UMTRI-83-46

DOWNSIZING OF HEAVY TRUCK WHEELS DUE TO EXTREME OVERINFLATION

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Sponsored by:

Lawler, Felix, & Hall

September 1983

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-83-46		

4. Title and Subtitle	5. Report Date
DOWNSIZING OF HEAVY TRUCK WHEELS DUE TO EXTREME OVERINFLATION	September 1983
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
J.D. Campbell, R.D. Ervin	UMTRI-83-46
9. Performing Organization Name and Address	10. Work Unit No.
The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, Michigan 48109	11. Contract or Grant No. N2 Contract - 6/3/83
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Lawler, Felix, & Hall 700 South Flower Street Los Angeles, California 90017	Final 6/83 - 9/83
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A series of experiments was performed in which heavy truck tires were inflated up to failure. The purpose of the experiments was to examine the alterations in rim dimensions which derive from the explosive failure of the tire. It was found that radial tires, in size 11-24.5/G, failed in a manner which resulted in the tire bead dismounting over the flange of the single-piece rim. This type of failure caused the bead seat circumference to decrease by approximately 5/8 inch. If such a tire failure was to occur in the field, and the rim downsizing dimension remain unnoticed, a hazard may exist since new tires mounted on such down-sized rims will explosively dismount at much lower pressure values than would apply in the case of new, full-sized rims.

17. Key Words	18. Distribution Statement
truck tire failure, overpressure, downsizing of rims, tire explosions	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		36	

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CHAPTER 1

INTRODUCTION

This document reports the results of tests on the overinflation failure of heavy truck tires on one-piece wheels performed by The University of Michigan Transportation Research Institute (UMTRI) under contract to Lawler, Felix, and Hall. These tests were conducted to determine:

- the inflation pressure resulting in over-pressure failure of new tires mounted on new rims
- the magnitude of rim downsizing resulting from over-pressure failure or dismounting of new tires on new rims
- the pressure at which tires will dismount from downsized rims

Tests were conducted on two styles of Budd 24.5x8.25 tubeless one-piece type wheels with 11x24.5 radial (load range G) and bias (load range F) tires. The test matrix contained 12 wheels (6 each of 2 styles), 11 radial tires, and 9 bias tires. Failure pressure was measured with new tires mounted on new rims for 3 radial tires and 2 bias tires on each of the two rim styles.

In these tests, all radial tires dismounted over the inside flange (opposite the disc side) at pressures between 315 psi and 335 psi with no apparent damage to the tire, but produced a downsizing of the inside bead circumference of .53 inch to .71 inch. One radial tire also suffered a 12-inch tear in its sidewall about 6 inches above and parallel to the bead. All bias tires suffered wholesale failure to the bead area at pressures between 300 psi and 305 psi, but produced little or no downsizing of the rims. All but one of the bias tires failed at the inside bead.

The pressure needed to fail new tires mounted on downsized rims was measured for 2 radial tires and 2 bias tires on each rim style. In all cases, the tire was seen to dismount over the downsized (inside) flange with no apparent damage to the tire and little or no additional downsizing of the rim. The radial tires dismounted from the downsized rims at pressures between 160 psi and 240 psi, and the bias tires dismounted at pressures between 135 psi and 165 psi.

Two new rims and tires were used in a test intended to simulate a tire bead hang-up and, thus, to induce a lower failure pressure. To this end, tests were run with a shaped metal wedge inserted in the wheel bead seat area. With the bias tire, the test terminated when the wedge became dislodged at 235 psi. With the radial tire, an air leak was introduced by the tire climbing partially over the wedge, thus limiting the pressure to 330 psi.

This report describes the sample of tires and rims employed in Chapter 2 and the apparatus and test methodology in Chapter 3. The detailed test results are presented in Chapter 4 and conclusions in Chapter 5.

CHAPTER 2

TEST SAMPLE

Six each of 2 styles of Budd 24.5x8.25 one-piece heavy truck wheels were tested. The 2 styles of wheel construction are distinguishable by a straight flange, rim A, or a curved flange, rim B, as shown in Figure 1. Manufacturer identification data stamped on each rim included the following:

Rim A (straight flange)	Rim B (curved flange)
Budd 79 F 15	Budd T DOT 25.5 x 8.25
LEDGEWELD	R 87650
DATE	DATE

Eleven radial-ply tires and 9 bias-ply tires were used in the test. All radial tires were Goodyear 11R-24.5 Unisteel 2 tubeless, load range G. All bias-ply tires were Goodyear 11-24.5 Super Hi Miler tubeless, load range F. Tires were purchased in two batches from the same retail source. They were not all from the same manufacturing batch.

For test identification, black Magic Marker was used to number the rims, A1 through A6, and B1 through B6. The tires were each branded on the sidewall using a hot iron for afixing a 2 or 3 digit code. The left digit of the tire code identifies the tire type, 1 for a radial tire and 2 for a bias tire. The other digits represent the tire sample number in the sequence of either bias- or radial-ply tires. The test identification number is a combination of the rim and tire identification codes. For example, test number A2-1-5 indicates the straight-flanged rim, number A2, mounted with radial tire number 5.

Appendix A contains a table of the manufacture date of each wheel and a table of the DOT number of each tire.

Appendix B contains data on the construction and bead strength of the tire types used in these tests.

1A. Rim Style A

Straight Flange

1B. Rim Style B

Curved Flange

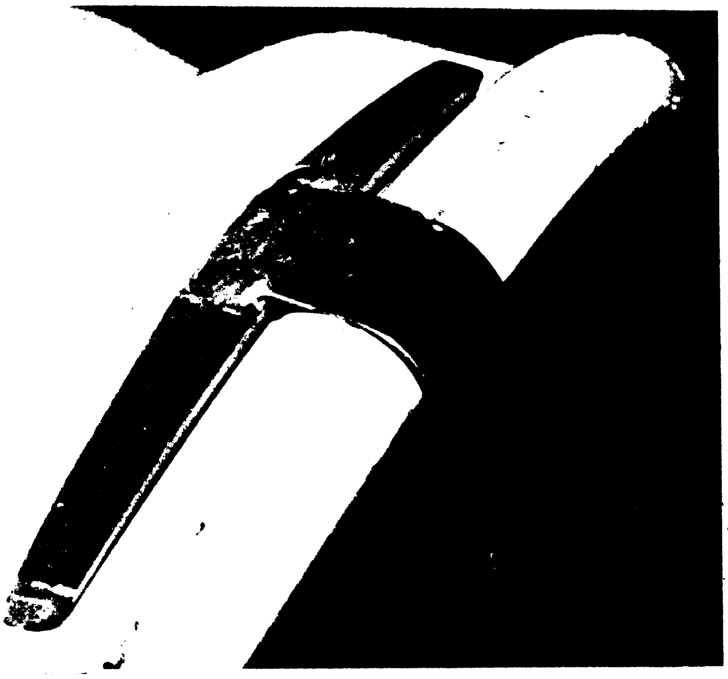

Figure 1. Close-up photograph of the two rim styles showing the main distinguishing feature. Rim A - straight flange; Rim B - curved flange. The steel wedge used in the "wedge test" is also shown.

CHAPTER 3

APPARATUS AND METHODOLOGY

The test apparatus consisted of a wheel/tire mounting fixture, a noise and blast containment pit, and tire inflation and pressure measurement equipment.

The mounting fixture and the test pit are shown in Figures 2, 3, and 4. The wheel was bolted to a flange which was welded to a section of 6-1/2-inch steel pipe such that the tire was centered between 2 steel end plates supporting the pipe. The mounting fixture was configured to suspend the test sample in the containment pit so that the exploding tire could not contact any rigid support structure. Thus clearance of approximately 16 inches was provided between the sidewalls of the mounted tire and the end plates shown in Figure 2.

The test pit was constructed of 4 4-foot by 8-foot 1/4-inch thick steel plates welded at the sides and set into the ground. Steel pipes were placed horizontally across the top of the pit to contain any large pieces attempting to exit the blast area vertically. Such pieces did not result from any of the tire explosions in these tests. By restricting the air blast to the vertical, the pit provided a significant reduction in noise propagated horizontally. However, although the pit was located about 370 feet from the nearest UMTRI offices, the shock wave caused windows to vibrate in those offices facing the test area.

The tire pressurization hardware is shown in Figures 5 and 6. A maximum pressure level of 270 psi was obtained from the heavy-duty compressor shown in Figure 5. Air flow was controlled with a shut-off valve located at the left end of the compressor tank, but not visible in the photograph. In order to achieve pressures in excess of 270 psi, a bottled nitrogen source was used. The nitrogen pressure was regulated to approximately 400 psi and flow was controlled with the shut-off valve seen below the regulator in Figure 6. The air and nitrogen sources were isolated from each other as required by the manually operated shut-off

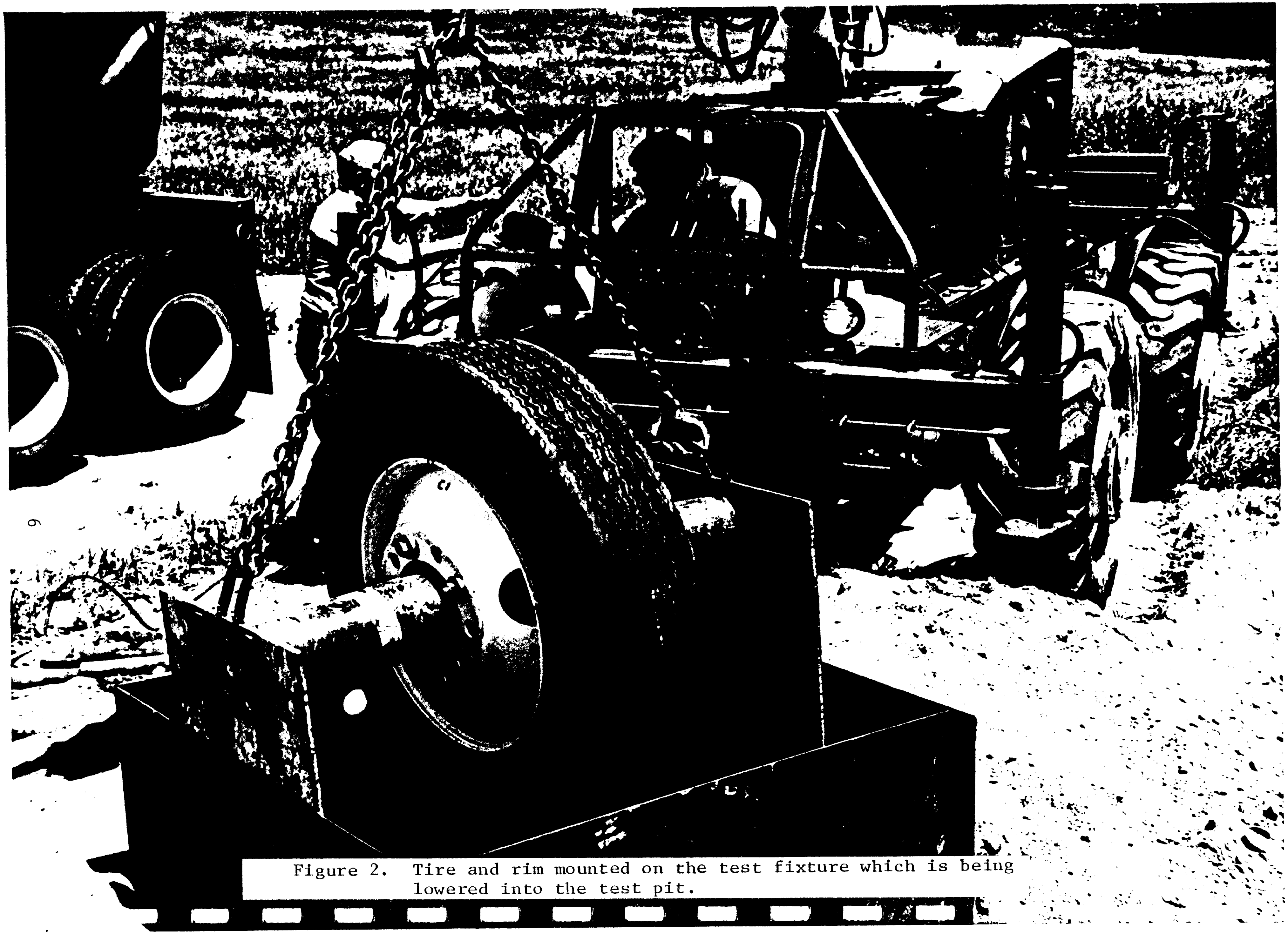

Figure 2. Tire and rim mounted on the test fixture which is being lowered into the test pit.

Figure 3. Close-up photograph showing the mounting flange welded to the 6-1/2 inch diameter tube.

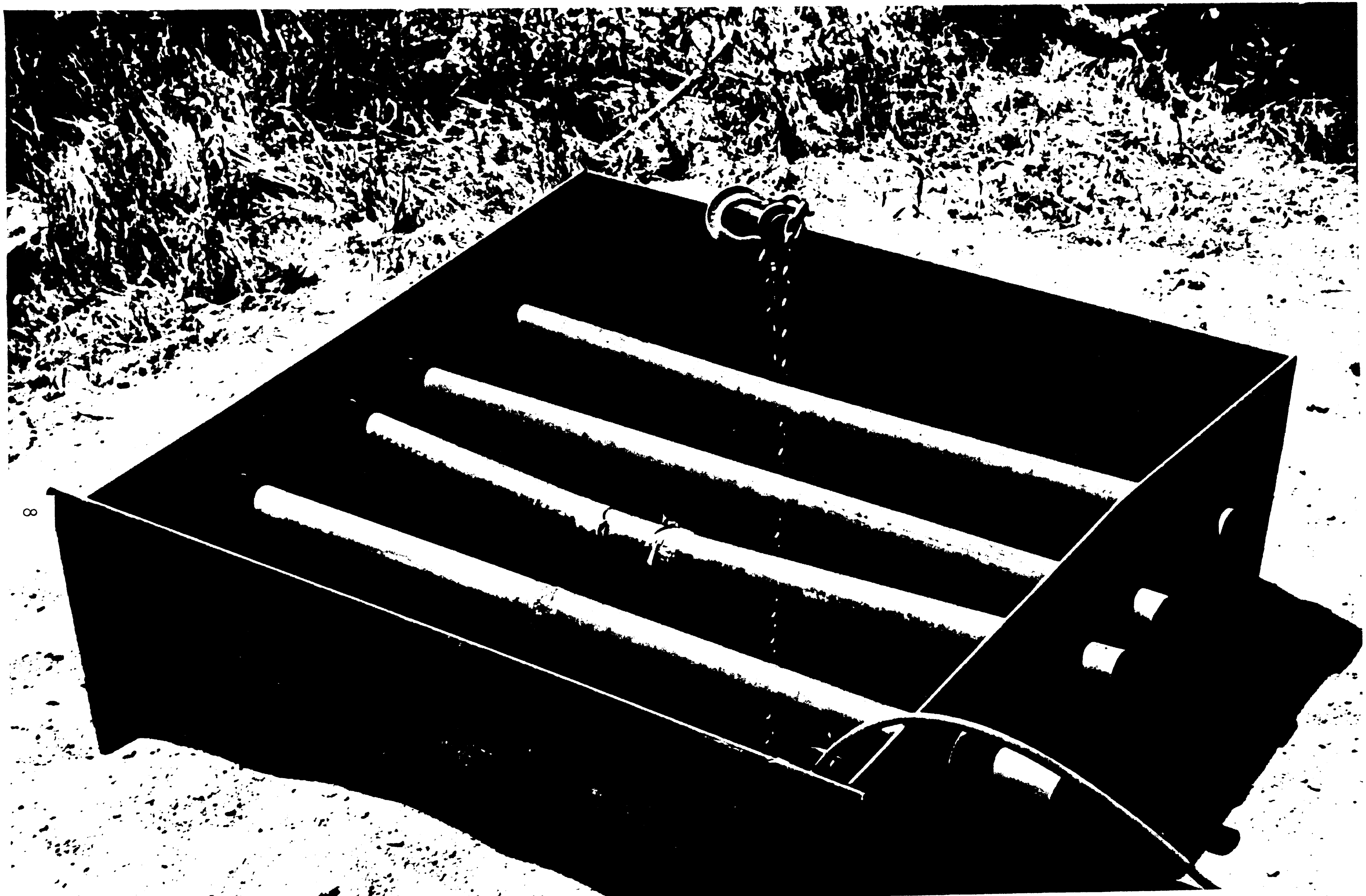

Figure 4. Test pit with steel retainer bars placed across the top opening. The inflation hose can be seen entering the pit at the lower right corner.

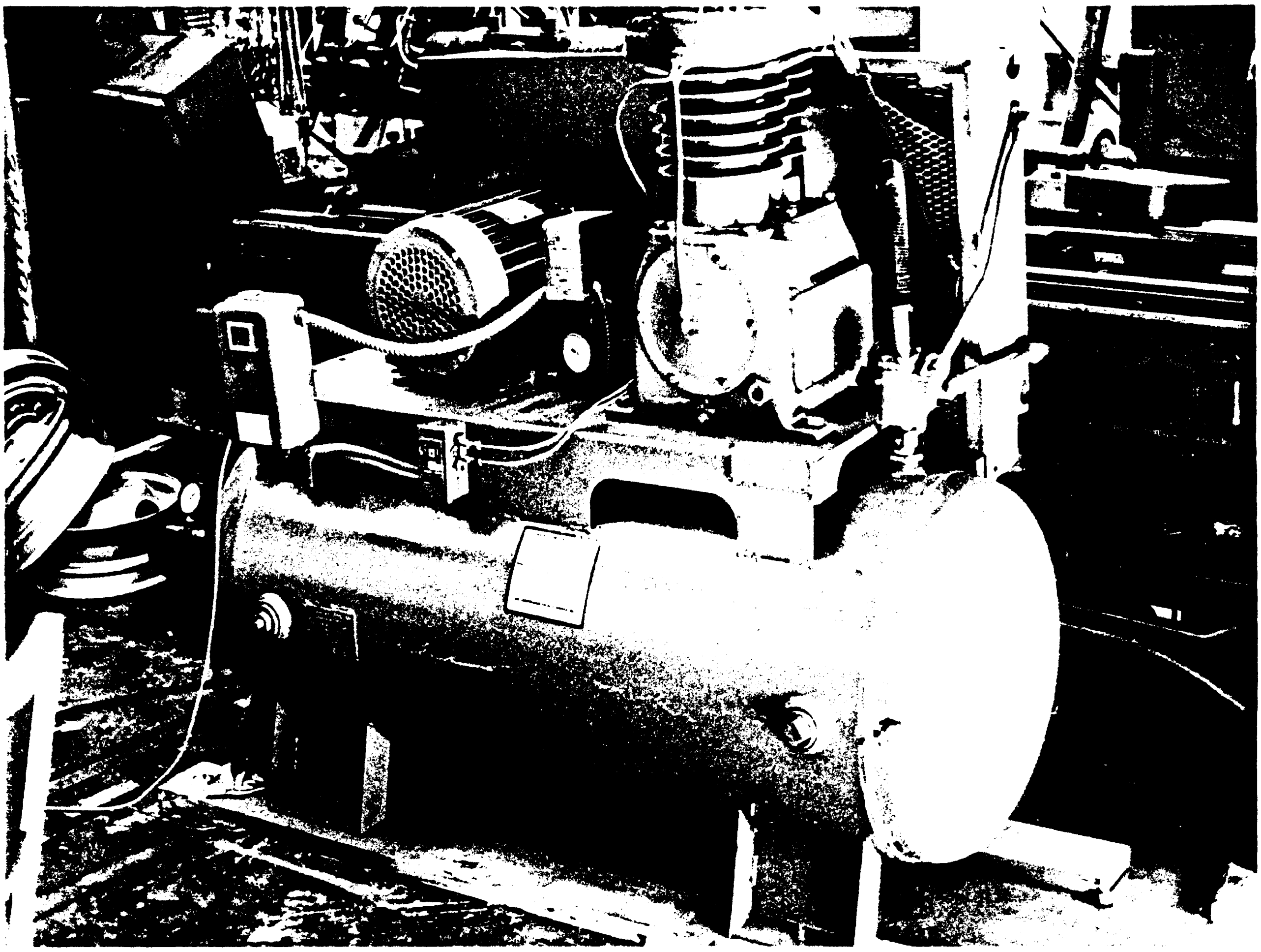

Figure 5. Heavy-duty compressor used to pressurize the test tires up to 270 psi.

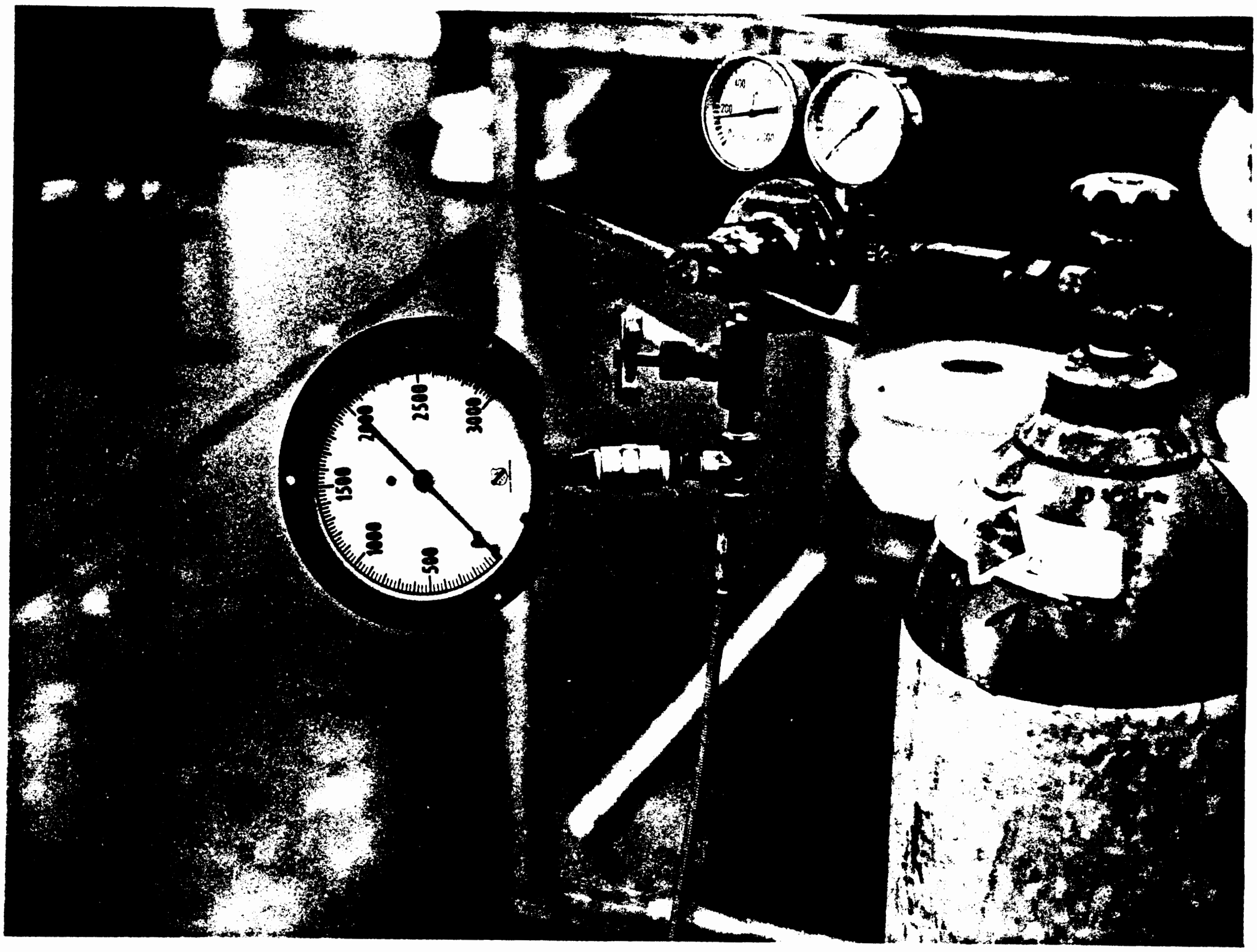

Figure 6. Nitrogen tank, regulator, and gauge assembly used to obtain a pressure boost for pressures over 270 psi.

valves. The compressor and nitrogen tank, located inside the UMTRI high-bay shop area, were connected to the test tire by approximately 400 feet of high-pressure hose having 5/16-inch inside diameter.

Tire burst pressures below 270 psi were read from the pressure gauge seen at the left end of the compressor tank in Figure 5. Above 270 psi, burst pressures were read on the master gauge mounted below the nitrogen shut-off valve seen in Figure 6. During inflation, the pressure drop in the long supply line was between 25 and 100 psi, depending on the flow rate. Accurate tire pressure readings were obtained by frequently closing the shut-off valve and reading the gauge after the line pressure stabilized. Both pressure gauges were calibrated on a dead-weight calibrator and the test readings were corrected accordingly. Accuracy of the burst pressure data is $\pm$ 5 psi.

Figure 1 shows photographs of the wedge device which was used in an attempt to simulate a bead hang-up and, thus, to induce a lower burst pressure. The wedge was 6-1/2 inches long and 3/8-inch thick and was contoured to fit both the bead seat circle and the fillet radius at the flange. The "nose" of the wedge was tapered so as to achieve tire contact tending to retain it against the wheel flange. The photograph in Figure 7 shows the wedge installed in a tire/wheel assembly and strapped to the test fixture.

The test procedures were essentially the same for all tests. The rim was inspected, the identifying data was recorded, and the rim was marked with a rim I.D. code (A1 to A6 or B1 to B6). Two reference marks, labeled C1 and C2, were placed on the rim approximately 90 degrees apart. Ten rim measurements were made and recorded before and after each test. A precision caliper was used to measure the width of the rim and its inside and outside flange diameter at the locations, C1 and C2. The outer-most circumference of both flanges was measured using a fiberglass cloth tape measure and the circumference of the inside and outside bead seats was measured using a ball tape.

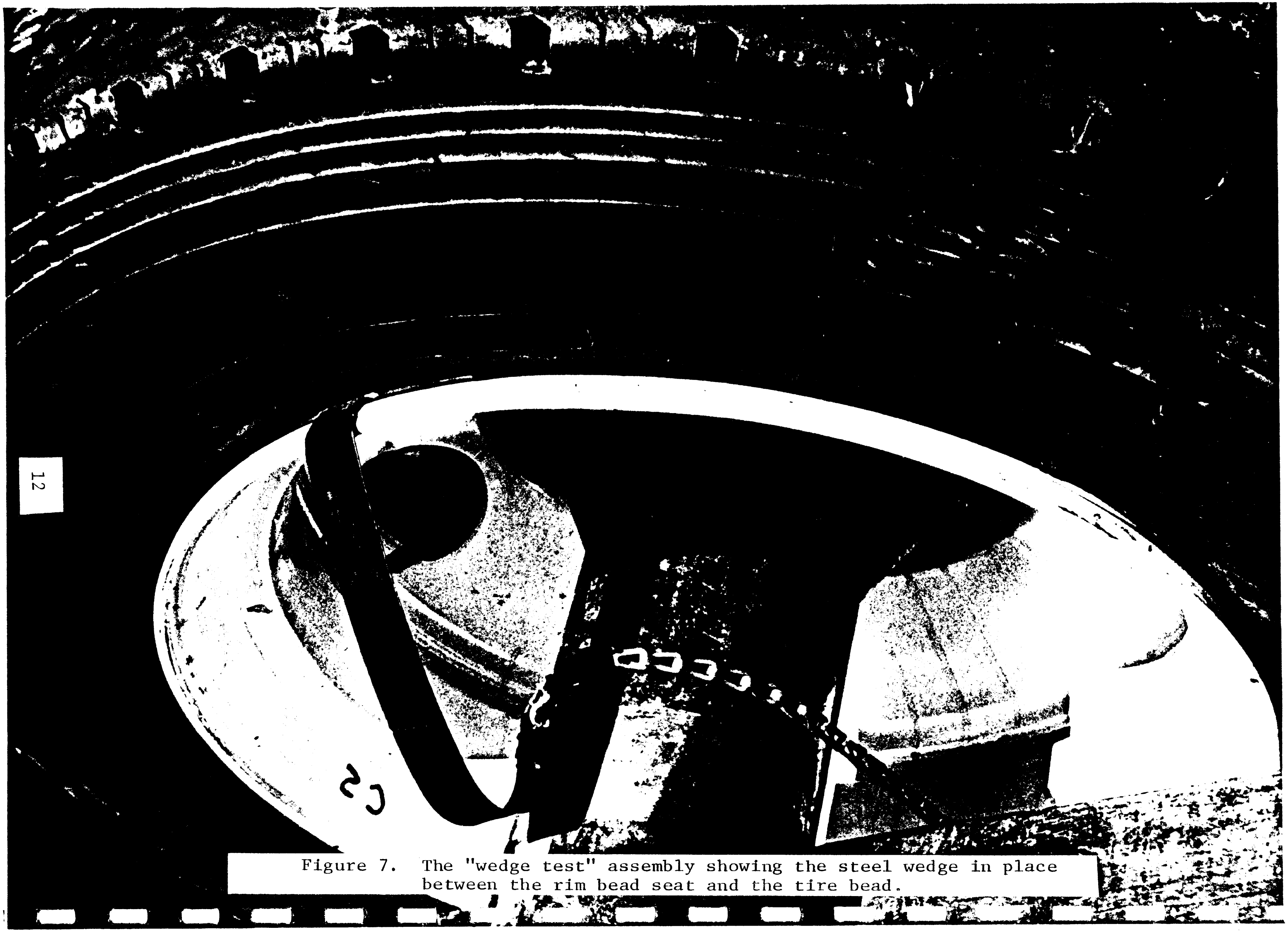

Figure 7. The "wedge test" assembly showing the steel wedge in place between the rim bead seat and the tire bead.

The photograph in Figure 8 shows a ball tape measurement being made on a downsized rim. Note the large overlap of the front and rear gauge fingers. The small notch seen in the rear gauge finger is .096-inch wide which is the manufacturing tolerance on the rim bead seat circumference. Thus, for in-tolerance rims, the gauge mark on the front finger must fall on or between the edges of the notch in the rear finger. The left notch edge represents the minimum in-tolerance circumference and the right edge the maximum. In-tolerance measurements were recorded in 5 increments: min., min.+, nom., max.-, and max. Out-of-tolerance measurements were recorded as max.+ (inches) and min.- (inches). On downsized rims, the large overlap of the ball tape gauge fingers, as seen in Figure 8, made it difficult to accurately measure the distance from the left edge of the notch on the rear finger to the gauge mark on the front finger. Thus such measurements are accurate to about .030 inch. All ball tape measurements were made with 3 people holding the ball tape firmly into the rim bead seat.

The test tire was inspected, its DOT number was recorded, and it was branded with the tire identification number. After a valve was installed in the rim, the tire was mounted manually using tire irons and mounting lubricant (Ruglyde 765-1338). All tires were mounted with the side imprinted with the DOT number on the outside (disc side) of the rim. The valve core was removed from the stem so that the tire could be safely deflated, if necessary, without approaching the tire and to permit remote pressure readings to be taken. After sealing the tire bead, a cap was placed on the valve to hold air in the tire while it was mounted on the test fixture and moved to the test pit. Just before lowering the tire into the pit, the cap was removed and the inflation hose was quickly connected.

The inflation of each tire up to the failure condition covered an approximate 10-minute period. Over half of this time was taken waiting for the line pressure to stabilize after the shut-off valve was closed in order to obtain an accurate tire pressure reading. As the expected burst pressure was approached, readings were taken at maximum increments of 5 psi.

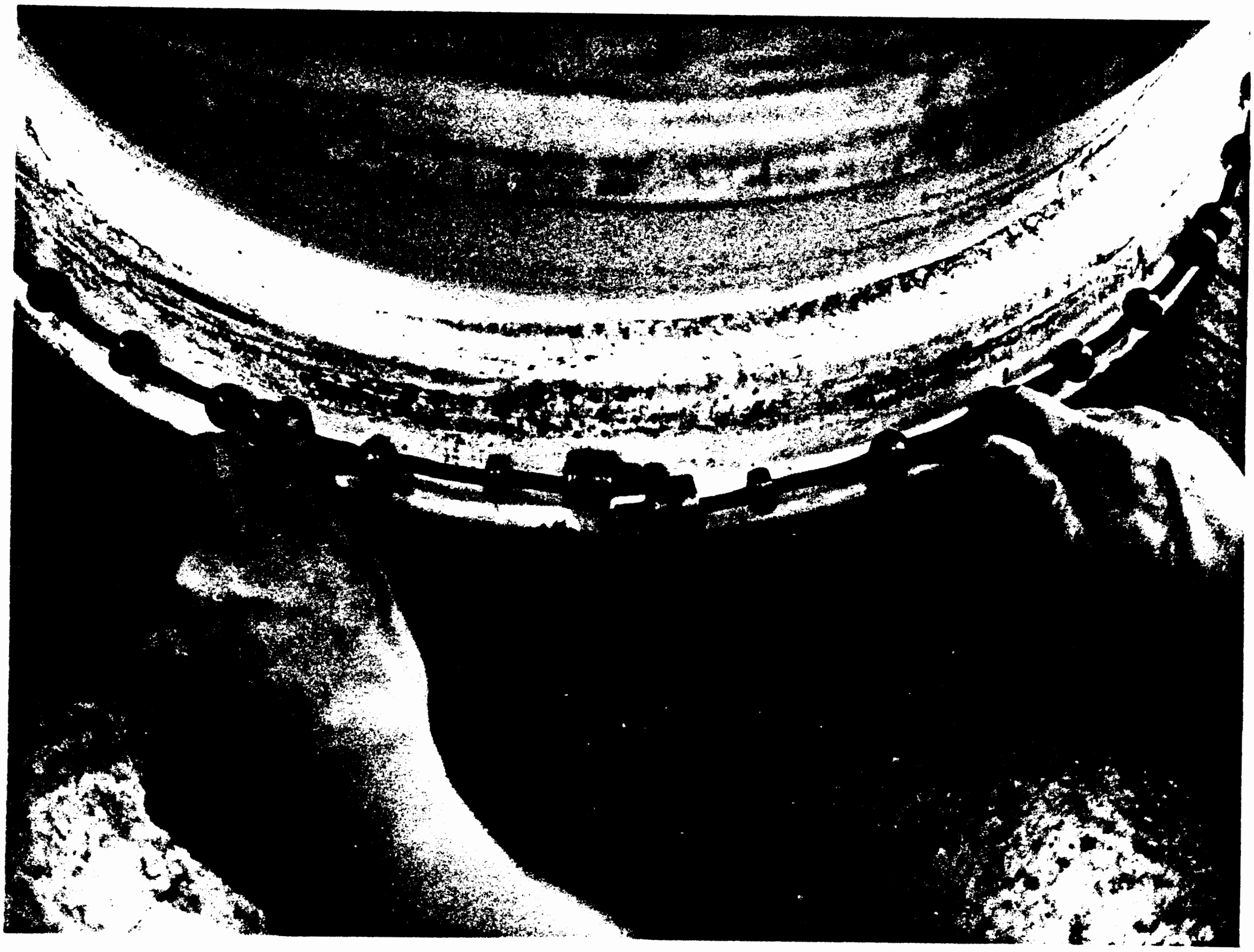

Figure 8. The ball tape as applied in measuring the bead seat circumference of a downsized rim.

After the test, the tire was inspected and the burst pressure and failure mode were recorded. The tire was then removed from the rim and the rim measurements were repeated.

Since it was anticipated that tires mounted on downsized rims might fail at very low pressures, there was concern for the safety of personnel handling the tire/rim assembly during the inflation efforts needed to get the tire bead seated. Thus, an inner tube was installed in each tire tested on a downsized rim and the inflation process was done only with the tire in the containment pit.

CHAPTER 4

TEST RESULTS

Tire data supplied by Smithers Scientific Services, Inc. (Appendix B) gave a bead breaking strength of 47,750 pounds for the radial-ply tires and 29,400 pounds for the bias-ply tires, and bead burst pressures of 341 psi and 276 psi, respectively. Although lower failure pressures were expected of the bias-ply tires, the tire bead strengths together with the rim flange strength produced interesting results.

In the tests of new tires mounted on new rims, all radial-ply tires dismounted over the inside flange of the rim at pressures from 315 psi to 335 psi with no apparent damage to the bead, and produced a downsizing of the inside bead seat circumference of 0.534 inch to 0.761 inch. A picture of a typical radial tire taken after the test is shown in Figure 9, simply revealing that the tire is intact and has no visible damage.

All bias-ply tires suffered massive bead failure at pressures from 300 psi to 305 psi, but produced very little or no downsizing of the bead seat. Figure 10 is a picture of a typical bias-ply tire taken after the test, showing extreme deformation of the tire bead. In some cases, bead wires could be seen piercing the rubber at 3 or more locations around the bead. Although one bias tire failed at the outside bead, all others failed at the inside bead.

In the test of new tires mounted on downsized rims, all tires (radial and bias) dismounted over the downsized flange at pressures ranging from 160 psi to 240 psi for the radial tires and from 135 psi to 165 psi for the bias tires, while producing little or no additional downsizing of the bead seat. Downsizing of the rims resulted in only slight visible distortion of the wheel flange and no visible distortion of the bead seat. A typical downsized rim is shown in Figure 11. Slight distortion of the inside flange (the flange nearest to the backdrop) can be seen in the photograph. The distortion consists primarily of localized flattening of the flange.

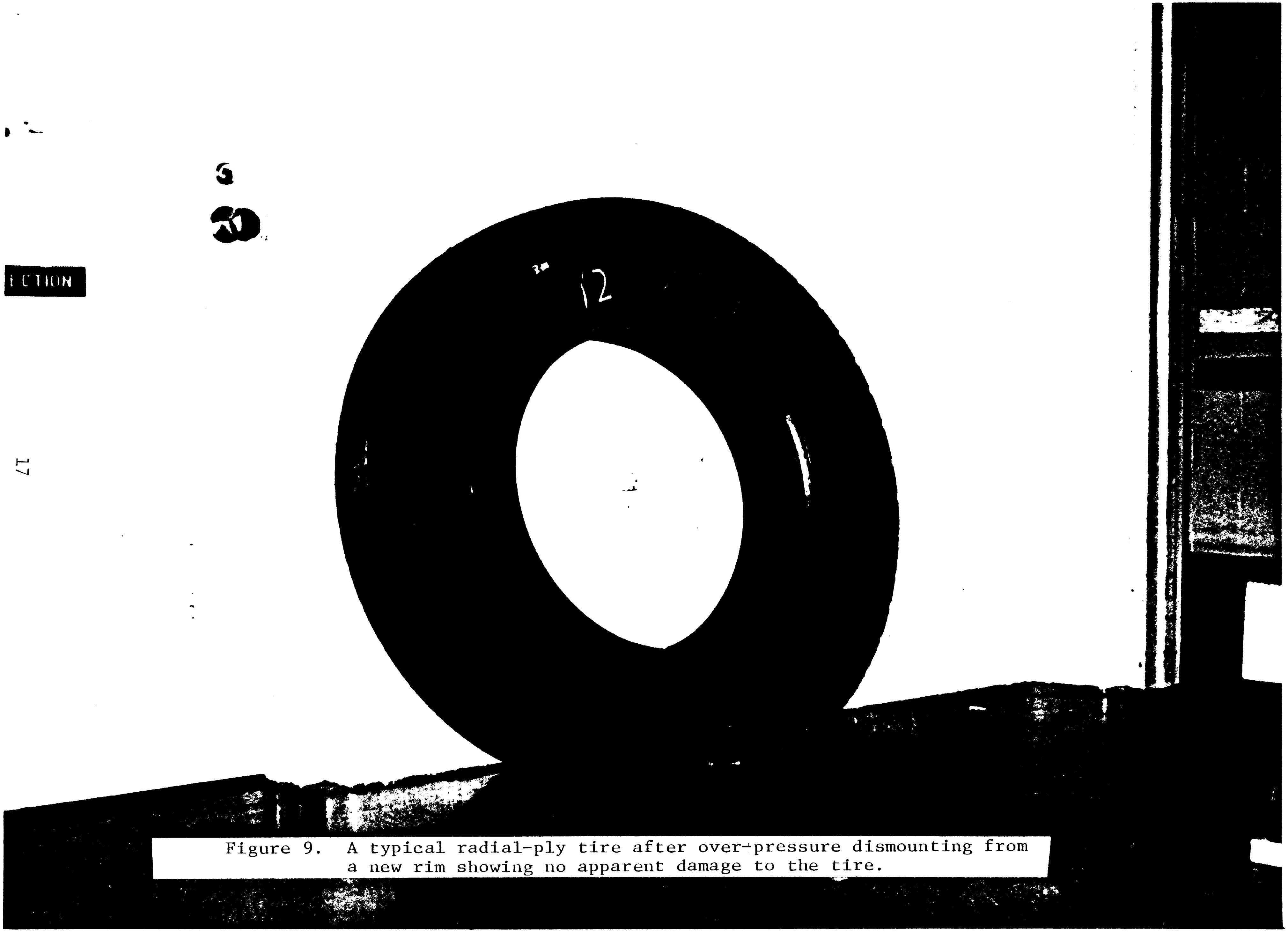

Figure 9. A typical radial-ply tire after over-pressure dismounting from a new rim showing no apparent damage to the tire.

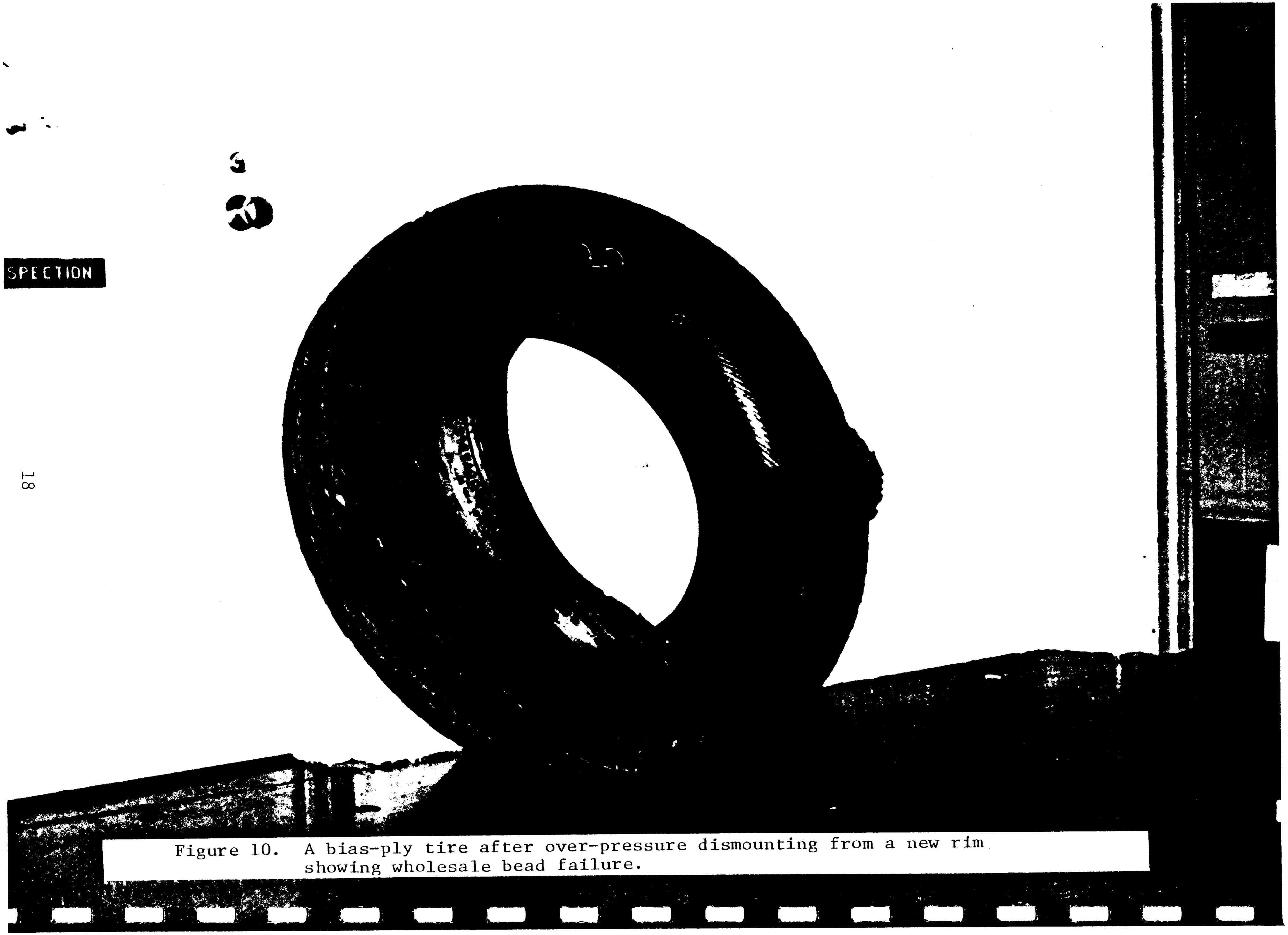

Figure 10. A bias-ply tire after over-pressure dismounting from a new rim showing wholesale bead failure.

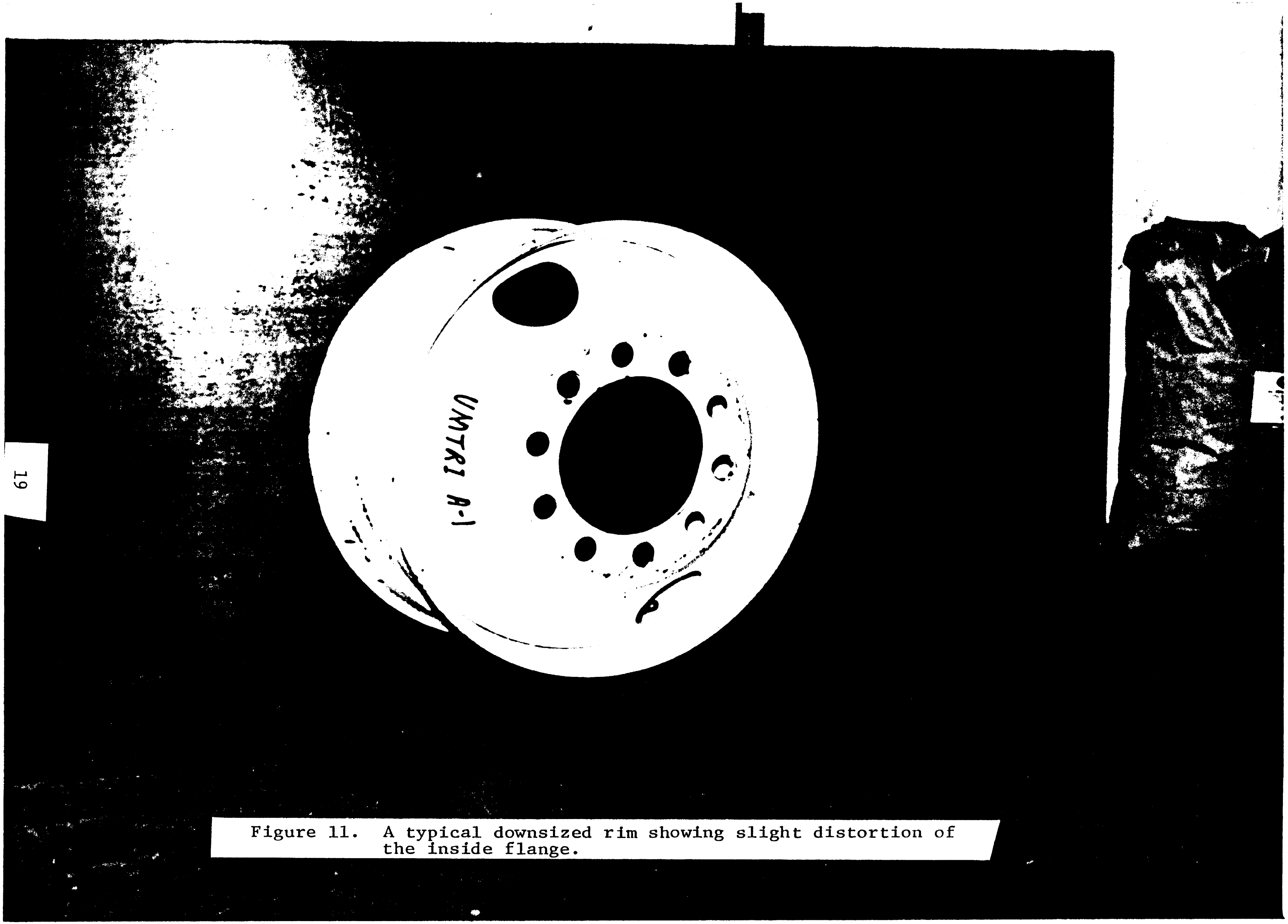

Figure 11. A typical downsized rim showing slight distortion of the inside flange.

Table 1 is a condensed summary of the results of these tests. Section 1A of the table gives the failure pressures for new rims mounted with new tires. On the average, a 13 psi higher pressure level was required to dismount radial tires from rim A than from rim B. The bias tires all suffered bead failure at essentially the same pressure on both types of rims.

Section 1B of Table 1 gives the decrease in the rim bead seat circumference (in inches) resulting from the test of new tires on new rims. We see that only the radial tires, in the process of dismounting over the inside flange, produced a significant downsizing of the bead seat. Average values are given in the table. For the radial tire cases the range of values is also given. On the average, the bead seat of rim type B was downsized .163 inches more than rim type A, and at pressures which were 13 psi lower, indicating that rim A is slightly stronger.

Section 1C of Table 1 gives the pressure levels at which new tires dismounted from the downsized rims. The quantity in parentheses is the inside bead seat circumference before the test, given in inches below the minimum tolerance circumference as measured with the ball tape. Thus a larger value corresponds to a smaller bead seat circumference. The radial tires dismounted at pressures ranging from 160 psi to 240 psi, and the bias tires dismounted at pressures ranging from 135 psi to 165 psi. As expected, the trend in the data indicates that smaller bead seat circumferences result in lower dismounting pressures. However, considerably more data is required to establish a statistically significant curve of bead seat circumference versus dismounting pressure.

Tables 2 through 4 are tabulations of all measurements made on the 12 test rims. In Tables 3 and 4, the tire type (R-radial and B-bias), the tire number, and the maximum tire pressure are listed in the column marked "Comments."

Table 2 gives the dimensions of the new wheels as they were received from Budd. Measurement of the outermost flange diameters with the fiberglass cloth tape measure was started after the first 4 tests were made on rims A1, A2, B1, and B2. The notation, N.M., in the tables stands for "not measured." One prominent feature in the dimensional data for new wheels

Table 1

1A. Inflation Pressures at which New Tires Failed on New Rims (psi)

Rim A (Straight Flange)		Rim B (Curved Flange)	
Radial	Bias	Radial	Bias
325	300	315	300
330	300	315	305
335		320	

1B. Rim Downsizing - Average of Ball Tape Measurement*

Rim A		Rim B	
Radial:	Inside - .551 (-.534 to -.564)	Radial:	Inside - .717 (-.659 to -.761)
	Outside - .011		Outside - .021
Bias:	Inside - .01	Bias:	Inside - .019
	Outside - .01		Outside - .002

1C. Inflation Pressures at which New Tires Dismounted from Downsized Rims**

Rim A		Rim B	
Radial	Bias	Radial	Bias
230 (-.438)	160 (-.438)	230 (-.563)	155 (-.563)
240 (-.438)	165 (-.438)	160 (-.625)	135 (-.625)

*Entries indicate total downsizing in inches

**Parenthetic entries show the initial downsized ball tape dimension in inches below the minimum tolerance

Table 2. New Rim Dimensions

Rim	Width (10" + in.)	Inside: Flange Dia. (25" + in.)	Inside: Flange Circum. (72" + in.)	Inside: Bead Seat Circum. (in.)	Outside: Flange Dia. (25" + in.)	Outside: Flange Circum. (72" + in.)	Outside: Bead Seat Circum. (in.)
A1 at C1	.114	.453	N.M.*	Max	.515	N.M.	Max
C2	.108	.454			.514		+.035
A2 at C1	.100	.462	N.M.	Max	.530	N.M.	Max
C2	.110	.450		+.020	.515		+.010
A3 at C1	.120	.570	8.125	Max	.510	8.250	Max
C2	.110	.450		+.010	.515		
A4 at C1	.120	.455	8.063	Max	.515	8.219	Max
C2	.115	.470		+.030	.505		
A5 at C1	.110	.460	8.063	Max	.510	8.219	Max
C2	.115	.440		+.030	.510		+.030
A6 at C1	.100	.455	8.031	Max	.530	8.250	Max
C2	.110	.460		+.020	.510		+.010
B1 at C1	.179	.479	N.M.	Max	.442	N.M.	Max
C2	.199	.524			.452		+.010
B2 at C1	.185	.490	N.M.	Max	.460	N.M.	Max
C2	.180	.485			.445		
B3 at C1	.210	.520	8.250	Max	.450	8.0	Max
C2	.175	.520		+.020	.460		+.035
B4 at C1	.165	.510	8.156	Max	.460	8.0	Max
C2	.190	.505		+.010	.450		
B5 at C1	.200	.475	8.156	Max	.425	8.0	Max
C2	.200	.500		+.040	.450		+.030
B6 at C1	.200	.465	8.156	Max	.420	8.0	Max
C2	.220	.520		+.010	.440		

*N.M. = not measured

Table 3. Rim Dimension After First Test

		Inside			Outside			
Rim	Width (10" + in.)	Flange Dia. (25" + in.)	Flange Circum. (72" + in.)	Bead Seat Circum. (in.)	Flange Dia. (25" + in.)	Flange Circum. (72" + in.)	Bead Seat Circum. (in.)	Comments
A1 at C1	.238	.090	7.031	Min	.520	8.250	Max	R 1-1
C2	.270	.119		-.438	.512		+.035	330 psi
A2 at C1	.105	.445	N.M.**	Max	.520	N.M.	Max	B 2-1
C2	.110	.445			.510			300 psi
A3 at C1	.163	.328	7.844	Min+	.513	8.250	Max	R 1-5
C2	.130	.397			.506			320 psi (wedge test)
A4 at C1	.304	.416*	7.000	Min	.506	8.219	Max	R 1-6
C2	.265	.110		-.438	.494			325 psi
A5 at C1	.106	.449	8.063	Max	.508	8.219	Max	B 2-6
C2	.114	.461		+.030	.560		+.020	300 psi
A6 at C1	.232	.138	6.844	Min	.520	8.219	Max-	R 1-7
C2	.192	.085		-.438	.500			335 psi
B1 at C1	.258	.200	7.000	Min	.430	7.969	Max	R 1-2
C2	.265	.190		-.563	.425			315 psi
B2 at C1	.185	.485	N.M.	Max	.455	N.M.	Max	B 2-2
C2	.185	.480			.448			305 psi
B3 at C1	.215	.505	8.250	Max	.443	8.000	Max	B 2-5
C2	.176	.498		+.020	.458		+.030	230 psi (wedge test)
B4 at C1	.397	.010	6.969	Min	.419	7.844	Max-	R 1-8
C2	.404	24.955		-.625	.390			315 psi
B5 at C1	.275	24.887	6.688	Min	.389	7.875	Max	R 1-9
C2	.387	24.993		-.625	.421			320 psi
B6 at C1	.190	.483	8.063	Nom	.395	8.000	Max	B 2-7
C2	.226	.468			.460			300 psi

*Probable measurement error

**N.M. = not measured

Table 4. Rim Dimensions After 2nd and 3rd Test

Rim	Width (10" + in.)	Inside Flange Dia. (25" + in.)	Inside Flange Circum. (72" + in.)	Inside Bead Seat Circum. (in.)	Outside Flange Dia. (25" + in.)	Outside Flange Circum. (72" + in.)	Outside Bead Seat Circum. (in.)	Comments
A1 at C1 C2	.250 .260	.140 .100	7.000	Min -.438	.510 .525	8.250	Max +.035	R 1-3 240 psi
A1 at C1 C2	.236 .243	.145 .056	6.969	Min -.438	.500 .524	8.250	Max +.035	B 2-4 160 psi
A4 at C1 C2	.314 .265	24.980 .085	7.000	Min -.438	.508 .496	8.219	Max	R 1-10 230 psi
A6 at C1 C2	.235 .186	.137 .093	6.844	Min -.438	.529 .507	8.219	Max	B 2-8 165 psi
B1 at C1 C2	.235 .285	.255 .135	6.875	Min -.625	.400 .445	7.969	Max-	R 1-4 230 psi
B1 at C1 C2	.235 .260	.250 .140	6.875	Min -.625	.395 .445	7.969	Nom	B 2-3 155 psi
B4 at C1 C2	.401 .404	.008 24.954	6.844	Min -.625	.426 .390	7.875	Min+	R 1-11 160 psi
B5 at C1 C2	.270 .379	24.885 24.982	6.719	Min -.625	.394 .426	7.875	Max-	B 2-9 135 psi

is that all wheel samples showed ball tape measurements that were at or slightly above, the maximum circumference tolerance.

Table 3 gives the dimensions of the wheels after the first test was made with each wheel. Given that new wheels were consistently near the "max" tolerance, the downsized dimensions, registered here as inches below the minimum tolerance, imply greater net reductions in the bead seat measurements, as cited earlier. For example, wheel B5 showed an initial bead seat measure of "max + .040" such that its downsizing to "min - .625" represents a net change of (.040 + .096 + .625), or .761 inches.

Table 4 gives the wheel dimensions taken after the second and, for wheels A1 and B1, the third test using wheels which were downsized in the first test.

The changes in rim dimensions, calculated from the data in Tables 2, 3, and 4, are tabulated in Tables 5 and 6. The average of the values measured at C1 and C2 were used for these calculations. The plus and minus signs indicate an increase or decrease in the dimension, respectively. Please note that an error appears to have been made in the measurement of the inside flange diameter of rim A4 listed in Table 3, which results in unreasonable and inconsistent values for the corresponding dimension changes in Tables 5 and 6. The values in question are marked by an asterisk in Tables 3, 5, and 6.

Significant dimensional changes occurred only for the cases of the radial tires mounted on new rims. For all other cases, the dimensional changes are of the order of magnitude of the measurement accuracy; that is, relatively small. In the case of the wedge test with the radial tire, rim A3 in Table 5, the tire did not dismount and the maximum pressure was limited to 320 psi by an air leak at the wedge. However, the maximum pressure was equal to the nominal dismounting pressure of the other radial tire tests and the dimension change data indicate that a small plastic deformation of the rim did occur.

Table 5. Rim Dimension Changes - New Rims/New Tires

Rim/Tire	Width	Inside Flange Dia.	Inside Flange Circum.	Inside Bead Seat Circum.	Outside Flange Dia.	Outside Flange Circum.	Outside Bead Seat Circum.	Max Pressure Comments
Radial Tires								
A1/1-1	.143	-.349	N.M.	-.534	.002	N.M.	0	330 psi
A3/1-5	.032	-.148	-.281	-.082	-.003	0	0	320 psi (wedge test)
A4/1-6	.167	-.200*	-1.063	-.564	-.010	0	0	325 psi
A6/1-7	.107	-.346	-1.187	-.554	-.010	-.031	-.034	335 psi
B1/1-2	.073	-.307	N.M.	-.659	-.020	N.M.	-.010	315 psi
B4/1-8	.223	-.525	-1.187	-.731	-.051	-.156	-.024	315 psi
B5/1-9	.131	-.548	-1.469	-.761	-.033	-.125	-.030	320 psi
Bias Tires								
A2/2-1	.003	-.011	N.M.	-.020	-.008	N.M.	-.010	300 psi
A5/2-6	-.003	.005	0	0	.024	0	-.010	300 psi
B2/2-2	.003	-.005	N.M.	0	-.001	N.M.	0	305 psi
B3/2-5	.003	-.019	0	0	-.005	0	-.005	230 psi (wedge test)
B6/2-7	-.002	-.017	-.093	-.058	-.003	0	0	300 psi

N.M. = not measured

*Probable error resulting from error in corresponding data point in Table 3

Table 6. Rim Dimension Changes - Downsized Rims/New Tires

Rim/Tire	Width	Inside Flange Dia.	Inside Flange Circum.	Inside Bead Seat Circum.	Outside Flange Dia.	Outside Flange Circum.	Outside Bead Seat Circum.	Max Pressure Comments
Radial Tires								
A1/1-3	.001	.016	-.031	0	-.002	0	0	240 psi
A4/1-10	.005	-.231*	0	0	.002	0	0	230 psi
B1/1-4	.002	0	-.125	-.062	.005	0	-.024	230 psi
B4/1-11	.002	-.020	-.125	0	.004	.031	-.048	160 psi
Bias Tires								
A1/2-4	-.016	-.020	-.031	0	-.006	0	0	160 psi
A6/2-8	-.002	.004	0	0	.008	0	.024	165 psi
B1/2-3	-.013	0	0	0	-.003	0	-.024	155 psi
B5/2-9	-.007	-.007	.031	0	.005	0	-.024	135 psi

*Probable error resulting from error in corresponding data point in Table 3

CHAPTER 5

CONCLUSIONS

Tests conducted with samples of one-piece heavy truck wheels, size 24.5x8.25, have demonstrated that extreme overinflation of the mounted tire can result in explosive dismounting of the tire over the inside flange of the wheel, accompanied by a substantial permanent downsizing of the rim bead seat and flange circumference dimensions. Inflation pressures necessary to produce rim downsizing, with radial-ply tires, are in excess of 310 psi.

Such downsizing is attained rather uniformly around the rim such that only slight deformation of the flange is visually apparent and there is no obvious distortion of the bead seat. The downsizing of the bead seat circumference ranged from .534 inch to .761 inch, or an average of approximately .6 percent of the overall bead seat circumference. The decrease in the overall flange circumference ranged from 1.063 inches to 1.469 inches—an average of approximately 1.5 percent of the overall flange circumference. Changes of this magnitude are not visually apparent.

New tires mounted on the downsized rims dismounted at considerably lower pressures than new tires mounted on the new rims. A radial tire and a bias tire mounted on minimally downsized rims dismounted at 240 psi and 165 psi, respectively. When mounted on rims with the maximum downsizing the radial tire dismounted at 160 psi and the bias tire dismounted at 135 psi.

A relatively high degree of repeatability was seen in the pressure levels at which the bias and radial tires failed, when mounted on new rims. The standard deviation of the pressure at which 4 bias tire specimens failed was 2.5 psi. The sample of 6 radials showed a standard deviation of 8 psi. Downsizing of the bead seat circumference following failure of the radials on new rims showed a standard deviation of 0.097 inches (with a mean value of 0.634).

Regarding the uniformity of the bead seat circumference (ball tape readings) of the as-new wheels in the test sample, the circumference measurements ranged from the max. tolerance dimension to max.+.035 inches, a spread of .035 inches. The mean inside bead seat circumference was max.+.016 inch with a standard deviation of .013 inch, and the mean outside bead seat circumference was max.+.013 inch with a standard deviation of .015 inch. The maximum difference between the inside and outside bead seat circumferences on any wheel was .035 inch.

The quantity of data collected was insufficient to establish an accurate curve of dismounting pressure versus bead seat circumference. However, the data tends to indicate that the dismounting pressure decreases exponentially with decreasing bead seat circumference. Thus, slightly larger values of rim downsizing than experienced in this test series would be likely to yield dismounting pressures below 100 psi.

Such downsizing could conceivably result from mechanisms other than a static overpressurization of the tire such as examined here. For example, if a truck operator were to run his vehicle for some distance on a deflated front tire, the inclination of the axle due to the loss of support on one side would concentrate the reaction forces on the outside flange of the wheel, presumably affording an opportunity for downsizing the outside flange and bead seat. Indeed, since all of the over-pressure type testing reported here showed failure only at the <u>inside</u> flange, there would appear to be strong support for the argument that a downsized outside flange and bead seat could be obtained in service only from some non-inflation type of mechanism—such as, for example, the front tire blowout scenario.

Another mechanism by which extreme overinflation of the tire could be achieved was brought to the attention of the research staff during the course of this project. This mechanism apparently involves an unauthorized, but fairly popular, practice for achieving bead seating with tubeless heavy truck tires. The practice involves spraying ether from an aerosol can (normally sold to enable cold-weather starting of heavy diesel engines) into the cavity of the tire and igniting it to produce an explosive inflation transient which seats the beads. The combustion of ether in air is known to be an especially powerful reaction which can produce rises in static pressure approaching 10 times atmospheric and short-lived transients which may reach as much as 40 times atmospheric pressure if the mixture is "ideal." Such a practice appears patently hazardous and suggests a possible means for over-pressurization and the attendant downsizing of rims.

APPENDIX A

WHEEL AND TIRE INFORMATION

Table A1. Date of Manufacture of Budd Wheels Used in Over-Pressurization Tests.

Wheel I.D.	Date	Wheel I.D.	Date
A1	4-08-83	B1	3-05-82
A2	4-08-83	B2	3-04-82
A3	4-08-83	B3	8-26-82
A4	4-08-83	B4	3-05-82
A5	4-08-83	B5	3-05-82
A6	4-08-83	B6	3-04-82

Table A2. DOT Number of Tires Used in Over-Pressurization Tests.

Tire I.D.	DOT Number	Tire I.D.	DOT Number
1-1	MC4F 85F 462	2-1	MD4F 9EK 053
1-2	MC4F 85F 462	2-2	MD4F 9EK 053
1-3	MC4F 85F 462	2-3	MD4F 9EK 053
1-4	MC4F 85F 462	2-4	MD4F CU0 223
1-5	MC4F BK0 482	2-5	MD4F 9EK 053
1-6	MC4F 85F 462	2-6	MD4F 9EK 053
1-7	JE4F BK0 512	2-7	MD4F CU0 263
1-8	JE4F BK0 512	2-8	MD4F CU0 263
1-9	JE4F BK0 512	2-9	MD4F CU0 263
1-10	JE4F BK0 512		
1-11	JE4F BK0 512		

APPENDIX B

TIRE DATA FROM SMITHERS SCIENTIFIC

File

Mr. Diedrich

June 8, 1983

Telephone Conversation With Tom Baker of Smithers Scientific Services, Inc.

This morning Mr. Baker called me with some information in response to our letter of June 7, 1983. That information is as follows:

Data for Super High-Miler, Custom High-Miler, and Custom Cross Rib (all bias ply tires):*/

Bead construction: Two bundles of steel wires in each bead. Each bundle consists of 7 wraps of 7 parallel wires, or 49 strands/bundle. Each bead therefore contains 98 wires.

Wire diameter: .037 inch

Wire breaking strength: 300 lb (each wire)

Total bead breaking strength: 29,400 lb

Total force exerted on wheel flange (360°):

At 75 psi (dual mount): 33,000 lb
At 85 psi (single mount): 37,000 lb

Tension on bead:

At 75 psi: 8000 lb
At 85 psi: 9070 lb

Tire pressure required to burst bead: 276 psi

Sidewall construction: 6 strands of nylon cord, each with breaking strength of 73 lbs.

*/ Bead and sidewall constructions are the same in all three bias models, and in both radials. The figures for the bias tires are based on tires in load range "F". According to Baker, almost all bias tires of size 1124.5 fall into that category. The data for the radial tires is based on tires in load range "G" for the same reason.

Data for Unisteel II and Unisteel TD (radial tires):

Bead construction: Single wire, wrapped 85 times around the bead.

Wire diameter: .051 inch

Wire breaking strength: 550 lb

Total bead breaking strength: 47,750 lb

Total force exerted on wheel flange (360°):

At 95 psi (dual mount): 41,771 lb
At 105 psi (single mount): 46,168 lb

Tension on bead:

At 95 psi: 13,026 lb
At 105 psi: 14,397 lb

Tire pressure required to burst bead: 341 psi

Sidewall construction: 1 steel ply, wound radially from bead to bead, at a density of 9 cords/inch. Each steel cord has a breaking strength of 400 lb.

Regarding our contention that the bead seat may have been pushed down by the force of the explosive separation, Baker seemed to think this was unlikely. He noted that, in some of Smithers' tire burst tests, the explosion of the tire walls caused the wheels to collapse. However, he noted that the collapse of the wheel is more of a "caving-in" phenomenon, in which the wheel actually collapses around the hub area. In his opinion it is unlikely that the bead seat was pushed down evenly by the force of an explosion.

In addition, Baker noted that our questions regarding sidewall strength are really not appropriate, because tire sidewalls are not susceptible to failure from over-pressurization. According to Baker, sidewalls fail only from heat buildup due to friction, or from material fatigue. When a tire is inflated to the point of explosion, the point of the failure is either the bead or the center of the tread area. Baker also added that, because of the angles and other variables involved in winding the body cords, it is mathematically very difficult to ascertain the failure point of a tire sidewall.

Baker is sending us a letter recapitulating this data.

PJD:mlk