. If this estimate is correct, then more than two billion gallons of crude oil were consumed in 1973 to manufacture 200 million passenger tires and 37 million truck and bus tires. Nearly two-thirds of the crude oil was required for the manufacture of passenger car tires.

Truck and bus operators have long accepted the economic advantages of using quality retreaded tires and there is little room for improvement in this area. However, passenger tires account for two-thirds of the tire disposal problem and two-thirds of the crude oil consumption, and the potential does exist for a major increase in the number of passenger tires presently being retreaded.

Any strategy for significantly increasing the demand for retreaded tires will have to be based on sound evidence that properly retreaded tires will meet the same safety criteria as new tires.

If it can be established that a properly designed new tire, properly maintained, and then properly retreaded, will continue to perform in such a manner as to meet new tire performance standards, or the equivalent, the first step toward increasing the acceptance of retreaded tires will have been taken.

However, barring reaction to any outside forces, such as drastically increased new tire prices or shortages as a result of the energy crisis, simple performance tests and standards alone will not make a major impact on the average consumer. Only extensive operating data from actual on-the-road experience can be expected to have any influence.

The Federal Government operates more than 400,000 vehicles, including 90,000 sedans and station wagons. Not only is this a source of all types of vehicles, traveling all kinds of terrain, but government purchasing and maintenance procedures lend themselves to a well controlled and documented test fleet.

As a first step toward investigating the increased use of passenger tire retreading as a means of resource recovery and reducing solid waste, this contract (EPA No. 68-01-2906) was awarded to study the feasibility of requiring the Federal Government to use retreaded tires.

SUMMARY

Tire Retreading

The tire retreading industry is more than 60 years old, but retreading did not make a serious impact in the tire market until the 1940's and World War II. At the peak of the war years, 20 million new passenger tires were produced and 30 million passenger tires were retreaded. But, in post-war 1948 nearly 70 million new passenger tires were produced while retreads plummeted to 5 million. Passenger tire retreading gradually recovered through the fifties and has stabilized at approximately 35 million units per year for the last 10 years. This represents less than 20 percent of the replacement market. Truck and bus retreading also matured during the war years, but after stabilizing at 7 1/2 million units per year through the early 1960's, a steady growth started about 1966 and truck and bus retreads now exceed 10 million units per year and represent over 30 percent of the replacement market

The American retreading industry is basically one of small shops. There are more than 5,000 retread manufacturers with 50 percent having an annual sales volume of less than $250,000 while less than 4 percent have a sales volume in excess of $1,000,000 per year.

Performance of Retreaded Tires

The overall performance of a tire is generally measured in terms of its performance in respect to high speed, tread wear, traction, endurance, and strength.

Available test data on the performance of retreaded passenger tires is very limited and inconclusive. Independent performance tests on retreaded tires have been conducted by The Department of Transportation (DOT) and The General Services Administration (GSA) in an effort to determine the performance of retreaded passenger tires currently marketed. These tests show extreme quality variations between retreaders. These quality variations are such that the "average" retreaded passenger tire has a performance level significantly below that of a new tire. However, there are instances where retreaded passenger tires have been shown to have performance properties approaching or equaling that of new tires. Also, the trucking and airline industries have had exceptionally good experience with retreaded tires. All of this indicates that quality retreads can be made. Unfortunately, the only significant, independent test programs conducted to date on retreaded passenger tires have been oriented toward an evaluation of existing retreaded tires available on the open market. There have been no independent tests, conducted on a statistically significant size sample, to determine the performance of retreaded passenger tires manufactured under optimum and controlled conditions of casing selection, inspection and retread processing.

There is little reliable operating or fleet data available for passenger tire retreads such as is available for truck or aircraft retreaded tires. Retreaded passenger tires are occasionally used for in-city fleet operation by taxi cabs or utilities, but this experience is totally unrelated to the typical high speed and endurance levels to which the average passenger tire is subjected.

Although there is an absence of both test data and fleet operating experience, it is highly probable that retreaded passenger tires can meet the same performance criteria as a new tire.

The cost for retreaded tires having performance characteristics equivalent to new tires could be quite high. This cost will be in proportion to the degree of confidence and reliability desired. The largest single unknown factor influencing this cost is casing inspection. Presently available non-destructive test (NDT) methods are expensive to install and require skilled operators.

The only independent tread-wear test data available for passenger retreads is that from GSA. In 1974, GSA conducted an extensive test series on retreaded passenger tires manufactured according to existing Federal specifications. The tread-wear varied from less than 10,000 miles to more than 25,000 miles. Again, the data is obscured by the extreme variations in quality. Certainly the potential exists for all, or at least most, of the retreaded tires to meet the 25,000 mile performance under GSA test conditions.

Improving Retreadability

Maintenance. Improved maintenance of tires could make an additional 10 to 15 percent of presently discarded tires suitable for retreading. This increase in casings available for retreading would permit a 50 percent increase in the number of passenger tires retreaded. Improved maintenance practices include: (1) exercise care in mounting and demounting tires; (2) remove tire when 2/32 inch tread remains; (3) maintain proper alignment, balance, inflation and rotate as recommended. These are simple precautions, readily put into effect by Federal Government agencies. Current GSA practices require that every car be serviced at 3,000 mile intervals, and that servicing includes inspecting the tires and taking any remedial action indicated--such as balancing or realignment. Getting the general public to implement these practices will be considerably more difficult.

New Tire Construction. Careful control of tire size and selected design parameters could make an additional 15 percent to 20 percent of discarded casings suitable for retreading. Approximately 11 percent of the inspected tire casings are rejected because they are of a size no longer popular. This results from continuing changes in automobile styling and sizes as well as from changes in tire technology.

Improvements in tire design will be required before the steel belted radial will lend itself to retreading. At the present time a high percentage of inspected steel belt radials are rejected for retreading because of belt edge separation. It is expected that this problem will be resolved either by design changes in the steel belt construction or by replacing the steel belts with textile belts. Textile belted radials are less susceptable to belt edge separation.

Sidewall damage accounts for 12 percent of casing rejections. A large part of this is due to sidewall aging or weather checking and will require improvements in sidewall compounds.

Bead damage accounts for 7 percent of casing rejections. Most of this can be eliminated by the use of more care in mounting and demounting tires, but additional improvement can be achieved by the increased use of fabric chafer strips in the bead area.

Federal Government agency purchasing procedures could make a significant contribution to reducing casing rejections due to tire size and design features and at no additional cost.

Economics of Retreading

The trucking industry has long recognized the economic advantages of retreading. The average retreaded truck tire will wear as well as a new tire, and for only one-third the cost.

Civilian and military aircraft also make extensive use of retreads for economic reasons. Most aircraft tires are retreaded 7 to 9 times.

Federal Government agencies are rapidly increasing their use of retreaded tires. In fiscal 1974, GSA retreaded 240,000 tires for an estimated savings of $7,000,000. These were primarily truck tires with passenger tires accounting for less than 20 percent of the total.

The economics of tire retreading are heavily dependent upon the initial cost of the tire. In general, the higher the cost of a new tire, the lower the percent of new tire cost for the retread (i.e., a $500 airplane tire may be retreaded for 20 percent of the new tire cost, a $150 truck tire for 33 percent, and a $20 passenger tire for 50 percent.)

The increased use of radial ply passenger tires, with their higher initial cost, will tend to make the retreading of passenger tires more economically attractive.

The Feasibility of Requiring The Federal Government To Use Retreaded Tires

At this point in time it is not feasible to require the Federal Government to use retreaded passenger tires. Federal agencies are making good progress in the use of retreaded truck tires with several agencies now having goals of 70 percent or more of replacement tires being retreads.

The benefits to be derived from the increased use of retreaded passenger tires must be delayed until; (1) independent, definitive performance tests have been completed to determine the performance of high quality retreads as compared to new tires, (2) new standards or specifications are developed to insure that only high quality retreaded tires are manufactured, (3) a highly reliable, but inexpensive method for casing inspection is developed, (4) radial tire belt edge separation problems are solved.

Once the above conditions have been successfully met, the benefits can be realized. By changing to radial ply passenger tires with 40 percent being retreaded, the potential exists for the Federal Government to:

(1) Save $1,000,000 per year (25 percent of present passenger tire costs),

(2) Reduce tire disposal by 75,000 tires (50 percent of present level),

(3) Save 1.7 million pounds per year in solid waste, (46 percent of present

discarded Federal passenger tire solid waste contribution),

(4) Save 9,000 barrels of crude oil per year (39 percent of present material and energy requirements for Federal passenger tire manufacture).

Changing the United States passenger tire utilization from belted/bias tires with 20 percent being retreaded, to radial tires with 30 percent being retreaded could potentially:

(1) Reduce scrap tire disposal by 58 million tires per year (a 40 percent reduction),

(2) Save 1.1 billion pounds per year of solid waste (33 percent of present discarded passenger tire solid waste),

(3) 8 million barrels per year of crude oil (33 percent of present crude oil requirements for passenger tire manufacture).

CONCLUSIONS

(1) There is an extremely wide variation in the quality of commercially available retreaded passenger tires.

(2) There is insufficient test data to conclusively determine the performance of high quality passenger tire retreads in comparison with new passenger tires.

(3) The successful use of retreaded tires by the trucking and airline industries confirms that high quality retreaded tires can be made. Experience in these industries shows performance comparable to that of new tires, and with major economic advantages.

(4) Tire scraps along Interstate highways result from both new and retreaded tire failures. The approximate split is 60 percent from retreaded and 40 percent from new tires.

(5) Improved maintenance procedures can make an additional 10 percent to 15 percent of discarded tires suitable for retreading. This could result in a 50 percent increase in the number of tires retreaded.

(6) Careful control of tire size and selected design parameters could make an additional 15 percent to 20 percent of discarded casings suitable for retreading.

(7) Federal Government agencies can implement maintenance procedures to increase casing availability at no apparent additional cost.

(8) Government agency purchasing procedures can make significant progress in reducing casing rejections due to tire size and design features. Again, at no apparent increase in cost.

(9) The major barriers to increased use of retreaded passenger tires are the uncertain quality and the emotional connotations connected to a "used" product.

(10) Radial tires offer the greatest opportunity for major improvements in reducing solid waste resulting from tire disposal. Radial tires also offer the greatest potential for reducing energy and material requirements for tire manufacture.

(11) The present generation of steel belted tires is posing serious problems for the retreader. However, these problems are expected to be resolved in the near future.

(12) Until it can be established that a properly retreaded passenger tire can meet new tire performance criteria, it is not feasible to require the Federal Government to use retreaded passenger tires.

(13) If equivalent performance can be demonstrated, significant savings can be realized in terms of dollars, energy, raw material, and solid waste.

RECOMMENDATIONS

On the basis of the conclusions reached during the course of this study, it is recommended that: (1) The Federal Government undertake a test program designed to determine the performance of retreaded passenger tires manufactured under optimum and controlled conditions of casing selection, inspection, and retread processing. The program should include enough tires to be statistically significant, and should start with new tires. The new tires should be thoroughly inspected, both visually and by various NDT methods. Tread wear should be under actual highway driving conditions. Before retreading the casings should again be inspected both visually and by NDT methods. Retreading should be done under carefully controlled conditions and in some instances tires should be retreaded more than once. (2) The Federal Government increase the use of retreaded passenger tires by GSA. The initial program should involve selected motor pools as pilot operations representing the geographic and climatic regions of the United States. Retreading should be performed only by high quality retread shops, under tight Government specifications, subject to frequent inspection by well trained inspectors, and contracted for under financial incentive contracts-not necessarily the lowest bid.

Strict tire maintenance procedures should be practiced and tire performance records maintained.

TIRE RETREADING

The tire retreading industry is more than 60 years old, but until World War II its impact on the tire market was negligable. From 1942 to 1944 virtually all civilian passenger tire needs were met by the retreading industry which expanded 500 percent from its 1941 base. At the peak of the war years, 20 million new passenger tires were produced and 30 million passenger tires were retreaded. But, in post-war 1948, when nearly 70 million new tires were produced, retreads plummeted to 5 million. Passenger tire retreading gradually recovered through the fifties and has stabilized at approximately 35 million units per year for the last 10 years representing less than 20 percent of the replacement market. Mud and snow tires are a major factor in the passenger retread industry, accounting for nearly 32 percent of all production as compared to only 14 percent for new passenger tires.

Truck and bus retreading also matured during the war years, but after stabilizing at 7 1/2 million units per year through the early 1960's, a steady growth started about 1966 and truck and bus retreads now exceed 10 million units per year and represent over 30 percent of the replacement market.

The retreading industry has always been oriented toward the small businessman and in 1960 it was estimated that there were 9,000 to 10,000 retread shops. In recent years there has been a trend toward larger shops, but fewer of them. Department of Transportation records indicate about 5,000 retread shops in 1974, but a recent review of this listing indicates that there may be considerably less than 5,000 retread shops actually operating. The National Tire Dealer and Retreader's Association estimates that in 1974, only 4 percent of the retreaders have a sales volume in excess of $1,000,000 per year, while 50 percent have annual sales of less than $250,000.

The Tire Retreading Process

The retreading of a tire involves a series of five steps, beginning with a careful inspection of the casing and ending with a final inspection of the completed product.

Primary Casing Inspection. A visual inspection is necessary to determine if the tire is acceptable for retreading. The inspection should be carried out in a well lighted work area, and the inspector should use a spreader to spread the tire beads sufficiently to expose all surfaces for potential defects.

Casings having any of the following conditions are not suitable for retreading:

(1) Exposed fabric in tread area

(2) Ply separation

(3) Oxidation or heavy weather checking

(4) Irreparable surface cuts

(5) Broken or kinked beads

(6) Damaged beads exposing cords

(7) Radial cracking

(8) Flex breaks

(9) Loose or porous liners

(10) Defective inner splices.

(11) Injury to ply cord fabric in bead area

(12) Temporary plugs in sidewall

(13) Previous section repairs

(14) Severe punctures

(15) Blisters in sidewall or carcass

(16) Severe groove cracking

(17) Broken ply or breaker cords

Following the casing inspection, the casing is measured to determine the proper matrix or mold size. The casing should not be retreaded unless the proper size equipment is available.

Buffing. Following inspection and measuring, the tire is buffed to remove the remaining tread rubber and to prepare a surface texture which will insure maximum adhesion of the new tread to the casing. It is very important that a retread has a buffed radius and tread width which conforms to the shape in which a casing will be cured. Until recently this precise shaping depended upon the skill of the buffing machine operator. At most shops the buffing is now accomplished by the use of automated buffers which inflate the tire to its normal running contour and buff the tire to a precise template.

Surface scorching of the tire must be avoided and racks or dollies should be used to store the buffed tires to prevent contamination.

After buffing a second inspection should be made to locate any cuts, nail holes or ply separations that were not detected during the first inspection. Also, a second bead to bead and diameter measurement should be taken to verify correct carcass matrix match-up.

Tread Application. Rubber cement is applied evenly over the buffed surface either by brush application or by a spray gun to promote adhesion between the casing and the tread rubber. Care must be taken to prevent the cement from becoming contaminated by foreign substances. After the cement has dried, the tread rubber for the hot cap process can be applied manually or with an extruder device.

The manual method uses a die size rubber of predetermined dimensions which will fill out the matrix design. The die sized strip of rubber is wound circumferentially around the tire. The operator must be careful to be certain that the tread rubber is applied directly to the center of the casing. In some cases a cushion gum has been pre-applied to the bottom of the die sized rubber to obtain optimum adhesion of the tread rubber and the casing.

The extruded ribbon method was pioneered by the Orbitread machines of AMF. The Orbitread machine is a cold feed extruder which develops its extrusion temperature primarily through frictional temperature in the barrel and at the extrusion head. The tires are built on an expandable inflated hub. The extruded strip of hot rubber is wound around the tire based on a pre-set card program which is set up on the control console.

After the tread rubber has been applied, the tire is transferred to a curing mold or matrix where the tread rubber is cured and a tread design molded into the rubber.

A more recent development is the precured tread process. In this case, the tread rubber is purchased as a partially cured strip of rubber with the tread design already formed. After cementing, an uncured cushion gum is applied to the casing or to the bottom of the precured tread and the tread is then applied to the casing.

Curing. The hot cap retreads are cured in individual molds at temperatures of 280F to 310F for about 2 hours. Air or stream at pressures upwards of 100 psi is used inside to provide molding pressure and in the case of steam to also reduce curing time.The precured (or cold process) treads are cured at far lower temperatures, in some instances below 200F, but for about 4 hours. These can be done in multiple unit heaters using vacuum or pressure differential to adhere the tread to the casing.

Final Inspection. After removal from the curing molds, the appearance of the finished retreads is inspected inside and out for any defects. Any excessive flash or vent rubber is trimmed off and the tire is labeled and stacked for warehousing.

Tire Retreading Problems

Three key factors influencing the quality of retreaded tires are: (1) tire size, (2) casing inspection, (3) retreading practices.

Tire Size. Tire size problems stem from two sources; the variations within a given size from different manufacturers, and changes in original equipment size or styling. FMVSS 109 establishes minimum size requirements for new passenger tires. These standards specify a size factor for each size of tire; i.e., a G78-14 has a minimum size factor of 35.02. The size factor is defined as the section width plus the outside diameter of the tire and FMVSS 109 limits the section width for a G78-14 to 8.93 inches. The diameter can vary as long as the sum of the two variables is not less than 35.02 and the section width no greater than 8.93 inches. Five new steel belted bias ply G78-14 tires were measured with the following results:

Manufacturer	O.D.	Section Width	Size Factor
A	27.05	8.32	35.37
B	27.17	8.41	35.58
C	26.81	8.49	35.30
D	27.38	8.40	35.78
E	27.31	8.26	35.57

All five tires comply with FMVSS 109 standards, but there is a variation of 0.57 inches in O.D. and 0.23 inches in section width.

Seven new G78-14, 4 ply polyester tires were then measured:

Manufacturer	O.D.	Section Width	Size Factor
T	27.27	8.31	35.58
U	26.92	8.29	35.21
V	27.39	8.76	36.15
W	27.53	8.34	35.87
X	26.64	8.50	35.14
Y	27.22	8.36	35.58
Z	27.00	8.23	35.23

Again all 7 tires meet the standard, but the O. D. varies by 0.89 inches and the section width by 0.53 inches. Mold size does not precisely control tire size. Changes in cord material, ply angle, and drum sets can cause significant differences in tire size coming from the same mold.

After the tires have been placed in operation, they will tend to grow with the bias ply tires growing more than the steel belted bias tires. The growth of tires is related to both tire design and materials of construction. FMVSS 117 for retreaded tires limits the section width change to not less than minus 3 percent nor more than plus 10 percent of the new tire specification. Thus the retreader is faced with wide variations in O.D. and section width from tires that are the same "size".

The problem is further compounded as original equipment manufacturers change from 14 inch wheels to 15 inch and also change the tire aspect ratios (ratio of tire height to tire width) from 78 to 70. For example, original equipment tires for a given model one year may be G78-14, and the following year be changed to G70-14 or perhaps G70-15.

These wide variations in tire size make it necessary that the retreader maintain a very large inventory of matrices, if he is a hot cap processor, or a large inventory of tread widths if he is a precured tread processor. If he does not maintain this inventory he must be very selective in the size and type of tire he retreads, or he forces the tire to fit his existing matrices or treads and produces an inferior product.

Casing Inspection. Procedures for casing inspection were previously described, however, it is often not possible to detect all defects within the casing by visual methods of inspection. Later in this report several methods of non-destructive testing (NDT) are described. It may be necessary to employ these advanced techniques if retreaded passenger tires are to meet high performance standards.

Retreading Practices. Perhaps the greatest number of defective retreaded tires result from the retread operators not following good retreading practices as defined by the various equipment manufacturers, material suppliers, and trade associations.

PERFORMANCE OF RETREADED TIRES

Widespread use of retreaded passenger tires cannot be expected until it has been proven that they can be operated with the same degree of safety and convenience as new tires.

In 1968, Federal Motor Vehicle Safety Standard 109 (FMVSS 109) was enacted for new passenger tires. Indoor laboratory dynamometer wheel tests are included in this standard establishing minimum performance levels, although there are still many questions regarding the validity or meaning of such tests. To date, there is no data establishing a direct correlation between these tests and actual road performance. However, this standard has been accepted by the tire industry and has been a factor in improving tire performance. The number of new tires failing the endurance portion of this test was reduced from 5.9 percent in 1970 to 0.87 percent in 1972 and high speed test failures were reduced from 4.5 percent to 0.11 percent during the same period.

In 1971, Federal Motor Vehicle Safety Standard 117 (FMVSS 117) was issued and it proposed to subject retreaded tires to a similar wheel test. However, the retreaded tires had an unacceptably high failure rate on the test wheel. The retreaders claimed that properly made retreaded tires perform as well as new tires under actual road conditions, and that FMVSS 117 was not a fair test in that it did not duplicate or correlate with road conditions. The U.S. Court of Appeals heard the case and invalidated the major performance criteria of FMVSS 117 including the indoor wheel tests.

The cost and time required to conduct actual on-vehicle road tests to qualify and evaluate the quality of tires is prohibitive. Extensive work is underway throughout the country to develop suitable laboratory tests or other accelerated methods that will correlate with road tests for both new and retreaded tires.

Tire Testing

The overall performance of a tire is generally measured in terms of its performance in respect to high speed, tread wear, traction, endurance, and strength. These characteristics are determined by means of: (1) actual road testing on public highways using standard vehicles, (2) closed track testing using either standard vehicles or trailers, (3) indoor wheel tests, (4) laboratory tests. New tire manufacturers routinely use all these methods in tire development and production control. Tire retreaders can seldom afford the luxury of such extensive test programs. The reasons are apparent when it is considered that the annual U. S. market for new passenger tires, approximately 185 million, is supplied by fewer than 20 manufacturers. On the other hand, nearly 5,000 retread manufacturers supply the 30 million passenger tires that are retreaded each year. As a result, most retreaders rely on tread rubber suppliers, or equipment manufacturers to do their research, testing and evaluation. This has resulted in an absence of independent test data. Test programs are sponsored or run directly by organizations who are associated with either the new or retread industries. The test programs that have been sponsored by retreaders directly are generally very limited in scope because of financial restrictions.

A thorough search throughout the retread industry located only four test programs involving a significant number of retread tires. These programs were conducted by DOT and GSA and are described below.

DOT-ARA. The National Highway Traffic Safety Administration (NHTSA) contracted with Automotive Research Associates, Inc. (ARA) for a series of tests on new and retreaded tires. The final reports were issued in mid-1973.

The tire constructions tested included 4 ply nylon bias, 2 + 2 polyester fiberglass belted bias, and two radial types; 2 + 2 rayon steel and 2 + 3 polyester steel and nylon. Similar constructions in the bias and belted bias allowed for a comparative evaluation of new tires versus retreads. Differences in radial construction did not permit a comparison between new and retreaded tires. Differences in retreading applications were also evaluated with some tires recapped using a hot process and others a precured tread process.

All tires were subjected to three tests. Conditions for these three endurance tests are listed below along with current test conditions for the FMVSS109 Endurance Test.

(1) FMVSS 109 Endurance Test Conditions

Environment Temp.	100F
Wheel Speed	50mph
Inflation Pressure	24psi

4 hours at 100% of rated 24 psi load

6 " " 109% " " " " "

24 hours at 117% of rated 24 psi load

34 hours total

(2) Proposed Modified 109 Endurance Test

Environment Temp.	100F
Wheel speed	50mph
Inflation Pressure	24psi

4 hours at 100% of rated 24 psi load

6 " " 109 " " " " "

24 " " 117 " " " " "

Run to Failure at 146% of rated 24 psi load

(3) Proposed SAE Endurance Test-Indoor Wheel

Environment Temp	100F
Wheel Speed	50mph
Inflation Pressure	32psi

4 hours at 100% of rated 24 psi load every 4 hours increase load by 15 percent of original load until failure.

(4) Proposed SAE Endurance Test-Trailer

Environment Temp.	Outside Ambient
Speed	70 mph
Inflation Pressure	32 psi

4 hours at 100% of rated 24 psi load.

Every 4 hours increase load by 15 percent of original load until failure.

Table 1 gives the average results for the 4 ply nylon, bias construction tires. The 146 percent overload DOT 109 test indicates that the Group F retreaded tires performed nearly as well as the new tires, and although the Group H retreaded tires did not run nearly as long--they did pass the existing FMVSS 109 requirements.

The SAE modified wheel test results show the Group F retreads outperforming the new tires, while the Group H retreads are nearly equal to the new tires.

However in the trailer test, neither group of retreads performed as well as the new tires.

Table 2 summarizes the average test results for groups of belted bias tires. In the 109 series both groups of retreaded tires outperformed the new tires, but in the SAE modified wheel test both retread groups performed at a slightly lower level than the new tires.

Again, in the SAE Trailer Endurance Test the retreaded tires performed significantly below the level of the new tires.

Table 1 and Table 2 both indicate that the retread tires can perform as well as new tires. The 146 percent overload DOT 109 Test indicates that the hot cap 4 ply nylon bias retreaded tires (Group F) performed equal to the new tires (Group A), while the precured tires in Group H only ran 36.5 percent as far. In the belted bias constructions (Group B, G and J) the retreaded tires out-performed the new tires with the precured tread tires running 25 percent further than the new tires.

TABLE 1
DOT-ARA TESTS
BIAS PLY TIRES

	New Tires	Retreaded Tires	
		Hot Cap	Precured
Code	A	F	H
Size	G78-15	G78-15	G78-15
Construction	4 P Ny	4 P Ny	4 P Ny
Hours on 109 Wheel	107.3	101.3	39.2
Ave. load at failure %	146	146	146
Hours on SAE Wheel	30.2	33.7	27.9
Ave. load at failure %	205	235	200
Hours on SAE Road	33.6	22.6	28.3
Ave. load at failure %	210	175	200
Required for FMVSS 109			
Hours on 109 Wheel	34	*	*
Load at completion of test(%)	117		

* Indoor Wheel Test not required for retreaded tires FMVSS 117

Source: DOT Report No. 109-ARA-73-DOT-HS-001-3-572-NHTSA 3-A817

TABLE 2
DOT-ARA TESTS
BELTED BIAS TIRES

	New Tires	Retreaded Tires	
		Hot Cap	Precured
Code	B	G	J
Size	G78-15	G78-15	G78-15
Construction	2+2 PG	2+2 PG	2+2 PG
Hours on 109 Wheel	37.9	42.1	47.4
Ave. load at failure%	146	146	146
Hours on SAE Wheel	23.3	21.4	20.2
Ave. load at failure%	175	175	175
Hours on SAE Road	25.0	19.1	14.6
Ave. load at failure	190	160	145
Required for FMVSS 109			
Hours on 109 Wheel	34	*	*
Load at completion of test (%)	117		

* Indoor Wheel Test not required for retreaded tires FMVSS 117

Source: DOT Report No. 109-ARA-73-DOT-HS-001-3-572-NHTSA 3-A817

Tires run to the SAE road test using the trailer indicated that the new tires were superior to the retreads. The 4 ply nylon bias retreaded carcasses out-ran the 2 + 2 polyester/fiberglass retreaded carcasses by as much as 51 percent. The new 4 ply nylon tires (Group A) our-ran the new 2 + 2 polyester/fiberglass tires (Group B) by approximately 34 percent.

The SAE wheel test comparisons indicate that, again, the retreaded tires performed as well as the new tires. However, overall, the 4 ply nylon bias retreaded carcasses out-ran the 2+2 polyester/fiberglass retread carcasses by as much as 48 percent.

Only two groups of precured retreaded tires showed superior running performance over the hot process retreads. Group H tires on the SAE road test were 25 percent higher than the Group F tires, however, significantly lower than the new tire performance. Group J on the overload 109 test out-ran the hot retreaded tires by 12 percent.

The three tests performed in this program emphasized overload as a method by which accelerated test results could be obtained on both new and retreaded tires. The data, therefore, should only be interpreted as a comparison between these two basic differences under overloaded conditions. To relate these test results to the comparable performance of a tire under actual service conditions would be misleading in that no correlation currently exists between these simulated tests and actual performance in service.

The value of these test results is limited since no control was exercised over the selection of casings to be retreaded, and no control or inspection was provided during the retreading process. Descriptions of the failure modes or the characteristics of the condition of each tire after the tests were generalized and lacked the necessary detail to permit an analysis to determine the cause of failure and to determine if the failure was related to the retreading procedure or other causes.

It would be highly desirable to determine what effect, if any, the various retreading procedures have on the integrity of the tire carcass. It would be expected that a precured process would have less effect, due to the reduced curing temperature, but this series of tests indicated superior performance for hot process retreads.

DOT-NDT TEST. A preliminary study of the relationship between failure of retreads during FMVSS 109 tests and flaws detected by non-destructive testing was undertaken by the Transportation Systems Center of the Department of Transportation in 1972 (Report No. DOT-TSC-NHTSA-73-1).

During this study, 137 retreaded passenger tires were purchased, subjected to tests, run on a Standard FMVSS 109 test wheel, re-examined by non-destructive means and analytically sectioned.

A comparison was made of those tires having holographically identified separations showing up on the first inspection prior to the wheel test. The 95 retreads which were considered passed had an average of 0.642 separations per tire, while the 42 tires considered failed had an average of 1.26 separations per tire. The remaining 10 tires encountered operating problems and did not generate any useful data. After the wheel test, the average number of separations in the passed category increased to 0.844, while the average number of separations in the failed category increased to 3.67. The inspections after the tires had failed, however, were not completely realistic since in many cases, the separation behind a tread chunk-out was no longer discernable by holography and separations had a tendency to grow and join together into one.

The relation of tire failure to construction type was considered to determine any long term trends. The results are shown in Table 3. The results of this project are somewhat inconclusive. Again, no attempt was made to control either the history of the casing or the quality of the retread. Table 3 does show a very high failure rate (53 percent) of 2 ply rayon tires and 2 ply polyester tires (44 percent). However, success of holography to predict failures is questionable in the case of the 2 ply casings where in one instance only one separation was found, but 8 tires failed and in the other only 2 separations were found but 7 tires failed.

The reverse situation appears to exist in the case of 4 ply bias construction tires. Here the failure rates range from 15 to 31 percent, while the number of separations found would indicate the probability of a much higher failure rate. Only 10 polyester/glass belted bias tires were examined, but they showed 38 separations and a 60 percent failure rate.

In summary, the results of this project suggest that: (1) 2 ply bias construction tires are not good candidates for retreading, (2) belted bias tires

TABLE 3
TIRE FAILURE VS TYPE OF TIRE CONSTRUCTION
USE OF HOLOGRAPHY

Type	No. of Tires Passed	No. of Tires Passed	Separations Located by Holograph Prior to Wheel Test	Average Separation	Percent Failed
2 Ply Rayon	7	8	1	0.1	53
2 Ply Nylon	1	0	0	0.0	0
2 ply Polyester	9	7	2	0.1	44
4 Ply Rayon	11	3	12	0.9	21
4 Ply Nylon	41	7	15	0.3	15
4 Ply Polyester	13	4	2	0.1	31
2+2 Rayon Rayon	5	0	5	1.0	0
2+2 Polyester Glass	4	6	38	3.8	60
4+2 Polyester Glass	0	1	0	0.0	100
TOTAL	91	36			28

Source: DOT Report No. DOT-TSC-NHTSA-73-1 are more prone to separations than bias ply tires, (3) 4 ply bias construction tires are the least prone to failure in the FMVSS 109 test, (4) the reliability of holography in predicting tire failure is questionable at this time.

Table 4 provides one additional bit of information in a summary of tires failed in relationship to the retread manufacturer. The failures range from 1 to 39 percent and indicate the wide variation in quality between retreaders. It can also be seen that 28 percent of all retreaded tires tested failed the FMVSS 109 wheel test.

DOT-FMVSS 109 Tests. To obtain background performance data on retreaded passenger tires, DOT evaluated a number of retreaded tires under the new tire standard, FMVSS 109. A 224 tire test program was initiated in 1971 to confirm the dimensional limits and dynamic laboratory test specifications of retreaded tires (Test Program No. DOT-HS-042-1-053). Three retreading companies were selected to supply a wide range of tire sizes and constructions.

Of the 224 tires tested, 26 were belted bias construction and 198 were bias construction. Over 50 percent of the bias construction tires were 2 ply rayon or polyester design. The remaining bias construction tires were 4 ply nylon, polyester or rayon. Belted bias tires were constructed of either rayon/rayon, nylon/fiberglass, or polyester/fiberglass.

Overall performance data of the tires for dimensions, endurance and high speed wheel tests are tabulated in Table 5. Twenty-three percent of the endurance tested tires failed to pass the 34 hours, 50 mph minimum requirement and 22 percent failed to pass the stepped speed, high speed phase. Only 7 percent failed to meet

TABLE 4
DOT-TSC
TIRE FAILURE BY RETREADER

Retreader	No. of Tires Run	No. of Tires Failed	% Failed
A	18	5	28
B	6	2	33
C	6	1	17
D	6	0	0
E	18	6	33
F	18	7	39
G	18	4	22
F	47	15	32
TOTAL	137	40	29%

Source: DOT Report No. DOT-TSC-NHTSA-73-1

TABLE 5
DOT TESTING OF RETREADED TIRES TO FMVSS 109
(TIRE FAILURES BY RETREADS)

Retreader	Dimensions Total Tires Tested	Dimensions Failures	Endurance Total Tires Tested	Endurance Failures	High Speed Total Tires Tested	High Speed Failures
A	81	3 (4%)	45	15 (33%)	36	10 (28%)
B	50	2 (4%)	25	4 (16%)	25	5 (20%)
C	93	10(11%)	45	8 (17%)	46	9 (20%)
TOTALS	224	15 (7%)	117	27 (23%)	107	24 (22%)

the minimum size factor or section width limits.

Failures were reported in relation to the established FMVSS 109 requirements but were not specifically attributed to retread processing or casing defects. The data does indicate, however, that one retreaded tire in four will not meet FMVSS 109 performance levels at a time when new passenger tires tested for DOT compliance to the same regulation had a failure rate of only 3.1 percent for endurance tests and 1.5 percent for high speed tests.

Table 6 lists test data by tire construction and shows a high percent of failures on the high speed test for the belted bias design. These tires were originally built prior to 1971 when the retread industry's experience with potential casing defects in the belted bias design was limited. As a result, many first generation belted bias tires may have been unknowingly retreaded while having breaker edge separations.

The poor endurance performance shown by the 2 ply bias tires is evidenced in Table 6 where 35 percent failed. Fifteen of the 18 failures were of rayon construction, although 16 other rayon tires did pass this phase of the test.

GSA Tests. The General Service Administration in September 1972, instituted a retread passenger tire test program. The purpose of the study was to evaluate the tread wear and casing durability performance of retreaded bias belted (non-steel) passenger tires under controlled testing and operational conditions.

Initially the program was established using GSA Interagency Motor Pool vehicles for testing under operational conditions with a final test phase using new tires being tested for qualification on the Qualified Products Lists (QPL). This

TABLE 6
DOT TESTING OF RETREADER TIRES TO FMVSS 109
(TIRE FAILURES BY CONSTRUCTION)

Retreaded Tire Construction	Dimensions Total Tires Tested	Dimensions Failures	Endurance Total Tires Tested	Endurance Failures	High Speed Total Tires Tested	High Speed Failures
2/0 (Bias)	101	8 (8%)	52	18 (35%)	50	9 (18%)
2/2 (Belted Bias)	26	2 (8%)	15	2 (13%)	11	8 (73%)
4/0	97	5 (5%)	50	7 (14%)	46	7 (15%)
TOTALS	224	15 (7%)	117	27 (23%)	107	24 (22%)

program proposed that for each vehicle equipped with retreaded passenger tires, there would be an equal number of vehicles equipped with new QPL tires. It was also intended that each vehicle from the Interagency Motor Pools would be operated under substantially similar conditions to determine tread wear performance of retreaded tires as well as develop performance comparison data for retreaded and new QPL tires.

A total of 488 passenger vehicles were utilized from the Interagency Motor Pool; 300 assigned to Personal Property Disposal personnel and 188 assigned to the Gallup Motor Pool.

Nineteen retreaders supplied a total of 1,542 retreaded tires for the Interagency Motor Pool test. These tires were utilized on 300 vehicles; 150 in the Personnel Property Disposal and 150 in the Gallup Motor Pool. A total of 188 vehicles were actually used having new tires from the QPL.

In September 1973 the retreaded tire data was summarized and recorded. (Table 7). From the total of 1,542 retreaded tires used in the test, 252 were recorded as having failed in service. This indicates a retread tire failure rate of 16.3 percent. The tread wear data showed an average mileage of 7,179 miles having a low of 5,683 miles and a high of 15,703 miles. A major contributor of tire failure was directed to tread separation, although insufficient records and limited failure descriptions did not permit a detailed analysis to determine if the failure was oriented to the retreading process or inherent in the carcass at the time of retreading.

TABLE 7
GSA-RETREAD TIRE TEST
(MOTOR POOL TEST ONLY)

VEHICLE ASSIGNED	QUANTITY	RETREAD EQUIPPED	NEW TIRE EQUIPPED
Personnel Property Disposal	300	150	150
Gallup Motor Pool	188	150	38
TOTAL	488	300	188

Total Tires Retreaded	1,542
Total Tires Retreaded	252
Average Percent Defective	16.3%
Average Wear Mileage	7,179 miles
(Worn to 2/32's)	
Total Tires Worn to 2/32's	62

DEFECT SUMMARY

Type of Defect	Number of Tires Defective	Percent of Total
Tread Separation	166	65.8%
Air Entrapment	28	11.1%
Carcass Defect	54	21.4%
Other	4	1.6%

The most useful data resulting from this Motor Pool test is that shown in Table 8. The failure rates range from 0 to 60 percent with an average failure rate of 16.3 percent. The tread wear showed a low of 5,683 miles and a high of 15,703 miles giving an average tread wear of 7,179 miles. Considering that all the retreaded tires were purchased from GSA approved contractors, and the tires presumably processed according to existing G.S.A. specifications, it must be concluded that much tighter specifications are required to insure a consistent, high quality product.

Unfortunately, in October 1973, after a review of the above data, it was decided to abort the Interagency Motor Pool test phase and to move on to the QPL test phase.

Retreaded tires tested in the QPL qualification phase of the GSA program were obtained from 8 retreaders and compared to new tires submitted from 17 new tire manufacturers. The test conditions were those required in Federal Specification ZZ-T-381M where identical vehicles are driven to 16,000 miles and the tires evaluated for tread wear.

Within the retreaded tire group, 6 of the 8 retreads used casings that had been retreaded by the hot curing method. The other 2 groups were used as controls and included both new and used casings as well as tires cured by the hot process and the cold (precured) process. The BB tire group shown in Table 9 contained 12 new tires which were buffed and retreaded using the hot cure method.

TABLE 8
GSA MOTOR POOL TEST
(RETREAD FAILURES BY CONTRACTOR)

Contractor	Total No. Tires Retreaded	No. Defective Tires	Percent Defective Tires
A	18	1	5.5
B	10	1	10.0
C	762	134	17.6
D	5	3	60.0
E	101	25	24.8
F	60	12	20.0
G	20	0	0
H	5	0	0
I	55	0	0
J	65	29	44.6
K	5	0	0
L	10	4	40.0
M	45	5	11.1
N	191	22	11.5
O	100	7	7.0
P	50	5	10.0
Q	20	0	0
R	15	4	26.7
S	5	0	0
TOTALS 19	1542	252	16.3

TABLE 9

QPL QUALIFICATION PHASE OF GSA TEST-RETREADED TIRE PERFORMANCE

Contract Retreader	Type Retread	Casing History	Casing Defects	Failures Improper Processing	Extrapolated Mileage to 2/32 Inch (Tire Completing 16,000 Miles)		
Control AA	Siped-Cold Precured	4 New 2 Used	1	0	Low High	21,430 26,008	3 (Tires)
Control AA	Regular-Cold Precured	4 Used 2 New	3	0		20,050	(1 Tire)
Control BB	Hot 416F	6 New	0	0	Low High	17,429 20,640	(4 Tires)
Control BB	Hot 416E	6 New	0	1	Low High	16,259 17,288	(3 Tires)
N	Regular Hot	6 Used	0	4	Low High	2,000 6,000	(Failed)
T	Regular Hot	6 Used	0	4	Low High	10,000 12,000	(Failed)
J	Regular Hot	6 Used	1	3	Low High	4,000 12,000	(Failed)
M	Regular Hot	6 Used	3	0	Low High	15,557 17,598	(2 Tires)
L	Regular Hot	6 Used	3	0		15,534	(1 Tire)
F	Regular Hot	6 Used	2	2	Low High	10,453 12,000	(4 Tires)

DEFINED FAILURES

Initial Test Tires	40	12 Casing	10 Processing	4 Early Wear Out	65% Failed
Spares	20	1 Casing	4 Processing	1 Early Wear Out	30% Failed
Total Test Tires	60	13 Casing	14 Processing	5 Early Wear Out	53.3%Failed

Six of these 12 tires were retreaded using the tread compound required in Interim Federal Specification ZZ-T-00416E and the other 6 were retreaded using the tread compound required in Federal Specification ZZ-T-416F, (4 test tires and 2 spares in each case). The objective of this testing was to determine which compound improved tread wear performance.

The AA tire group also shown in Table 9 contained 12 tires retreaded by the precured tread method. Two different precured treads were incorporated, one being called the "regular" and the other "siped" (cut across tire tread to produce biting traction edges). Six tires were retreaded using the "regular" precured treads (4 used casings and 2 new casings) and 6 were retreaded using the "siped" precured treads (2 used casings and 4 new casings).

Within the new QPL tire group, 46 samples, amounting to 2 tires per sample, totaling 92 test tires, were selected at random by regional QAS personnel from a batch of 100 or more tires. These tires represented the current production from 17 new tire manufactures.

The test route was rated at 65 miles per mil wear and all the tires were operated over the same route under identical operating conditions, except for the first 3,500 miles where the new tires for qualification were tested at 60 mph plus or minus 5 mph. Thereafter, the test speeds for the new and retreaded tires were reduced to a maximum of 55 mph to meet State and Federal speed regulations established during the fuel crisis.

Results of the retread QPL test phase (Table 10) revealed that the 40 initial

TABLE 10
FAILURE MODES OF RETREADED TIRES TESTED
(DURING QPL PROGRAM)

	Number Tires Tested	Casing Failure	Failures Improper Processing	Failures Early Wear-Out	Tire Performed Satisfactory*	Removed End of Test**	Percent Failure
Initial Test Tires	40	12 Tires (30 %)	10 Tires (25 %)	4 Tires (10 %)	14 Tires (35 %)		65%
Spares	20	1 Tire (5 %)	4 Tires (20 %)	1 Tire (5 %)		14 (70%)	30%
Total Test Tires	60	13	14	5	14*	14**	53.3%

* Completed tread wear test of 16,000 miles
**Tires remaining on vehicles upon completion of test.
Road mileage varied between 6,000 and 12,000 miles.

retreaded tires showed an abnormal overall failure of 65 percent. These failures were attributed to casing defects (30 percent), retread processing (25 percent), and early wear-out (10 percent) occurring between 8,000 and 14,000 miles. Fourteen tires (35 percent) completed the 16,000 test mileage. The 20 spare retreaded tires which were utilized to supplement tire failures of the initial test phase showed an overall failure of 30 percent. Causes of failures were attributed to casing defects (5 percent), retread processing (20 percent), and early wear-out (5 percent). Mileage of the retread spare tires ranged between 4,000 to 12,000 miles, however, most spares were not run the full duration of the test program.

A summary of the retreaded control tires (Table 9) showed that the BB tire group, retreaded with the 416E tread compound, had 1 tire failed at 14,000 miles due to severe radial cracking. The remaining three completed the 16,000 miles. Extrapolated tread wear mileages to 2/32 inch wear-out, computed to a low of 16,259 miles and a high of 17,288 miles.

The BB control tire group retreaded with the 416F tread compound all completed the 16,000 miles of test. Extrapolated tread wear mileages to 2/32 inch computed to a low of 17,429 miles and a high of 20,640 miles.

The AA control tire group retreaded with the regular cold precured process experienced 3 failures due to casing defects. The fourth tire completed the 16,000 miles of test. Extrapolated tread wear mileage to 2/32 inch wear-out computed to 20,500 miles.

The other 3 tires evidenced extrapolated tread wear mileages computed to a low of 19,113 miles and a high of 20,812 miles.

Control tires retreaded with the "siped" precured treads in the AA control group experienced 1 failure due to a casing defect. The other 3 tires completed the 16,000 test mileage. Exprapolated tread wear mileages to 2/32 inch computed to a low of 21,430 miles and a high of 26,008 miles for the 3 tires. The casing defect tire had extrapolated mileage of 19,345 miles.

A comparison of AA and BB retreaded control tires with the non-control retreaded tires in Table 11 is made to consider the ability of the GSA retread contractors to deliver a satisfactory retread tire which can compete with a new tire. As described earlier, control tires utilized used and new casings which were buffed and retreaded. Non-control tires were used casings which were hot retreaded by 6 GSA retreading contractors. These tires evidenced a huge 88 percent failure rate as compared to the 14 percent evidenced by the BB control tires.

The AA retreaded control tires had 50 percent failures which were all contributed to casing defects. The precured method of retreading, with its lower curing temperature, should not harm the tire casings. Therefore, GSA did not consider these as retread failures. Accordingly, extrapolated mileages to 2/32 inch showed a low of 20, 050 miles to a high of 26,008 miles, indicating that the precured retread process can provide tread wear mileages comparable to new tires.

Results of the new tires tested for QPL qualifications (Table 12) indicated

TABLE 11

COMPARISON OF CONTROL AND NON-CONTROL RETREADED TIRES

TEST GROUPS	NUMBER TESTED	NUMBER FAILED	PERCENT FAILED	EXTRAPOLATED MILEAGE TO 2/32 in. WEAR-OUT
Control Tires				
AA (Precured Cold Process)	8	4	50%	Low 20,050 High 26,008
BB (Hot Cure Process)	8	1	14%	Low 16,259 High 20,640
Non-Control Tires				
GSA retreader furnished (Hot Cure)	24	21	88%	Low 15,534 High 17,598
Total	40	26	65%	

Control tires AA utilize new and used casings.

Control tires BB utilize all new casings (new buffed and retreaded).

Non-control tires are all used casings.

TABLE 12

NEW TIRES TESTED FOR QUALIFICATION

	Number Tires Tested	Casing Failures	Failures Early Wear-Out	Tires Performed Satisfactory*	Removed End of Test**	Percent Failure
Initial Test Tires	92	5 Tires (5%)	6 Tires (7%)	81 Tires (88%)	N. A.	12 %
Spare Tire	8	0	0		8 Tires (100%)	0%
	100	5	6	81*	8**	12%

* Completed tread wear test of 16,000 miles.

**Tires were removed before completion of the 16,000 test mileage requirement.

that 11 of the 92 test tires failed between 6,000 to 15,000 miles due to early wear-out and casing failures. This constitutes a failure rate of 12 percent. The remaining 81 tires completed the 16,000 miles of test and had extrapolated mileages to 2/32 inch computed to a low of 17,284 miles and a high of 37,807 miles. The cut off for listing on the QPL is estimated at 22,414 miles. This means that bias belted tires exhibiting tread wear mileages over 22,414 miles will be listed on QPL.

The QPL phase of this GSA test program again reflects the extreme variations in quality between retreaders presumably following the same set of specifications.

In summarizing the tire testing described in the preceeding pages, it must be concluded that the available test data on the performance of retreaded passenger tires is very limited and inconclusive. Independent performance tests on retreaded tires have been conducted by DOT and GSA in an effort to determine the performance of retreaded passenger tires currently marketed. These tests show extreme quality variations between retreaders and these quality variations are such that the "average" retreaded passenger tire has a performance level significantly below that of a new tire. However, there are instances where retreaded passenger tires have been shown to have performance properties approaching or equaling that of new tires. It is unfortunate that the only significant, independent test programs conducted to date on retreaded passenger tires have been oriented toward an evaluation of random retreaded tires available on the open market. There have been no independent tests, conducted on a statistically significant size sample, to determine the performance of retreaded passenger tires manufactured under optimum and controlled conditions of casing selection, inspection and retread processing.

Retreaded Passenger Tire Failures

During the course of this project retreaders, retreader organizations, and other people associated with retreading were interviewed. Most of those interviewed estimated the passenger retreaded tire failure rate to be about 4 percent, that figure being based on the percentage of tires being returned to the retreader for adjustment. New tire adjustment rates are highly confidential, but 3 percent is the commonly accepted rate as an industry average.

On this basis, the adjustment rate, or failure rate, for retreaded tires is only one percent higher than that for new tires. The 4 percent figure is probably somewhat misleading since the average use of passenger retreads is considerably different than that of new passenger tires. Although detailed figures are not available, it is felt that most passenger retreads currently in service are used within cities and seldom exposed to the stresses of high speed interstate highway driving. If retreaded passenger tires were used in the same manner as new tires, it is possible that the adjustment rate would increase. The large number of small retreaders and the reduced value of retreaded tires makes it much less likely that adjustable retreads will be returned to the retreader than in the case with new tires.

Very few of the retreaders interviewed were able to provide a breakdown of the causes for retread passenger tire failures, but from the records that were available, the data was compiled for Table 13. The major cause of retread failure is ply

TABLE 13

REASONS FOR RETREAD ADJUSTMENTS

(EXCLUDING ROAD HAZARD)

	PER CENT
Bead Failure	1
Out of Round	8
Casing Separation	58
Tread Separation	18
Sidewall	7
Air Leak	5
Other	3
	100

separations in the casing. This type of failure accounts for 58 percent of all retread failure. Tread separation is not nearly so serious, accounting for only 18 percent of the failures.

The high incidence of failures resulting from casing failures pinpoints the largest single problem facing the retread industry--how to determine the quality of a used casing.

Non-Destructive Testing of Tires

Recent years have seen substantial advances in the technology of nondestructive testing (NDT) of tires. The four methods used most frequently are holography, X-ray, infrared, and ultrasonics. These four methods are briefly described in the following sections.

Holography. Optical holography, or holographic interferometry, is a new and highly regarded method for accurate NDT. In this procedure coherent light is used in recording and reconstructing three-dimensional images and light interference fringe patterns. When the target material is stressed, subsurface anomalies appear in the form of small surface displacements. In the case of tires, the stress is usually induced by subjecting the tire to a slight vacuum. The interferometric pattern produced by the surface displacement brought about by the vacuum is readily apparent and indicates the location, size and shape of the anomaly.

In a typical installation a holographic tire analyzer will accomodate a wide range of tire sizes. The tire is manually spread open using four spreaders, allowed to relax, and then placed in position on the analyzer. The cover is lowered and a double exposure hologram is made of the tire. The first exposure is made at atmospheric pressure, and the other made with the tire subjected to a partial vacuum. The resulting interference fringe patterns show the location and type of anomalies, particularly ply separation.

A typical holographic tire analyzer will cost approximately $50,000 and can analyze about thirty tires in an eight hour day. At this rate, the cost for operator time and machine depreciation would amount to at least one dollar per tire.

X-ray. X-ray has been widely used in tire analysis for many years, but it was primarily limited to examination of the tire bead structure. The new X-ray systems lend themselves to non-destructive testing for centering of belts, open or overlapping cords, correct belt end locations, foreign matter in the rubber, or trapped air voids. A modern high speed X-ray unit for tire analysis will cost approximately $110,000 and can analyze a tire in about two minutes. In this case, the cost for operator time and equipment depreciation would be about fifty cents per tire.

Infrared. Infrared sensing provides a qualitative thermal profile of the tire and can detect hot spots which have proven to result in tire failure. Areas of localized heating can be determined, but relating these to specific conditions within the tire has been found to be difficult--except in a destructive test.

Infrared test units are currently available for a cost of $10,000, but the analysis could require from three minutes to two hours, depending on the characteristics of the tire being tested. This could result in a testing limit of four to six tires a day. The cost per tire could be even higher than for holography.

Ultrasonics. Ultrasonic non-destructive testing is based on the fact that sound waves introduced into a material, such as a tire, can be reflected or moderated by a discontinuity such as a void or delamination.

Most ultrasonic tire testing is by means of either the pulse echo or thru-transmission approach. In pulse echo testing, a pulse of energy is coupled into the speciman and the time required for the energy to be reflected to a transducer can be measured. This measurement gives the depth of any discontinuity or other interface of interest lending itself to the identification of ply or cord separation. This is usually a single transducer method and allows a one sided pulsing and receiving method without access to the inside of the tire. Thru-transmission involves the transmission of an ultrasonic wave into the material from the sending transducer, then out the opposite side where the energy leaving the material is received by the receiving transducer.

Different methods for coupling are used-air to air, water to air, and water to water. Most of the newer systems are based on air to air coupling. A typical aircoupled ultrasonic system for testing tires will cost about $10,000 and requires about five minutes per tire. This would result in a cost for labor and equipment of about fifty cents per tire.

Interstate Highway Roadside Survey

Scraps of rubber litter the side of every major highway. It is generally assumed by the passing motorist that these chunks and strips of rubber are the remains of a retreaded tire. In order to verify the source of these tire scraps, a total of 1,067 pieces of tire rubber were picked up along the side of Interstate highways in Ohio, Pennsylvania, Arizona, Minnesota and Wisconsin. The results are tabulated in Table 14.

TABLE 14

Interstate Highway Roadside Survey of Scrap Tire Rubber

Passenger Tire		Truck Tire	
New	Retread	New	Retread
84	60	364	559

Passenger Tires--42% retreads

Truck Tires------61% retreads

All Samples------58% retreads

Severe limitations must be placed on the interpretation of the data resulting from this survey. Since there is no way to accurately determine the number of truck, bus, and passenger car tires--retreaded or new--that have passed a given point along the highway, accurate and precise statistical information cannot be obtained. However, it can be established that retreaded tires are not the sole source of scrap rubber along the roadside. In fact, along any given section of highway, 30-50 percent of the rubber is probably from new tires.

The passenger tire figures should be viewed very critically. Although they show only 42 percent of the scrap to be from retreads, it should be recognized that less than 20 percent of the passenger tires on a high speed interstate highway are likely to be retreads. On the other hand, at least 40 percent of the truck and bus tires on the interstate are likely to be retreads. However, it is also not realistic to conclude that if 40 percent of the truck and bus tires on the road are retreads, and that if 60 percent of the scrap is from retreads, that retreads have a higher failure rate than new tires. Since only small pieces of rubber were available for examination, it was not possible to determine the cause of failure, i.e., road hazard or carcass failure totally unrelated to the fact that the tire had been retreaded.

Non-Passenger Tire Retreads

Truck, aircraft, and racing tires have long been successfully retreaded. However, in each of these cases the tire design and use differs widely, with all three differing from the average passenger tire.

Truck tires are subjected to continuous operating speeds and loads approaching 100 percent of capacity. Aircraft tires see short durations of high speed and heat followed by extended periods of extreme cold. Racing tires are subjected to high heat and cornering traction for short durations, but with reduced loads. The passenger tire is subjected to sustained Interstate highway speeds, often overloaded and underinflated and is required to maintain its integrity over a lifetime approaching 30 million flex cycles, while being subjected to variable conditions of weather, road hazards, and perhaps the most severe of all--consumer misuse and abuse.

Aircraft tires are routinely retreaded 7 to 9 times, and are able to meet and exceed all Federal safety regulations. Truck tires frequently run 100,000 miles or more on the original tread and then another 100,000 miles on each of 2 or 3 retreads. Both cases present a strong argument that tires can be successfully retreaded. However, there are critical operating and design differences between aircraft, truck, and passenger tires which do influence the relative retreadability of these tires.

A 49 x 17, 28 ply rating airplane tire, which is used on many modern jet aircraft, is designed to carry a 43,200 pound load at 180 pounds per square inch inflation pressure. Under such operating conditions, the tire deflects 3.7 inches, Stated another way, for every 1,000 pounds of carrying capacity, the tire deflects 0.086 inches. A typical 10.00-20, 12 ply rating truck tire is designed to carry a 4,760 pound load at 75 psi inflation pressure when used in dual applications. Under these designed operating conditions, the tire deflects 1.25 inches or 0.260 inches per 1,000 pounds of load. A GR78-14, 4 ply radial passenger tire designed to carry 1,380 pounds at 24 psi inflation pressure, deflects 1.5 inches, or 1.086 for every 1,000 pounds of load, more than 12 times the loaded deflection of the aircraft tire and 4 times that of the truck tire.

It is obvious the passenger tire is much more flexible than the typical airplane or truck tire. This is because a passenger tire is designed to act as a shock absorber. The passenger tire forms an integral part of the automotive suspension system which is designed to give optimum passenger comfort.

The aircraft tire acts in a limited capacity as a shock absorber, but it is primarily a rigid support member not intended to absorb road hazards or supply additional riding comfort. The primary function of the truck tire is to carry high loads for sustained periods over the highway. The shock absorbing properties of a truck tire are minor when compared to the passenger tire. The truck tire is designed to provide for maximum service life, not as a comfort device.

The useful strength of any tire is related to its designed carcass strength and contained air pressure. The 49 x 17 airplane tire, discussed earlier, weighs nearly 220 pounds and develops its strength through the use of approximately 20 ply layers and 180 psi contained air pressure. The average 10.00-20 truck tire weighs 100 pounds, and has 6 or more ply layers and operates with 75 psi contained air pressure. By comparison, a passenger tire with 2 or 4 ply layers operates at 24 psi contained air pressure and weighs approximately 30 pounds. It is apparent that the stiffer, less flexing carcasses lead to increased mileage in the case of truck tires, and more retreads in the case of airplane tires.

Passenger tires could not perform their designed function as an integral part of the suspension system of the passenger vehicle if they were designed to operate with stiff sidewalls and high inflation pressures. This difference in construction and operating characteristics results in unfortunate limitations for the retreading of passenger tires.

Due to the excessive flexing required of the passenger tire, the tread scrubs itself away while maintaining high levels of traction, resulting in far less mileage than that obtained with the less flexible truck tire. Also, as a result of the excessive flexing and transmittal of road shocks to the tire sidewalls, a hinge point is developed at the edges of the tread mass or belt edges. The rigid tread shocks are transmitted through this point to the flexible sidewalls. Belted bias and radial passenger tires thus become susceptible to belt edge separation which may further limit retreadability.

IMPROVING RETREADABILITY

Tire Design

Tire technology has led to the development of three basic types of tire construction; the bias ply, the belted bias ply, and the radial ply. Until the late 1960's essentially all passenger tires manufactured in the United States were bias ply. The modern radial ply tire was a European development introduced into the United States in major quantities in the late 1960's. The belted bias tire was an intermediate American development which bridged the gap between the bias ply and radial ply tire designs.

Bias Ply Construction

The early bias ply design consisted of individual layers of cotton or rayon fabric coated with rubber having a directional or bias cord angle. In each individual layer or ply, the fabric cords were placed at an angle or bias to the direction of tire travel. Each subsequent ply was built into the tire at an equal but opposite angle to the ply below. In a four ply tire the first and third ply cords run in the same direction, while the second and fourth ply cords run in the opposite direction (see Photograph 1). This practice was necessary to give the tire stability and strength to carry the vehicle load at optimum inflation pressures.

Cotton was originally used and the development of new, stronger, textile fibers led to the use of rayon and nylon as improved tire cord. These were followed some time later by the introduction of polyester tire cords for passenger tires. Today nylon and steel are used for truck and airplane tires and rayon, polyester, glass and steel are used for passenger car tires.

The four ply bias tire is the least troublesome construction currently being retreaded. However, the mileage potential of the bias ply tire is limited by the squirming action of the tread as it goes through the footprint area and by its higher operating temperature in the tread shoulders. The bias ply tire is also more susceptable to road hazard damage than the belted tires.

The two ply bias tire was standard equipment on new cars for several years, but never gained acceptance in the retread shops. Retreaders have indicated that the two ply bias tire experienced a high percentage of road hazard failures.

The good experience retreaders have had with the four ply bias and the bad experiences with two ply bias, correlates well with the DOT indoor wheel test data reported in the previous section.

Belted Bias Construction. This construction utilized the bias design principle discussed previously, but has the added feature of narrow pieces of ply cord placed directly under the tread at an angle closer to the direction of travel than the bias plies (Photograph 2). This added material is called a belt and gives rigidity to the tread area, reducing squirm and heat build-up and resuling in longer wearing tires. The belted bias tires also offer increased protection from road hazard failures.

Belted bias tires were subject to many development problems which ultimately became problems for the retreader. The early use of fiberglass as a belt material led to extensive casing rejections by the retreader for broken belts or separated belts. The reject level reached a point where many refused to accept glass belted casings. Later generations of glass belted tires have overcome most of the early problems and retreaders now routinely process glass belted bias tires.

Radial Tire Construction. The modern radial tire was developed in Europe and contributed to increased tire wear while maintaining high traction capabilities. Early designs incorporated rayon ply cords and rayon belt cords. The radial tire gets its name from the radial ply cord direction utilized. Instead of placing the individual plys at a bias to the direction of the tire travel, the radial ply cords are placed nearly perpendicular to the direction of tire travel. The textile or steel belt cords are placed at a low bias angle to the direction of tire travel giving the tire a rigid tread area. The radial ply cords also allow the sidewall to absorb the flextures generated in service with a minimum of friction or fatigue (see Photograph 3). The result is a superior wearing tire having high road hazard resistance, reduced heat build-up, increased traction and superior overall performance.

Radial design tires are now beginning to reach the retreader, and as has been true of all new tire constructions, there are problems. A high percentage of steel belted radial casings are being rejected because of belt edge separations.

Reasons For Casing Rejection

Twenty-four retread shops were visited to determine the manner in which casings received for retreading were inspected and the reasons for which those not suitable for retreading were rejected. Only limited details were obtained from the individual retreaders, since most of them purchase casings from jobbers or intermediaries who pick up casings from service stations, tire stores, or other collection points. The jobbers then presort the casings before selling to a retreader. A generalized tire collection system is outlined in Figure 1, indicating the possible sources and avenues by which tires flow to the retreader. It was found that there is no consistent definition of a Class I casing. Most jobbers indicated a wide variation in the casings that would be acceptable to the retreaders they served. Their customers generally included those retreaders who would only accept the top 10 percent of the total casings handled, retreaders who would be satisfied with the second 10 percent quality level, and retreaders who would accept the third 10 percent or lower. Obviously the prices varied with the top 10 percent commanding the highest price.

Throughout the interviews with retreaders and used tire jobbers, a definite pattern was established as to the reasons for casing rejection, but definite numbers were not available. In order to get actual numbers to confirm these estimates, arrangements were made for two men to spend one week at Lakin Industries of Chicago, Illinois

During that week, they inspected 3,780 passenger tires and recorded the

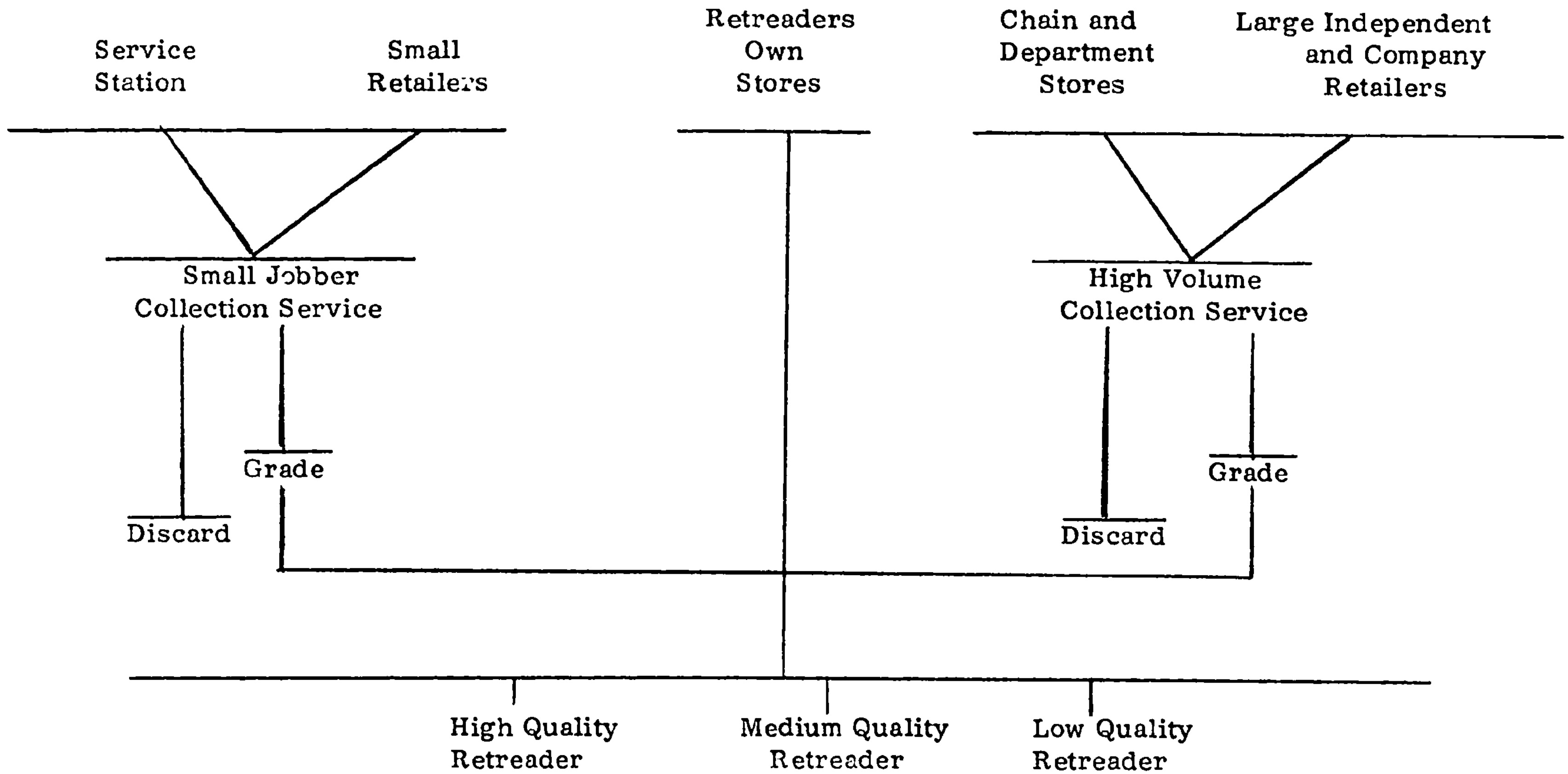


Figure 1. Collection and distribution of used tire casings to the retreader.

cause of rejection as a function of tire construction. The Lakin facility grades nearly 2-1/2 million tires per year, and it was felt that the 3,780 tires inspected were a thoroughly representative sample. The results of the survey are shown in Table 15. The major causes for rejection are illustrated in Photographs 4 through 10.

Photograph 4 is typical of damage to a bead resulting from improper mounting or demounting of the tire from the rim. Bead damage permits air and moisture to penetrate into the ply layer, eventually causing ply separation and tire failure. Two ply bias tires reflected a somewhat higher susceptability to bead damage in the survey. This is probably due to the lighter construction utilized in many two ply tires and the absence or minimal use of fabric chafer strips in such tires. Photograph 5 illustrates excessive tread wear, poor balance, and poor alignment. Not only was the tire not removed when 2/32 inch of tread remained (as is required by law in many states and as recommended by tire manufacturers), but only one fabric ply remains. Uneven tread wear from side to side is evidence of misalignment, while uneven wear around the circumference indicates poor balance. Photograph 6 is another example of excessive tread wear resulting from poor alignment. In this instance, the edge of the top belt has been exposed on the one side, while ample tread remains on the opposite side. This type of tire damage is especially common in radial tires on front wheels which require proper inflation as well as proper alignment. The 60.9 percent rejects for textile belted bias tires is somewhat misleading due to the small

TABLE 15
REASONS FOR PASSENGER TIRE CASING REJECTIONS

Type of Tire / Type	Bias Ply		Bias Belted			Radial			Average
	2 Plies	4 Plies	Textile Belt	Glass Belt	Steel Belt	Textile Belt	Glass Belt	Steel Belt	
Bead Damage	10.2%	6.6%		6.9%					7.0%
Tread Worn Out	2.9	12.2	60.9%	9.1%				12.5%	10.6%
Road Hazard Damages	1.5	.9		.4				12.5	.9%
Cut	9.5	10.5		17.7				25	12.5%
Fatigue		1.3				33.3%			.6%
Separation	1.5	.4		16.9				25	6.9%
Size Not Used For Retreads	29.2	8.7		2.2				25	10.5%
Too Many Punctures	2.2	3.1		5.2					3.4%
Severe Sidewall Cracking	13.1	15.7	8.7	8.7		33.3			12.2%
Studded		1.7	13.0	.4					.8%
Tread Cracking	.7	.9		10.0					4.5%
Previous Cap	2.9	6.1		.4					3.0%
Other		.9		1.7	100%				2.2%
Good	26.3	31.0	17.4	20.4		33.3			24.9%
Total	100%	100%	100%	100%	100%	100%		100%	100%

sample size (only 67 as compared to 1,467 glass belted bias tires). The high reject rate was strictly related to too many miles, and had no relation to tire design.

Photograph 7 is an example of excessive air pressure leading to heavy wear in the center of the tread and the flat spot outlined by crayon indicates a belt separation. Belt separations of this type account for a very large number of casing rejections, especially in the early generation glass belted bias tires (16.9 percent). In addition to the high percent of rejects at this point of inspection, the glass belted tires also account for the highest percentage of rejections by the retreader at post buffing inspections.

The 25 percent steel belted radial rejections due to separations are more typically the type illustrated by the cross-section in Photograph 8. The separation between the two belt plies at the lower edge of the belts is clearly visible.

Photograph 9 is typical of the damage caused by the environment to which a tire is exposed. This example is typical weather-checking and is common to most tires more than 6 years old. This time period is drastically reduced in the Los Angeles area, where high concentrations of ozone hasten the appearance of severe sidewall cracking. The Los Angeles area casing rejection rate for weather checking is many times the rate in the rest of the country. Among the first line retreaders in that area, sidewall checking is the most frequent cause for casing rejection. Lower quality retreaders frequently purchase such casings and paint the sidewalls after retreading to improve the tires appearance, but not its quality. This ozone cracking is objectionable from an appearance standpoint but it is rarely the cause of tire failure.

Many of the rejections reported under the category of sidewall cracking, also resulted from the physical damage incurred by bumping and scuffing curbs, rocks and other obstacles.

Photograph 10 illustrates a cut that has penetrated the cords, resulting in a non-retreadable casing. This picture also illustrates the tread wear indicators that are incorporated into every tire tread design. When the solid rubber bar appears across the width of the tread, as in this picture along side of the cut, only 2/32 inch of tread remains. At that time, the tire should be removed from service. A tire with minimum tread remaining is far more susceptible to damage from cuts.

Tread cracking accounts for 10 percent of the glass belted bias tires rejected in Table 15, but these were nearly all one design and the problem was caused by tread rubber compounding--not the glass belt design.

Steel belted bias tires also show a 100 percent rejection, this was due to the fact that no retreader in the area could process the tires--not to a specific failure.

Sizes not desired for retreading is a major cause for rejection. Most of the two ply tires were old and of a size no longer used. Steel belted radials were a small sample and sizes rejected were from European cars not widely used in this country.

Tire Maintenance

Improved maintenance of tires could make an additional 10 to 15 percent of discarded tires suitable for retreading. This increase in casings available for retreading would permit a 50 percent increase in the number of passenger tires presently retreaded. Nearly 24 percent of the casings rejected as unsuitable for retreading are rejected because of (1) bead damage, (2) excess tread wear, (3) cuts, (4) punctures (refer to Table 15). These causes for rejection can be virtually eleminated by rigorous adherence to basic tire maintenance procedures including: (1) exercising care in mounting and demounting tires; (2) remove tire when 2/32 inch tread remains; (3) maintain proper alignment, balance, and inflation and rotate tires as recommended. These are simple precautions, readily put into effect by Federal Government agencies. Current GSA practices require that every car be serviced at 3,000 mile intervals, and that servicing includes inspecting the tires and taking any remedial action indicated--such as balancing or realignment. Getting the general public to implement these practices will be considerably more difficult.

Improved Retreadability by Tire Design

For the first time since World War II, new tire manufacturers have an incentive to increase the retreadability of a new tire. Raw material and evergy shortages have become a harsh reality and it is imperative that the maximum benefits be realized from every tire produced. Concurrently an awareness of environmental limitations has been growing. Solid waste disposal is a major environmental problem--and waste tires are a major part of that problem. Many municipal waste disposal stations will no longer accept scrap tires, and where they do, charges of 25 cents per tire and higher are not uncommon.

To reduce the number of casings rejected for retreading, new tire manufacturers should consider ways of protecting the bead to make it less susceptable to damage. Returning to the use of chafers which protect the bead toe should reduce the tendency of the bead toe rubber to tear during mounting or demounting.

If a retreaded tire is expected to have an 80,000 mile life, as could well be the case with retreaded radials, the sidewall must be compounded to last an 8 to 10 year life without excessive weather checking.

Many problems plaguing tire retreaders result from the wide variations in tire dimensions within a given size of tire and the many varieties of tire sizes and designs produced by each tire manufacturer. Leaders in the new tire industry have acknowledged this problem, and there may now be a trend toward reducing the number of tire types presently manufactured. This would bring American practice more in line with European where tire sizes are limited regardless of the manufacturer. Although the driving force behind such a change may be to reduce inventory and distribution costs, the retreader will benefit.

The tire retreader also benefits from changes in tire design resulting from constant improvements in new tire construction. New tire manufacturers constantly have adjustment rates, or failure rates, as an incentive to improve new tire designs. New tire designs are not placed into production until after extensive in-house and field testing. But, use by the consumer under a wide range of operating conditions is the final proof of performance, and as consumer mileage accumulates, product limitations are encountered and design changes may be required. This was true with the bias and belted bias designs and is currently ture with the radial designs. Retreaders were quick to point out the belt edge separation problem with the radial tires, especially with the steel belted radials.

Design changes to increase breaker edge adhesion and reduce the belt edge separation problem are currently being put into practice. Three such practices are outlined in Figure 2 showing fabric overlays incorporated in different configurations. The retreader will benefit from a reduction in this problem as second and third generation casings become available.

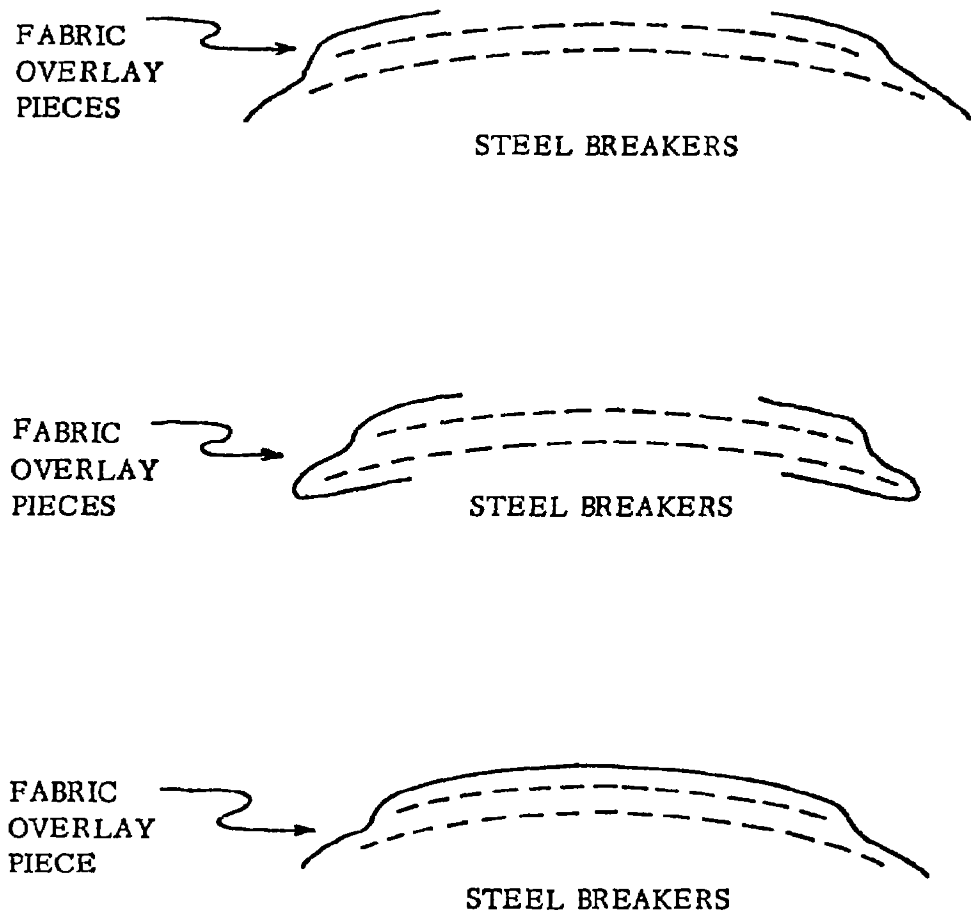


Figure 2. Typical design considerations to eliminate or reduce steel breaker edge separation on radial tires.

ECONOMICS OF RETREADING

The economics of retreading the larger and more expensive tires are widely accepted. The average retreaded truck tire is often expected to wear as long as a new tire and for only one-third the cost. Civilian and military aircraft also make extensive use of retreads for economic reasons. Most aircraft tires are retreaded 7 to 9 times with each retread costing only 20 percent of the cost of a new tire, but performing equally well.

In 1970, the U. S. Army set a goal of meeting 75 percent of their replacement tire needs with retreaded tires. They have nearly achieved this goal, and report savings of more than $30 million in slightly less than 5 years.

The economics of tire retreading are heavily dependent upon the initial cost of the tire. In general, the higher the cost of a new tire, the lower the percent of new tire cost for the retread, (i.e., a $500 airplane tire may be retreaded for 20 percent of the new tire cost, a $150 truck tire for 33 percent, and a $20 passenger tire for 50 percent).

Passenger Tire Retreading Cost Factors

Individual retreading cost components vary widely from one retreader to another, and are heavily dependent upon volume. But, as an average, the three major cost components (excluding casing cost) fall into the following ranges:

Material Costs	$3.00 to $4.00
Labor	1.50 to 2.00
Overhead	1.50 to 2.00
Total Mfg. Costs	$6.00 to $8.00

Material costs, primarily tread rubber, consistently account for 50 percent or more of manufacturing costs. Tread rubber requirements range from less than 7 pounds for a small 83 series tire to more than 11 pounds for the larger 78 series tires. Nine pounds of tread rubber is a generally accepted average covering all sizes of passenger tires. Hot cap tread rubber prices range from 30 cents to 45 cents per pound depending on quality and quantity, while precured tread rubber costs approximately 75 cents per pound.

With direct manufacturing costs averaging $7.00, most retreaders would like to retail their product for $14.00 and would wholesale it for $10.00, again excluding the cost of the casing. Comparing the retail price of $14.00 for retreads with a price of $20.00 for new bias ply tires, illustrates one of the major reasons why retreads have not been able to increase their share of the replacement tire market. Most people would rather pay $20.00 for a new tire, than to pay $14.00 for a retreaded tire.

As the price of new tires increases, the retread becomes more competive. For example, a typical GR78-14 WSW steel belted radial retails for about $60.00. A good retreader will process a radial for very little additional cost, but now he can retail his product for $20.00 to $25.00 and still be less than one-half the price of a new tire. And, at the same time, he is able to increase his profit margin.

The difference between a good retreader and a poor retreader is not always apparent in terms of direct costs. The use of the lowest quality tread rubber instead of a premium grade will result in manufacturing savings of about $1.00 per tire. But, manpower and equipment are equally as important in terms of quality as direct costs. If a retreader does not have the proper equipment, or if he misuses what he has, the result will often be a substandard product.

However, the greatest variable lies in the quality of the retreaders manpower. Aside from the necessity of closely adhering to set operating standards, all casing selection and inspection is performed manually. Thus, all decisions as to what is retreaded and how it is retreaded are in the hands of the operating crew.

If reliable and economical non-destructive test methods can be perfected and their effectiveness demonstrated, much of the human factor can be removed from casing inspection and selection.

The retreading industry is currently seeking NDT equipment that would meet their requirements with a capital investment of about $10,000. Such a cost would permit inspections for about 50 cents per tire.

THE FEASIBILITY OF REQUIRING THE FEDERAL GOVERNMENT TO USE RETREADED TIRES

Federal Government agencies are currently engaged in an extensive program to increase their use of retreaded tires. The main effort has been concentrated on truck tires where both economic and performance factors have been well established. The Army appears to have led this effort with a policy that at least 75 percent of its replacement tire needs will be met with retreaded tires. At the present time the Army has reached the 73 percent level world-wide, and in Europe 80 percent of replacements are met with retreads. The Army program has concentrated on truck tires with only limited passenger tire retreading. In Fiscal 1974, GSA retreaded 240,000 tires (including continental United States Army retreads) with at least 80 percent being truck tires.

Available test data on the performance of retreaded passenger tires is very limited and inconclusive. Independent performance tests on retreaded tires have been conducted by DOT and GSA. These tests show extreme quality variations between retreaders and a performance level generally below that of a new tire. However, there are instances where retreaded passenger tires have been shown to have performance properties approaching or equaling that of new tires.

There is no reliable operating or fleet data available for passenger tire retreads such as is available for truck or aircraft retreaded tires. Retreaded passenger tires are occasionally used for in-city fleet operation by taxi cabs or utilities, but this experience is totally unrelated to the typical high speed and endurance levels to which the average passenger tire is subjected.

Until it can be established that a properly designed new tire, properly maintained and then properly retreaded can meet new tire performance criteria, the Federal Government cannot be expected to implement an unrestricted policy of requiring the use of retreaded passenger tires.

Costs and Benefits of The Federal Government Using Retreaded Passenger Tires

The benefits to be derived from the increased use of retreaded passenger tires must be delayed until: (1) independent, definitive performance tests have been completed to determine the safety of high quality retreads as compared to new tires, (2) new standards or specifications are developed to insure that only high quality retreaded tires are manufactured, (3) a highly reliable, but inexpensive method for casing inspection is developed, (4) radial tire belt edge separation problems are solved.

Once the above conditions have been successfully met, significant savings can be realized in terms of dollars, energy, raw material, and solid waste disposal.

In fiscal year 1973, the Federal Government owned and operated a fleet of 98,041 sedans and station wagons that traveled nearly 900 million miles. This can be compared to a total United States passenger car mileage of 986 billion miles in 1972. Not only does the government fleet represent 0.1 percent of the passenger car miles traveled throughout the United States, but government purchasing and

Maintenance procedures lend themselves to a well controlled and documented test fleet. Successful use of retreaded passenger tires by this Government fleet could be expected to have a major impact on the average consumer's reaction to retreaded tires. The major barriers to the increased use of retreaded passenger tires by both the general public and the Federal Government are the uncertain quality and the emotional connotations connected to a used product.

Tire Maintenance. Current GSA practices require that every car be serviced at 3,000 mile intervals. This service procedure includes inspecting the tires and taking any remedial action indicated--such as balancing or realignment. Since these procedures are now required, there should be no additional cost involved for providing improved maintenance services. It will be necessary to educate both the drivers and maintenance crews in order to get strict compliance with the proper tire maintenance procedures.

New Tire Purchasing. Existing Federal Government purchasing procedures are adequate to meet the requirements for purchasing tires more suitable for retreading, and at no increase in cost. The only modifications to be made in existing procedures would be to restrict tire purchases to tires that pass a retreadability specification in addition to meeting existing QPL requirements.

The retreadability specification would be based on actual field experience with retreading and post retreading operation. Radial tires offer the greatest opportunity for making major improvements in reducing solid waste and for reducing energy and material requirements for tire manufacture, however, they are now posing serious problems for the retreader. These problems will be solved, but some tires will be more retreadable than others and these can only be determined by actual field experience.

Environmental tests will also be a key factor in the retreadability specifications. A radial tire capable of a 40,000 mile first life and a second 40,000 mile retread life presents new requirements for sidewall aging. For the average consumer the 80,000 miles might mean a life of 8 to 10 years, or longer.

Obviously these new retreadability specifications will require time to develop, but the cost for introducing such improvements into a tire should be minor.

Passenger Tire Retreading. Improvements in Federal Government tire maintenance and purchasing procedures are expected to make a major increase in the number of passenger tire casings that would be suitable for retreading. A concentrated educational effort could probably improve the total number of casings that are retreadable. Current levels of casing rejections and estimated values for maximum improvement in both the government and public sector are shown in Table 16.

Tests conducted by GSA reveal a wide variation in quality throughout the retreaded tires manufactured by GSA approved contractors, following GSA specifications. In the QPL treadwear portion of the test, the tires supplied by retreader "F" indicated treadwear as low as 10,453 miles, while the control tires were as high as 26,000 miles. Tire economics hinge on the average cost per mile, and a policy of buying from the lowest bidder without any measure of mileage can

TABLE 16

REASONS FOR CASING REJECTION

Type of Damage	Estimated Percent Rejected		
	Current	Best Federal	Best U. S.
Bead	7	3	4
Excessive Treadwear	11	2	6
Road Hazard	1	1	1
Cuts	12	9	10
Separations	7	7	7
Unpopular Size	11	2	8
Punctures	3	2	3
Sidewall Damage	12	6	9
Tread Cracking	4	2	3
Other	7	4	4
Total Rejected	75	38	55
Retreadable	25	62	45

only be false economy.

Any change in Federal retread specifications should consider the addition of a QPL type of tread wear qualification test, followed by random sampling of products to insure the level of treadwear. Additional changes in Federal passenger tire retread procurement should consider the addition of more trained inspectors for frequent visits to the contractor, and the use of financial incentive contracts to encourage the production of a quality product.

Maximum benefits for the Federal Government should be realized from a closed loop system utilizing improved Government tire purchasing and maintenance procedures, processing these same tires through retread shops operating in accordance with strict Government specifications, and then placing these retreaded tires into Federal Government service.

Potential Dollar Savings. Detailed figures were not available for the total number of passenger tires purchased annually by the Federal Government. But, it is possible to arrive at a close approximation based on the total miles driven by Government passenger vehicles. Assuming four belted bias tires per vehicle, averaging 26,000 miles per tire, for the total 900 million miles, 138,462 tires would be required. At an average GSA purchase price of $28.00 per tire, the Federal Government spends about $4 million each year for passenger tires. This estimate is in good agreement with a fiscal 1971 GSA report indicating that the Federal Supply Service (FSS) had purchased 73,219 passenger tires for $2 million and FSS has estimated that they purchase about 50 percent of the total passenger tires used by the Federal Government.

Any economic advantage that might be realized by the use of retreads, must be based on a true cost per mile. Consider the case of a new belted bias G78-14 having a GSA cost of $28.42, and the same size retread from a GSA retreader in the District of Columbia for $7.65, or 27 percent of the new tire cost. There is a tendency to claim a 73 percent reduction in cost, but the new belted bias tire can be expected to average 26,000 miles or a cost of 0.11 cents per mile. While the retread may deliver only 10,000 miles (on the basis of GSA tests), at a cost of 0.08 cents per mile, or a 27 percent savings, not 73 percent.

Figure 3 illustrates the savings possible by the use of retreaded tires. On the basis of an annual expenditure of $4 million with zero passenger retreads, an annual savings of $1.1 million could be realized if 40 percent of the replacement tires were retreads purchased at 30 percent of the cost of a new tire-mile.

It is very probable that stricter GSA retreading specifications may increase the cost of retreaded tires to the point where 50 percent of the new tire-mile cost is more realistic. At this level the annual savings for 40 percent retreads is $800,000.

Present GSA retreading specifications require that the GSA furnish all casings to the retreader. This is a good policy because it insures that all casings being retreaded at least met Government standards as new tires. The policy does limit the number of tires that can be retreaded. Table 16 indicates that as many as 62 percent of the discarded casings could be retreadable, provided the recommended maintenance and purchasing policies were followed. But, it seems very unlikely

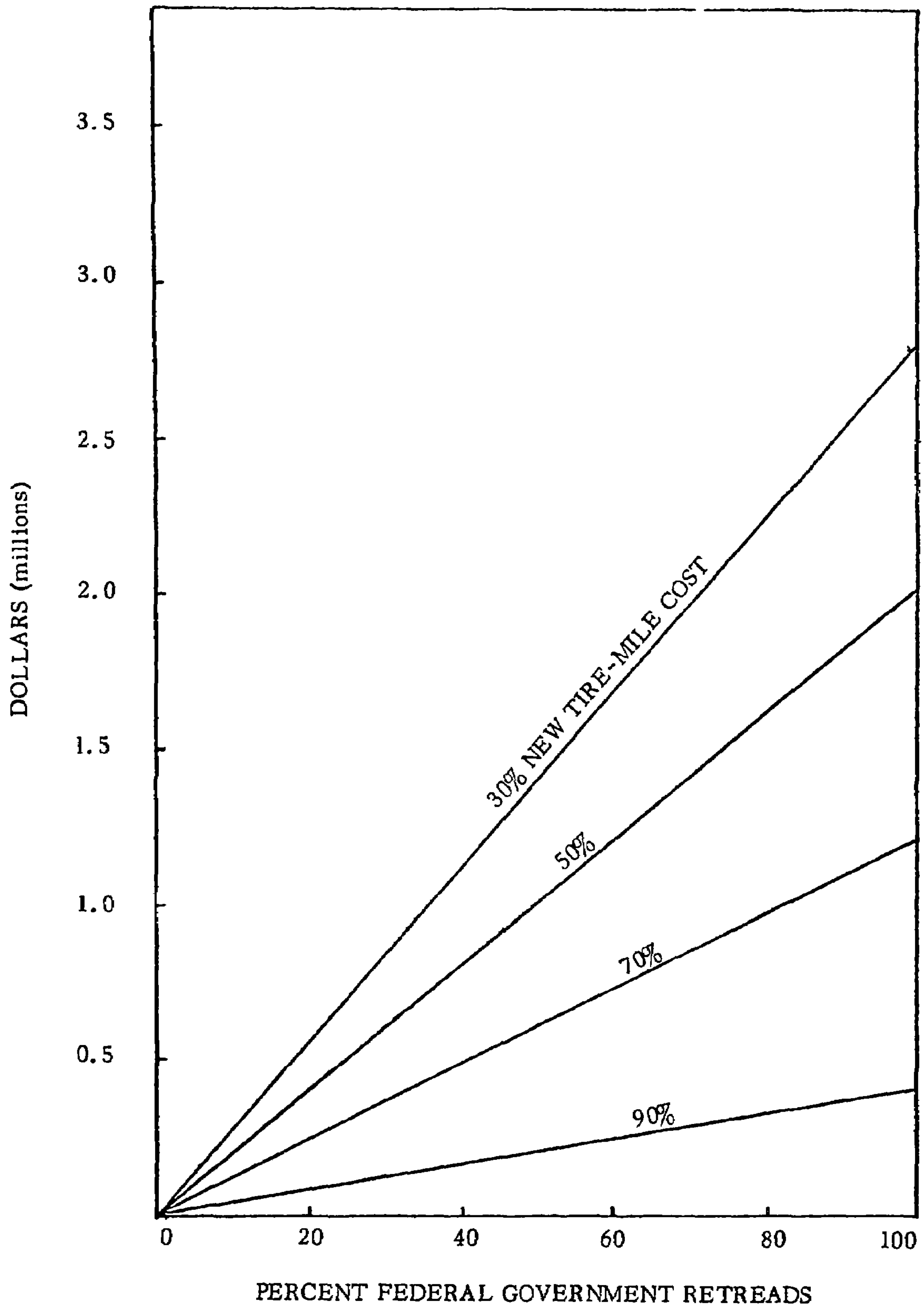


Figure 3. Dollar savings as a percent of Federal Government passenger retreads and as a percent of new tire-mile costs.

that anything exceeding 40 percent retreadable could be attained in the near future.

An increase to even 40 percent will require nearly doubling the number of casings now suitable for retreading.

The possibility does exist for the Federal Government to use retreaded tires for all replacements. In such a case retreaded tires for 50 percent of a new tire-mile cost, would save $2 million per year. However, this would entail the use of non-government purchased casings, resulting in less control of the quality of final product. A situation that would be difficult to justify at this time.

Potential Solid Waste Reduction. In 1973 the American public discarded nearly 143 million passenger tires (more than 3 billion pounds) into the nations solid waste stream, The Federal Government contributed about 150,000 of these tires. Retreading tires can make a significant reduction in the number of tires discarded annually, as can improvements in tire design to give a longer wearing tire. The benefits to be derived by both the improved mileage tire and retreading are illustrated in Figures 4 and 5 and tabulated in Tables 17 and 18.

Government passenger cars are presently operating with a mixture of bias, belted bias, and a few radial tires. If the Federal Government was limited to only bias ply tires (average tread life of 20,000 miles), they would discard 180,000 tires per year. Retreading 100 percent of these tires would reduce the discards to 90,000, but this same reduction can be achieved by using radial tires (average of 40,000 miles). Additional reductions in the number of Government tires scrapped annually can be achieved by retreading the radials. Radial retreads were

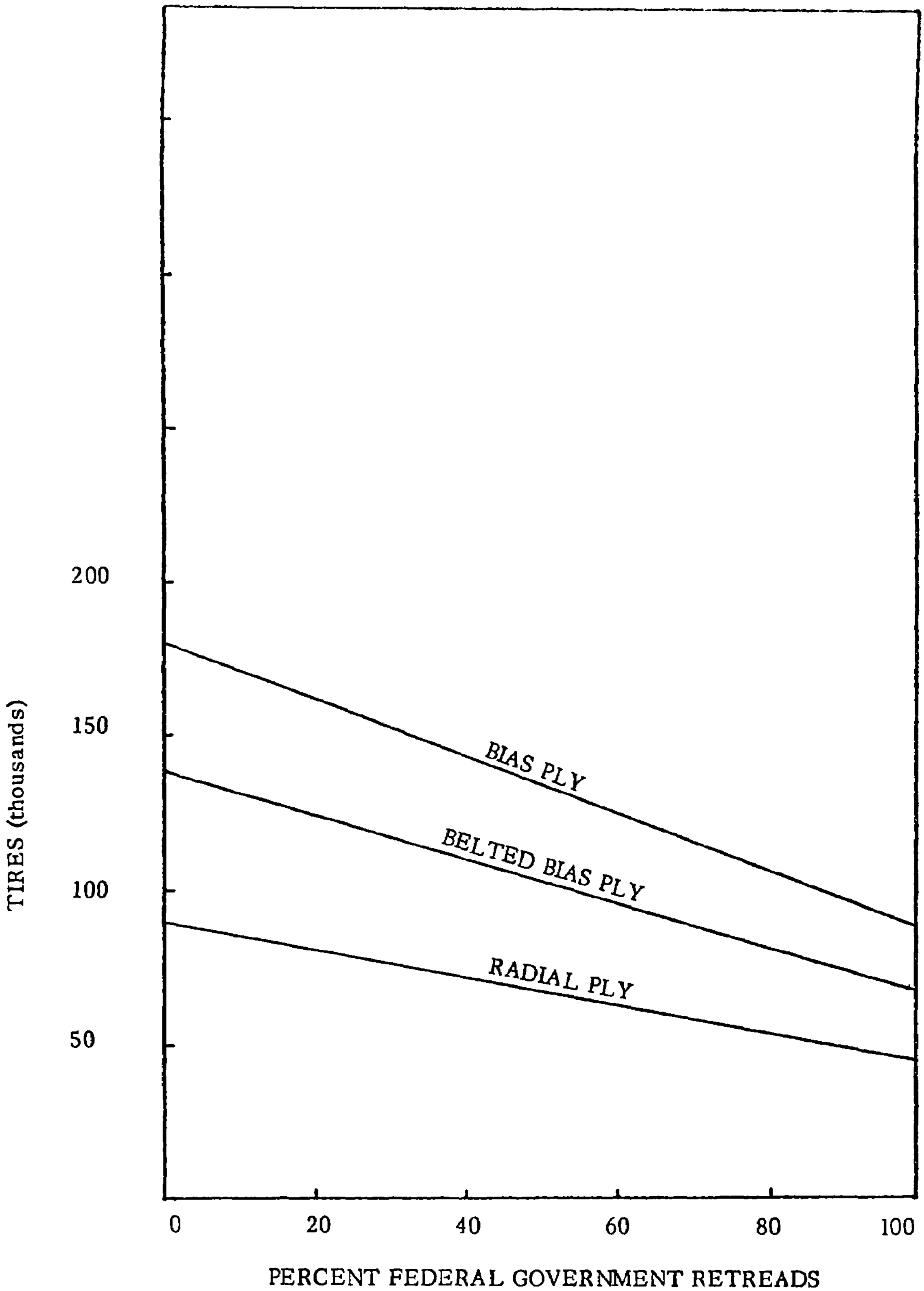


Figure 4. Tires discarded to solid waste as a percent of Federal Government passenger tires retreaded.

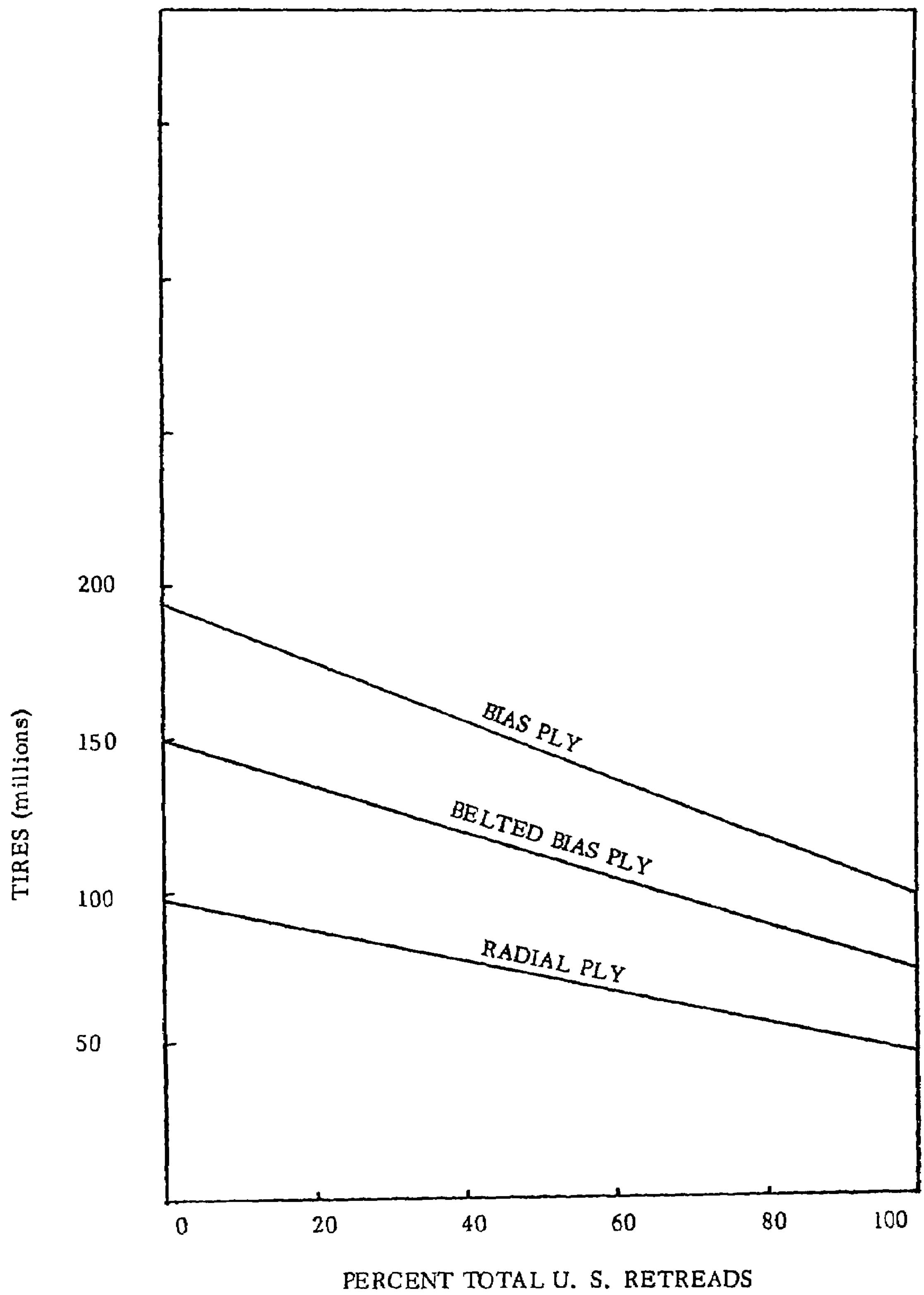


Figure 5. Tires discarded to solid waste as a percent of total U. S. passenger tires retreaded.

TABLE 17

EFFECT OF RETREADING AND TIRE

DESIGN ON THE NUMBER OF PASSENGER TIRES

DISCARDED ANNUALLY BY THE FEDERAL GOVERNMENT

(IN THOUSANDS OF TIRES)

	Percent Retreaded				
Tire Design	0	20	30	40	100
Bias	180	162	153	144	90
Belted Bias	138	124	117	110	69
Radial 1	90	81	77	72	45
Radial 2	90	83	80	77	56

Basis: <u>Bias tire;</u> 20,000 miles on original tread, retread 20,000 miles

<u>Belted bias tire;</u> 26,000 miles on original tread, retread 20,000 miles.

<u>Radial tire 1;</u> 40,000 miles on original tread, retread 40,000 miles.

<u>Radial tire 2;</u> 40,000 miles on original tread, retread 25,000 miles.

TABLE 18

EFFECT OF RETREADING AND TIRE DESIGN ON THE TOTAL NUMBER OF PASSENGER TIRES DISCARDED ANNUALLY IN THE U.S.

(IN MILLIONS OF TIRES)

	Percent Retreaded				
Tire Design	0	20	30	40	100
Bias	197	177	168	158	99
Belted Bias	151	137	129	121	76
Radial 1	99	89	84	79	49
Radial 2	99	91	88	84	61

Basis: Bias tire; 20,000 miles on original tread, retread 20,000 miles.

Belted bias tire; 26,000 miles on original tread, retread 26,000 miles.

Radial tire 1; 40,000 miles on original tread, retread 40,000 miles.

Radial tire 2; 40,000 miles on original tread, retread 25,000 miles.

evaluated at two levels of tire mileage. There is considerable disagreement within the retread industry as to the desirability of a 40,000 mile retread. The 40,000 mile tread life can be obtained with existing technology, but the major concern centers on the integrity of the tire casing and its ability to withstand the effects of aging, weathering, abuse, and flexing over an 80,000 mile lifetime. As a result of this concern, many retreaders are proposing a 25,000 mile retread until more actual operating experience is available.

It is apparent that the Government could achieve a reduction in tire disposal from their present 150,000 tires per year to 99,000 by converting to radial tires and a further reduction to 75,000 to 80,000 by retreading the radial tires. However, major reductions resulting from the retreading of radial tires will not be realized until problems, such as belt edge separations, have been resolved.

Similar reductions can be experienced by the total U.S. population. In 1973, the 143 million discarded tires were comprised primarily of bias and belted bias tires with a few radials included. A complete switch to radial tires with an average 40,000 mile tread life would reduce the 143 million tires to 99 million, (a 31 percent reduction). Retreading at the present rate of 20 percent would further reduce this to 91 million tires for a total reduction of 37 percent. A 50 percent increase in the number of discarded tires to 84 million, giving an overall reduction of 40 percent from the present 143 million.

Similar values in terms of total pounds of solid waste discarded are given in Figure 6 for Federal Government tires and in Figure 7 for total U.S. tires.

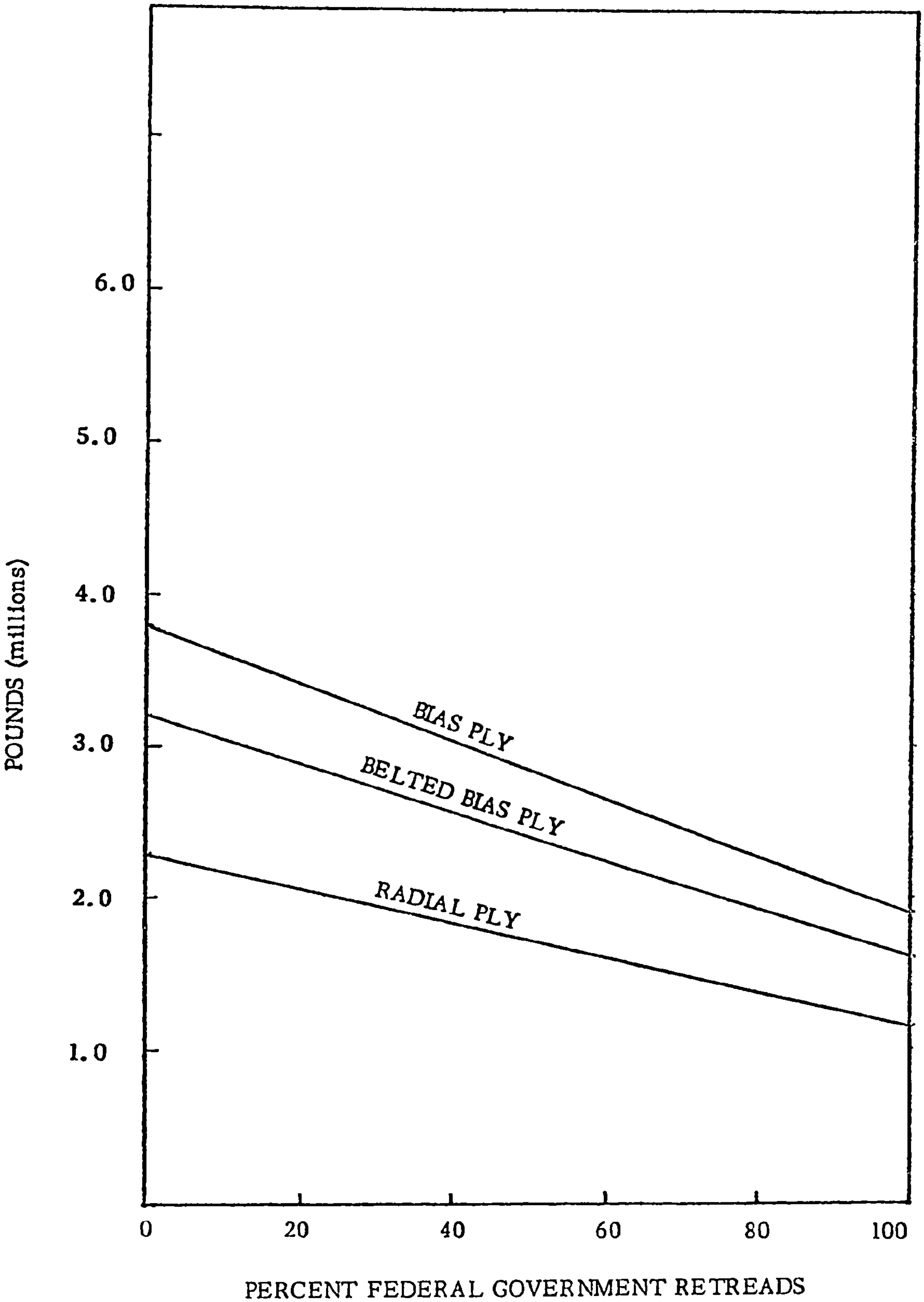


Figure 6. Solid waste generated annually as a percent of Federal Government passenger tires retreaded.

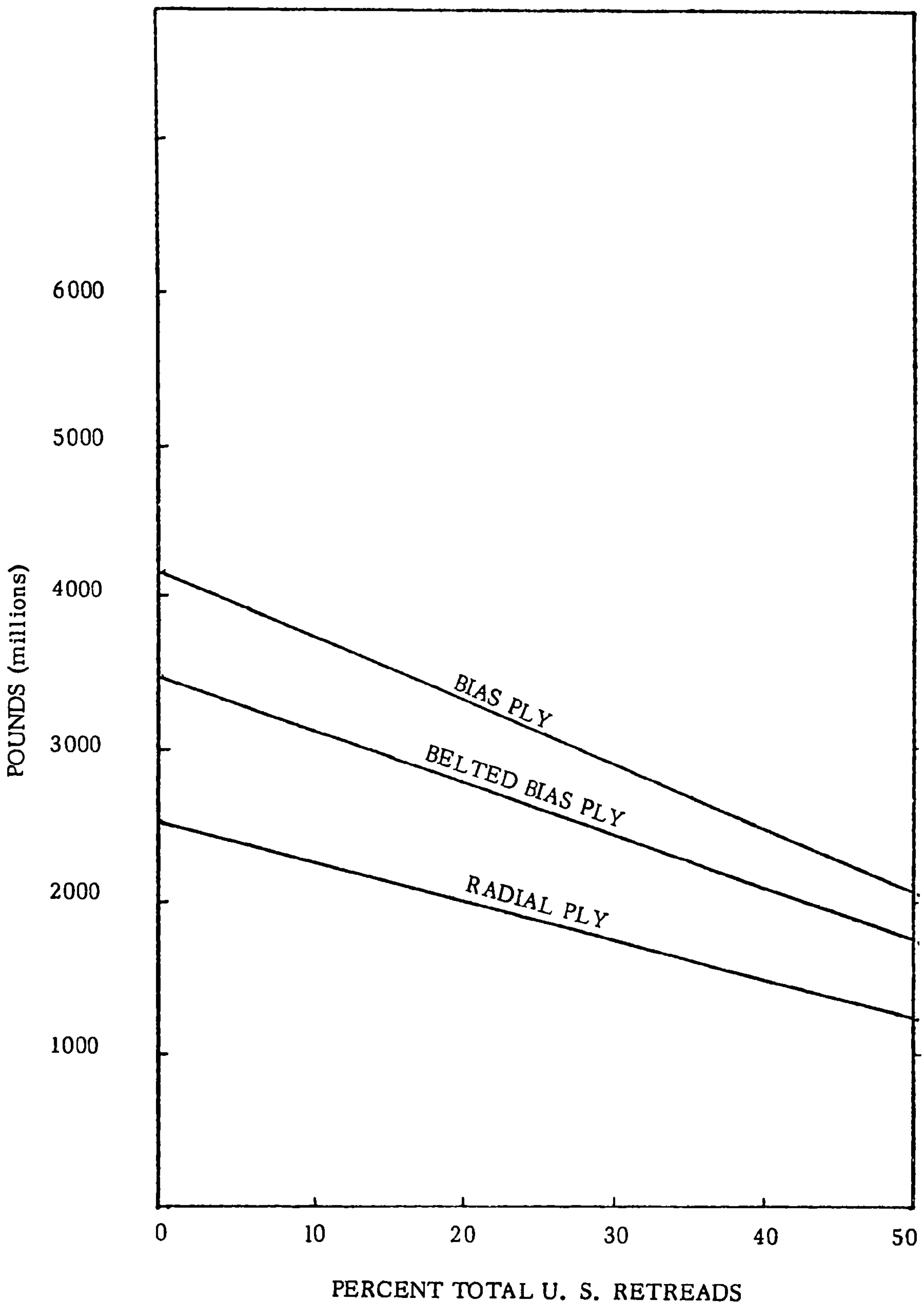


Figure 7. Solid waste generated annually as a percent of total U. S. passenger tires retreaded.

The change over to radials is proceeding at a rapid pace with 1974 figures indicating original equipment (O.E.) tires to be 40 percent radials, up from 2 percent in 1972, and replacement tires reached 20 percent radial as compared to 4 percent in 1972. It is now estimated that by 1980, nearly 90 percent of O.E. tires will be radials, as will 40 percent of all replacement tires.

Potential Reduction in Raw Material Requirements

A second benefit to be derived from the increased recycling of tires by retreading, will be a reduction in petroleum consumption. Industry sources have estimated that it requires seven gallons of crude oil to make the average passenger tire. Five gallons as raw material feedstock, and two gallons to supply the required energy. Retreading a tire requires only about 1/3 as much crude oil. This energy savings represents the energy that would be conserved from the retreading of a tire rather than the production of a new replacement tire. Replacement of the tread requires an average of 9 pounds of material as compared to 27 pounds for the average total tire.

The material requirements for manufacturing tires for the Federal Government as a function of the percentage of tires retreaded is shown in Figure 8 and Table 19.

By changing from its present mix of passenger tire constructions to radial tires the Government could save about 7,000 barrels of crude oil per year. Reaching a 40 percent retread level with radials would save about 9,000 barrels of crude oil per year (a 39 percent reduction from present material and energy requirements

Federal passenger tire manufacture).

Material requirements for the manufacture of passenger tires for the U.S. are shown in Figure 9 and Table 20.

Changing the U.S. passenger tire utilization from belted bias tires with 20 percent being retreaded to radial tires would save about 6 million barrels of crude per year, retreading 20 percent of the radials, an additional 1.3 million barrels, while 30 percent retreaded radials would save an additional 0.6 million barrels, for a total reductions of 8 million barrels per year. (A 33 percent reduction from the present crude oil requirements for passenger tire manufacture.)

TABLE 19

EFFECT OF RETREADING AND TIRE DESIGN ON BARRELS

OF CRUDE OIL REQUIRED TO MANUFACTURE PASSENGER TIRES

FOR THE FEDERAL GOVERNMENT

(IN THOUSANDS OF BARRELS)

	Percent Retreaded				
Tire Design	0	20	30	40	100
Bias	25.7	24.1	23.4	22.6	17.9
Belted Bias	22.4	21.0	20.3	19.6	15.3
Radial 1	16.2	15.1	14.5	13.9	10.5
Radial 2	16.2	15.6	15.2	14.9	13.0

Basis: 1 pound of tire material requires approximately0.007 barrels of crude oil

Bias tire; average weight 25 pounds, retread weight 9 pounds

Belted bias; average weight 27 pounds, retread weight 9 pounds.

Radial tire 1; average weight 30 pounds, retread weight 9 pounds.

Radial tire 2; average weight 30 pounds, retread weight 9 pounds.

TABLE 20

EFFECT OF RETREAD AND TIRE DESIGN ON BARRELS OF

CRUDE OIL REQUIRED TO MANUFACTURE TOTAL U.S. PASSENGER TIRES

(IN MILLIONS OF BARRELS)

	Percent Retreaded				
Tire Design	0	20	30	40	100
Bias	28.2	26.4	25.6	24.8	19.6
Belted Bias	24.6	23.0	22.2	21.5	16.8
Radial 1	17.8	16.5	15.9	15.2	11.5
Radial 2	17.8	17.1	16.7	16.3	14.2

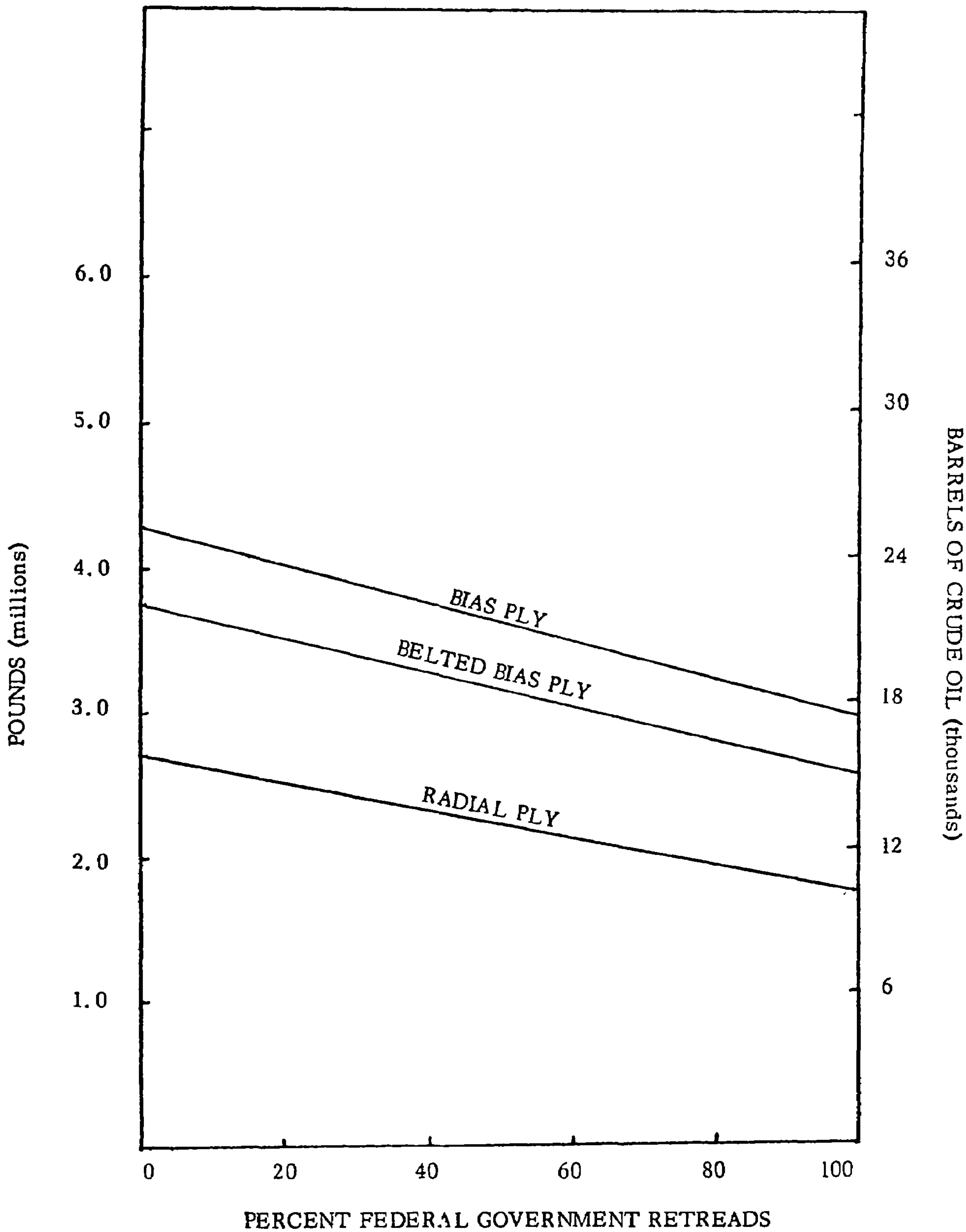
Basis: 1 pound of tire material requires approximately 0.006 barrels of crude oil.

Bias tire; average weight 25 pounds, retread weight 9 pounds.

Belted bias; average weight 27 pounds, retread weight 9 pounds.

Radial tire 1; average weight 30 pounds, retread weight 9 pounds.

Radial tire 2; average weight 30 pounds, retread weight 9 pounds.



Figure, 8. Annual material requirements as a percent of Federal Government passenger retreads.

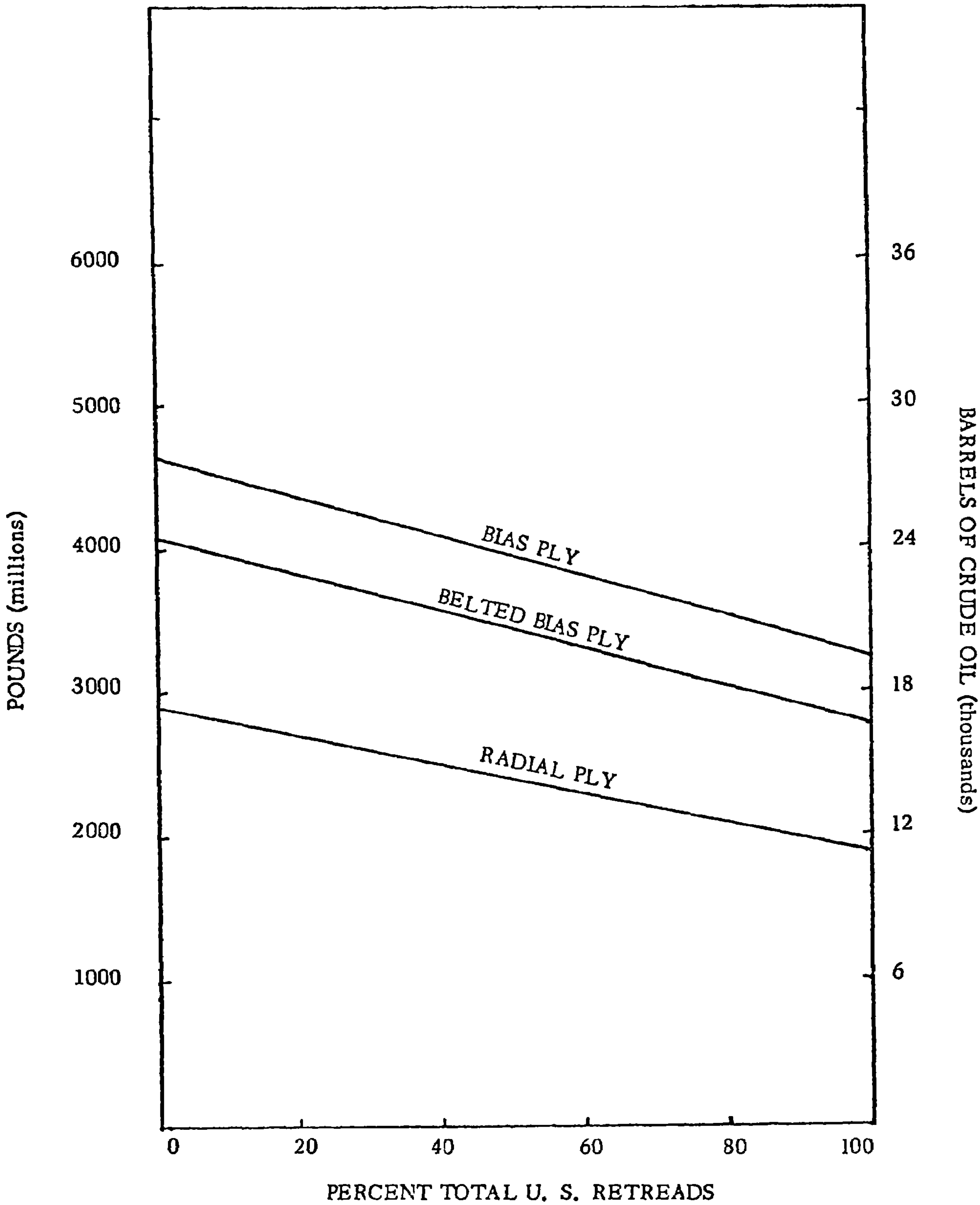
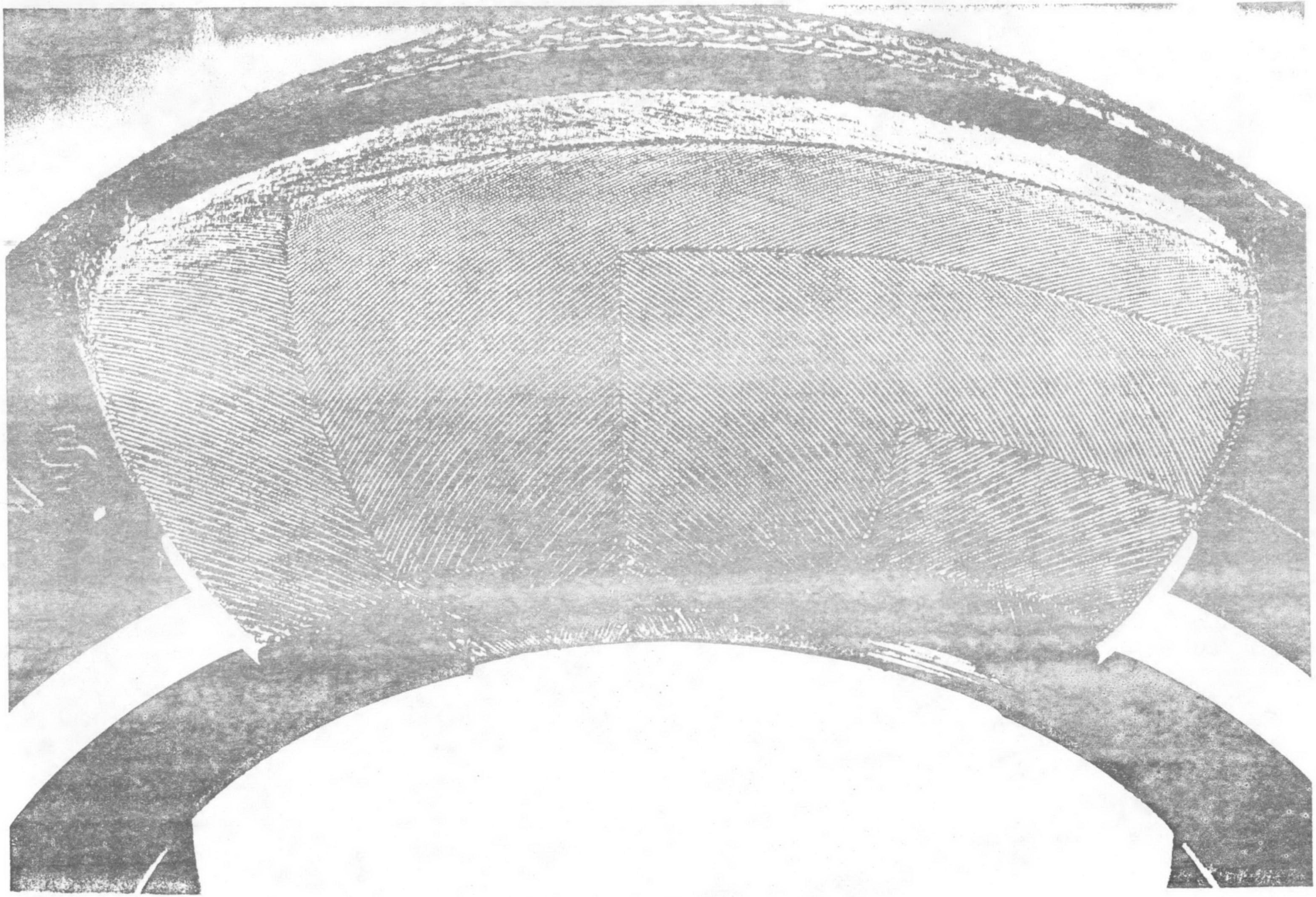
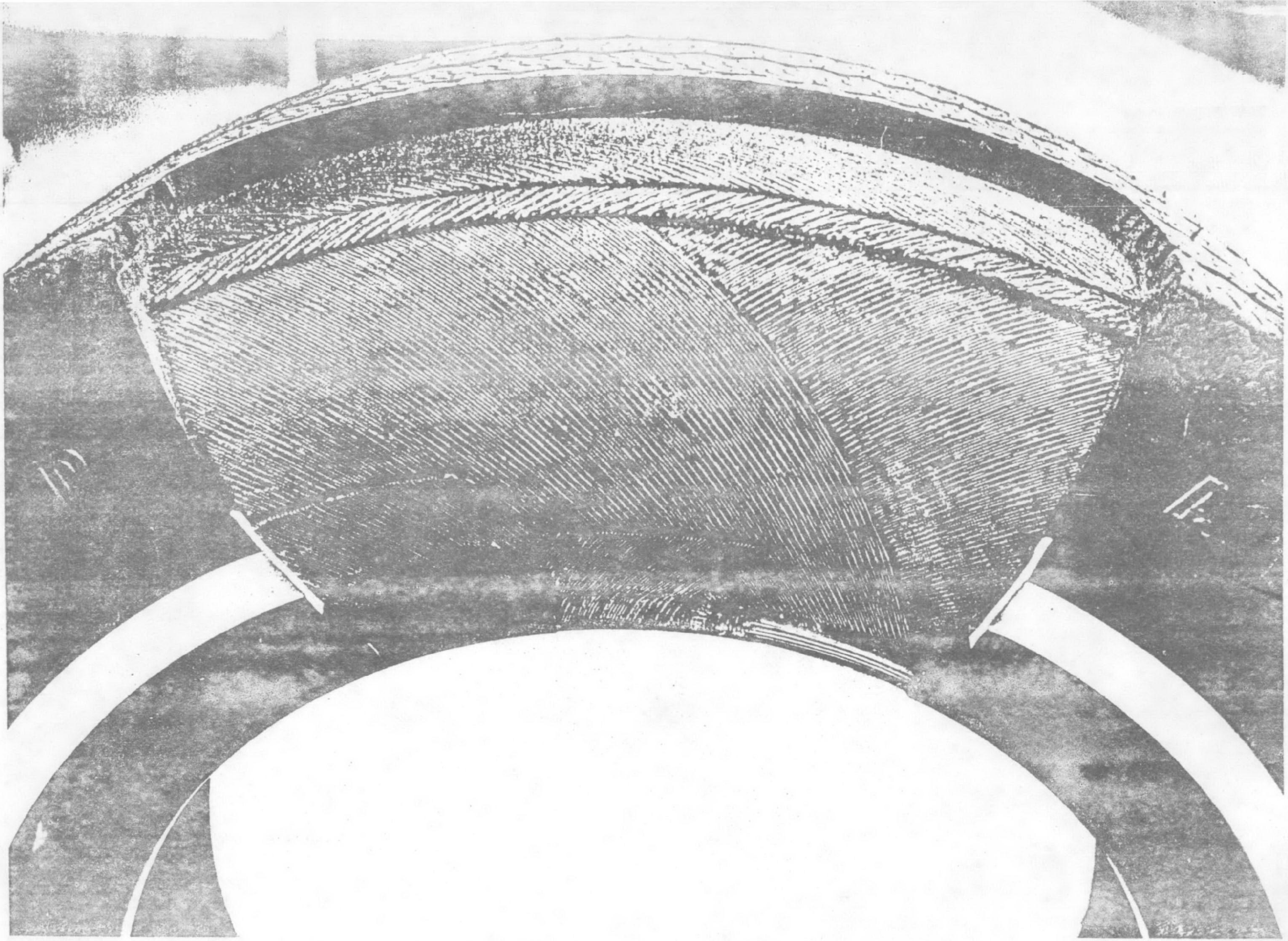


Figure 9. Annual material requirements as a percentage of total U. S. passenger tire retreads.

APPENDIX

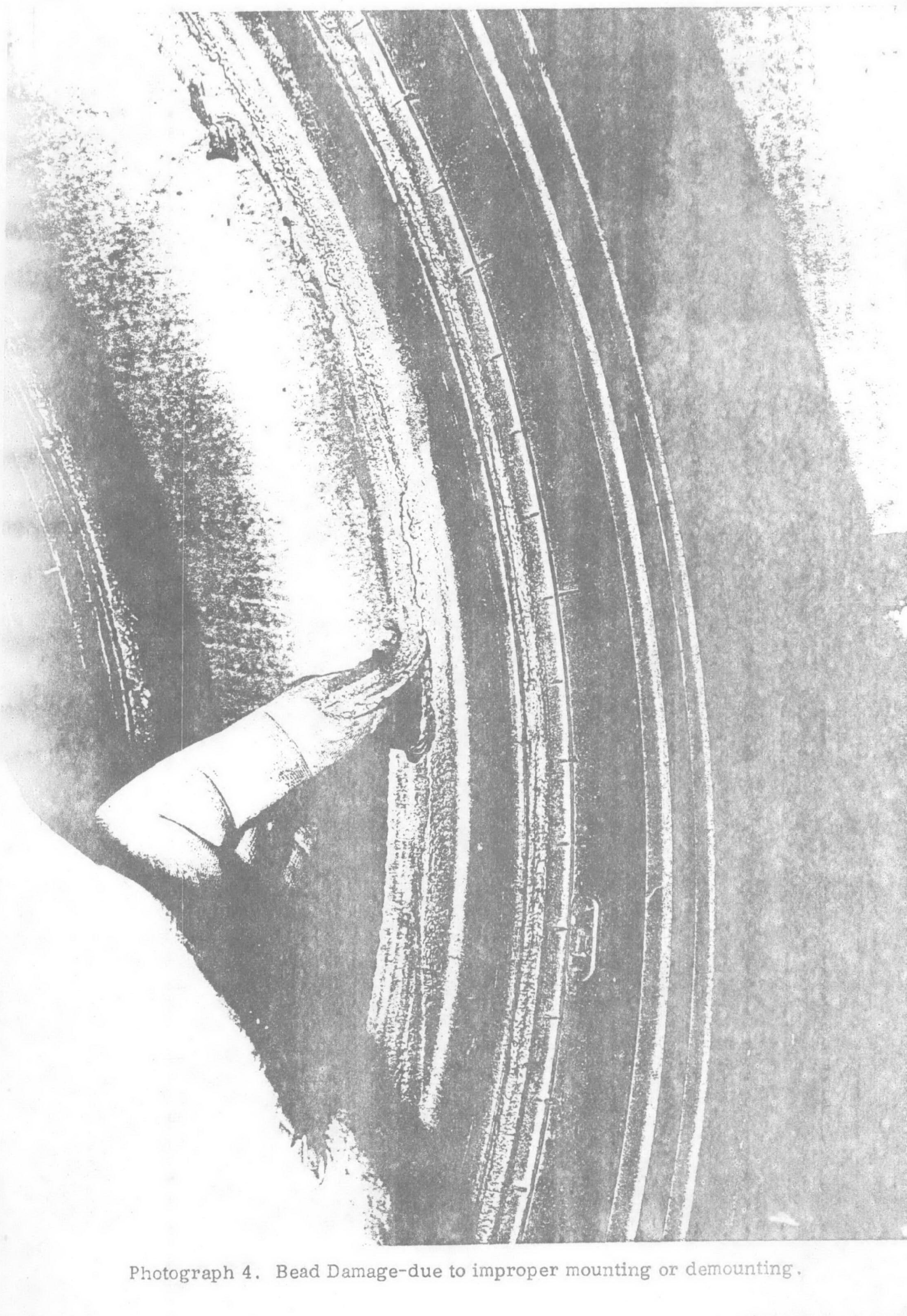


Photograph 1. Bias Construction. 4 Bias Plies



Photograph 2. Belted Bias Construction. 2 Bias Plies and 2 Bias Belts

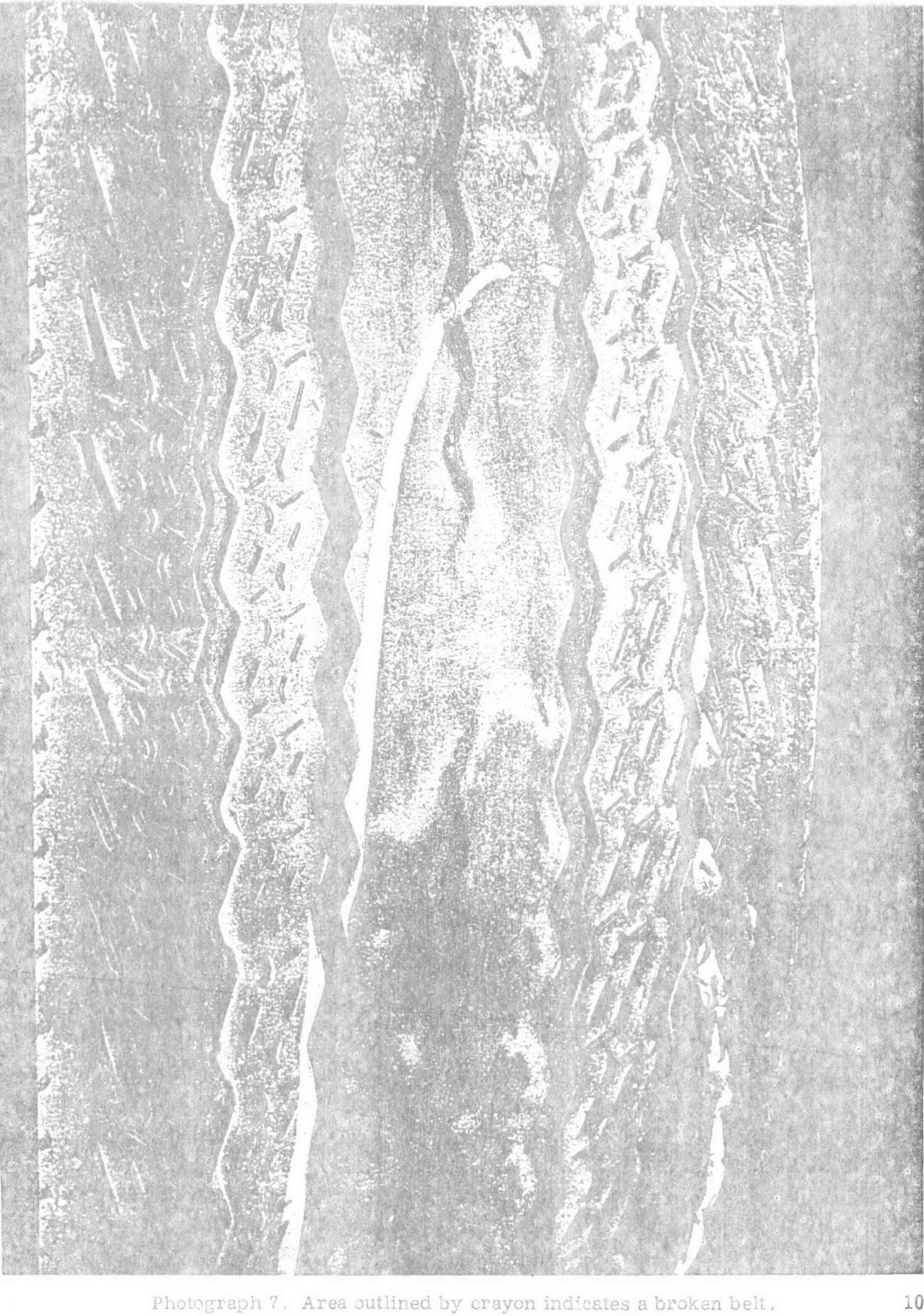
Photograph 3. Radial Construction. 2 Radial Plies and 4 Bias Belts.



Photograph 4. Bead Damage-due to improper mounting or demounting.

Photograph 5. Excessive tread wear, poor balance and poor alignment.

Photograph 6. Exposed belt edge resulting from poor alignment.



Photograph 7. Area outlined by crayon indicates a broken belt.

Photograph 8. Belt edge separation.

Photograph 9. Sidewall weather checking.

Photograph 10. Deep cut. Tread wear indicators appear above cut.

GLOSSARY OF TERMS AND ABBREVIATIONS

Aspect Ratio

A numerical term which expresses the relationship between the standing height of the tire and the cross section width. (H/W=Aspect Ratio).

Bead

That part of the tire that is shaped to fit the rim. Made of high tensile steel wires that are wrapped in woven fabric and then held by the plies.

Bead Heel

Outer bead edge that contacts the rim flange.

Bead Toe

The inner bead edge of the tire

Breaker

Special cord fabric cushion between tire tread and cord body which reduces road shock effect on carcass while permitting less tread squirm and resultant increased tread wear.

Buttress

Portion of tread running around shoulder and blending into sidewall.

Chafer

Reinforcing fabric and rubber around the bead in the rim flange area to prevent chafing of the tire by the rim parts.

Cushion

The thickness of rubber over, under and between the breaker plies.

Cushion Gum

A tacky rubber compound, usually approximately 1/32nd inch gauge, used to form cushion and adhesion between fabrics and between tread and ply.

Dip

A rubber and chemical solution into which the cords are dipped to get adhesion with the rubber in calendering and in service.

Durometer

A device to measure the hardness of rubber. For example, a tire tread may be defined as 60 Durometer which means that it shows this degree of hardness when tested with the durometer.

Elasticity

The property of matter by virtue of which it tends to return to its original size and shape after removal of the stress causing deformation such as stretching, compression, or torsion. It is the opposite of plasticity.

Flash

Fin produced by excess rubber squeezed out between edges of mold during curing process.

Flipper

Reinforcing fabric around the bead wire for strength and to tie the bead wire into the tire body.

Green Tire

The completed rubber/fabric tire construction just prior to being cured into its final shape.

Modulus

A term used to denote resistance to being stretched.

Mold

The heated cavity in which tires are vulcanized.

Nonskid

Tread pattern providing skid protection.

Non-Skid Depth

The groove deptn of the tread (used to indicate remaining wear left in tire).

Ozone

A form of oxygen produced by electricity. Accelerates ageing in tires.

Ozone Checking

Formation of fine cracks in surface of rubber due to ozone in air.

Ply

Layer of rubber-coated parallel cords forming unit of tire carcass.

Ply Adhesion

Strength of attraction or adhesion between adjacent plies.

Polymer

A material consisting of large units (molecules) made by joining many smaller building blocks (simple molecules). Usually used to describe synthetic rubber.

Post Inflation

The process of inflating a tire immediately after it is removed from the factory mold and keeping it under inflation until it has cooled. Also known as "Pressure Tempering".

Radial Cracking

Surface openings, generally in shoulder or sidewall of tire, running parallel to tire radius.

Radial Ply

A tire with cords running radially from bead to bead (90 degrees to center-line of the tire).

Ribs

Tread sections running circumferentially around tire.

Section Height

Distance between tread crown and bead seat.

Section Width

Measurement of distance through cross sectional width of a tire at widest part, exclusive of scuffing rib when inflated to normal pressure and not under load.

Seventy-eight Series

A tire which when mounted will have an aspect ratio of seventy-eight.

Shoulder

Outer edges of tread.

Sidewall

Zone of tire between buttress and bead.

Sipe

To cut across a tire tread to produce biting traction edges.

Sixty Series Tire

A tire which when mounted will have an aspect ratio of approximately sixty.

Size Factor

The sum of the section width and the overall diameter

Specific Gravity

Ratio of the weight of a given volume of any substance to that of the same volume of water. The higher the specific gravity, the denser or heavier the substance.

Squeegee

A thick rubber added between plies.

Static Loaded Radius

Distance from center of wheel to ground on vehicle which has rated load, normal inflation, and is not in motion.

Tapered Bead

Tires with a taper on the base of the bead for compression on the rim to seal tubeless tires and to prevent slip.

Tread

Portion of tire which comes in contact with the road.

Tread Depth

The distance in thirty-seconds of an inch measured from the tread surface to the bottom of the grooves in a tire.

Tread Elements

The parts of the tread design which are separated from each other and made distinct by the sipes and rib or lug design molded into the tire.

Tread Radius

The radius of the circle that coincides with the arc of the tread cross section. The longer the tread radius, the flatter the tread will be.

Tread Wear Indicators

Narrow bars of rubber molded at a height of 2/32 inch across the bottom of the tread grooves. When the tread wears down to these bars, the tire should be replaced.

Vents

Raised embellishments on tire to aid molding.

Vulcanization

Process of combining rubber with sulphur or certain other additives under influence of heat and pressure to eliminate tackiness when warm, and brittleness when cool, and to otherwise improve the useful properties of rubber. Also known as curing.

Weather Checking

Fine hairline cracks in surface of rubber, caused by oxidation and other atmospheric effects.

WSW

White sidewall tire.

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