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HS-805-029

COMPARISON OF PRE AND POST ROAD TEST ULTRASONIC INSPECTION RESULTS ON 134 PASSENGER TIRES

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Cambridge MA 02142

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FINAL REPORT

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NOTICE

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16. Abstract

A study was conducted to compare ultrasonic inspection data from 134 tires prior and subsequent to road tests in order to determine whether excessive tread wear could be related to characteristics detected by the ultrasonic inspection. Analysis of data on all tires after road test resulted in the finding that nine of the tires exhibited substantial changes which may be related to abnormal tread wear.

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PREFACE

The work described herein was accomplished with the cooperation of W. J. Woehrle of UNIROYAL Inc., Detroit, Michigan and H. Meyer of Gummi-Meyer GMBH of Aachen, West Germany.

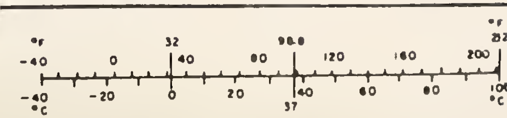
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION AND SUMMARY

The principal objective of the study reported here was to compare data from 134 tires prior to and subsequent to road tests, in order to determine whether excessive tread wear could be related to characteristics detected by ultrasonic inspection.

The tires inspected by ultrasonics (described in Section 2), were road tested in accordance with a procedure described in Reference 1, were re-inspected ultrasonically and the two ultrasonic data sets were compared. The findings of this comparative analysis were that nine tires exhibited substantial changes in the ultrasonic data.

2. DESCRIPTION OF EQUIPMENT

Tire inspection by reflection ultrasound utilizes narrow band pulses of acoustic energy,(1) coupled to the tire by a water envelope.(2) The tire-handling part of the system used for this investigation is shown in Figure 2-1. It consists of a rotatable spider with three arms. On each arm, when in the vertical position out of the water, a tire can be mounted and inflated. The arm is then moved 120° into the inspection position where it is rotated through an array of transducers, shown in Figure 2-2 (shown out of the water for clarity). The inspection scan requires about 20 seconds after which the tire is returned to the vertical position deflated, removed, and replaced by another tire for inspection. Transducers are independently adjustable to ensure that the ultrasonic energy flux is perpendicular to the laminar structure of the tire. For a group of similar tires, the adjustment is carried out manually under water and requires about 30 minutes. No further adjustment is required for a sequence of similar tires from the same manufacturer. The location of transducers around a typical tire is shown in Figure 2-3. Figure 2-4 is a printout of the display produced by the inspection system. Along the horizontal axis of the display, there are twenty channels of information, one from each transducer. Channels designated 2 - 6 cover the serial number sidewall, channels 7 - 9, one shoulder, channels 10 - 13 the tread center, channels 14 - 16 the other shoulder, and channels 17 - 21 the other sidewall. The vertical axis of the display represents the 360° clockwise rotation of the tire when viewed from the serial-number side, with 0° at the top, 180° half-way down and 360° at the bottom.

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(1) Feasibility of High Resolution Pulse-Echo Techniques for Automobile Tire Inspection, Ryan, R.P., June 1973, DOT-TSC-NHTSA-72-11, U.S. Department of Transportation, Interim Report.

(2) A Semi-Automated Pulse-Echo Ultrasonic System for Inspecting Tires, Ryan, R.P., July 1977, Interim Report, DOT-TSC-NHTSA-76-3 U.S. Department of Transportation .

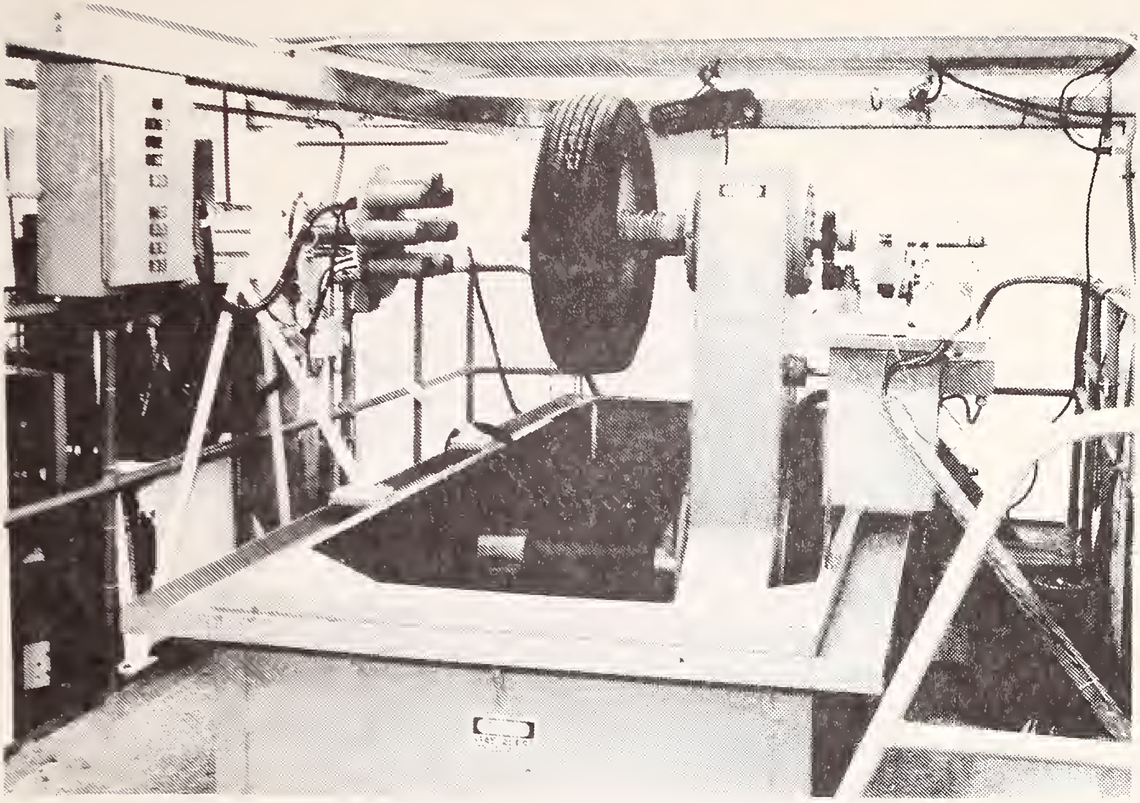


FIGURE 2-1. ULTRASONIC INSPECTION SYSTEM

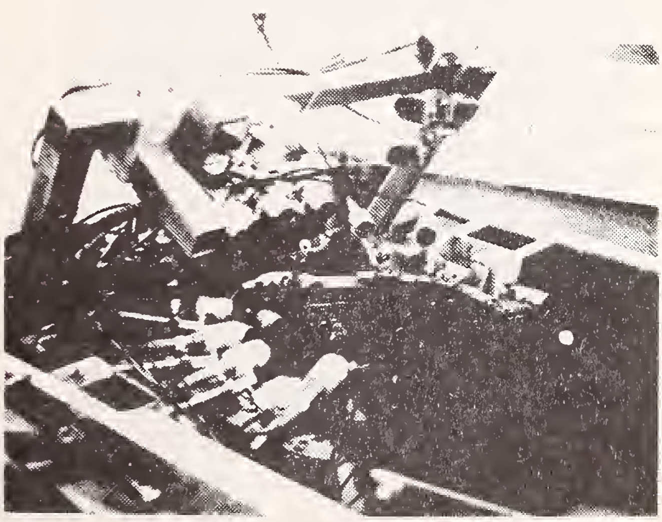


FIGURE 2-2. TRANSDUCER ARRAY

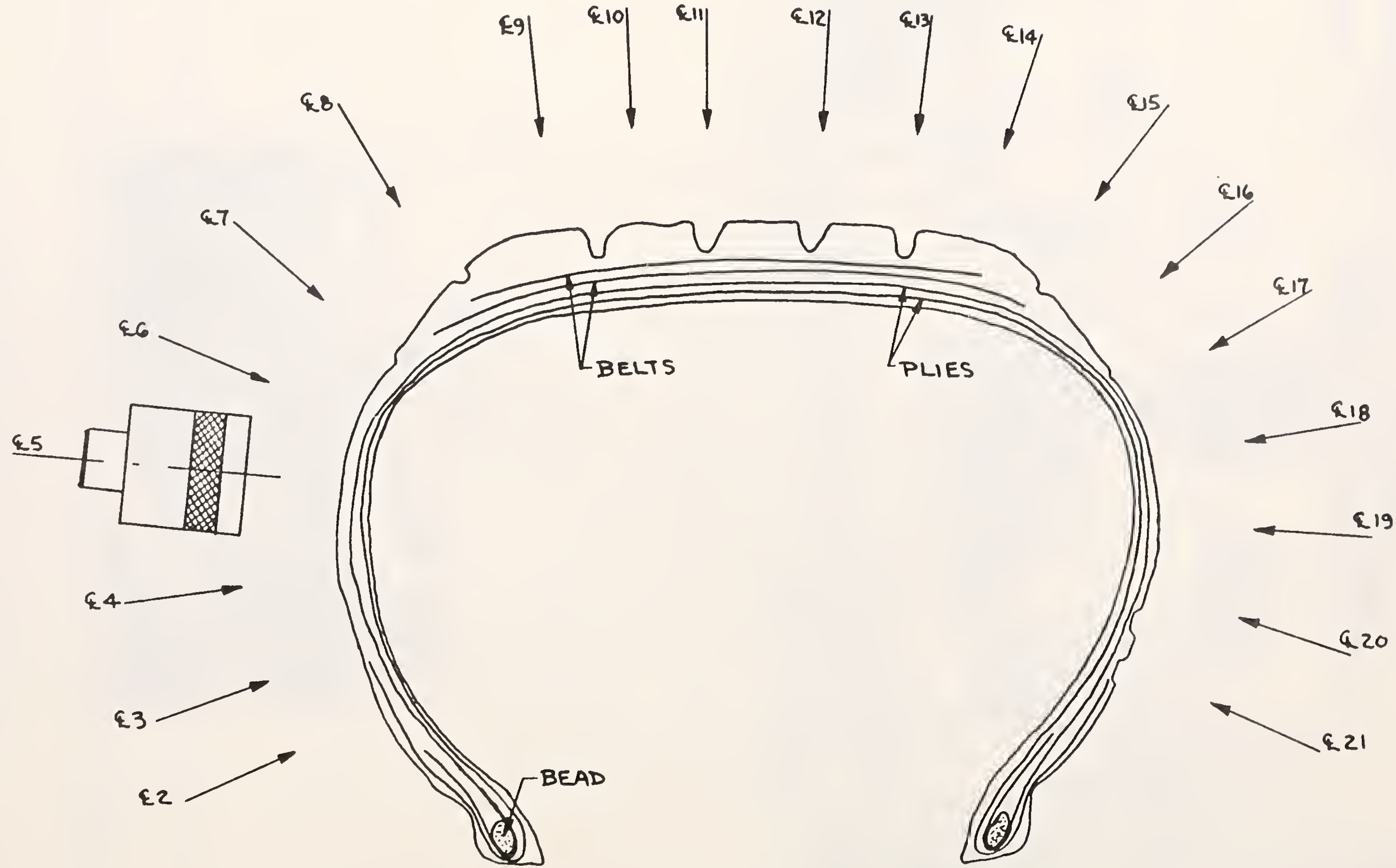


FIGURE 2-3. TRANSDUCER LOCATIONS

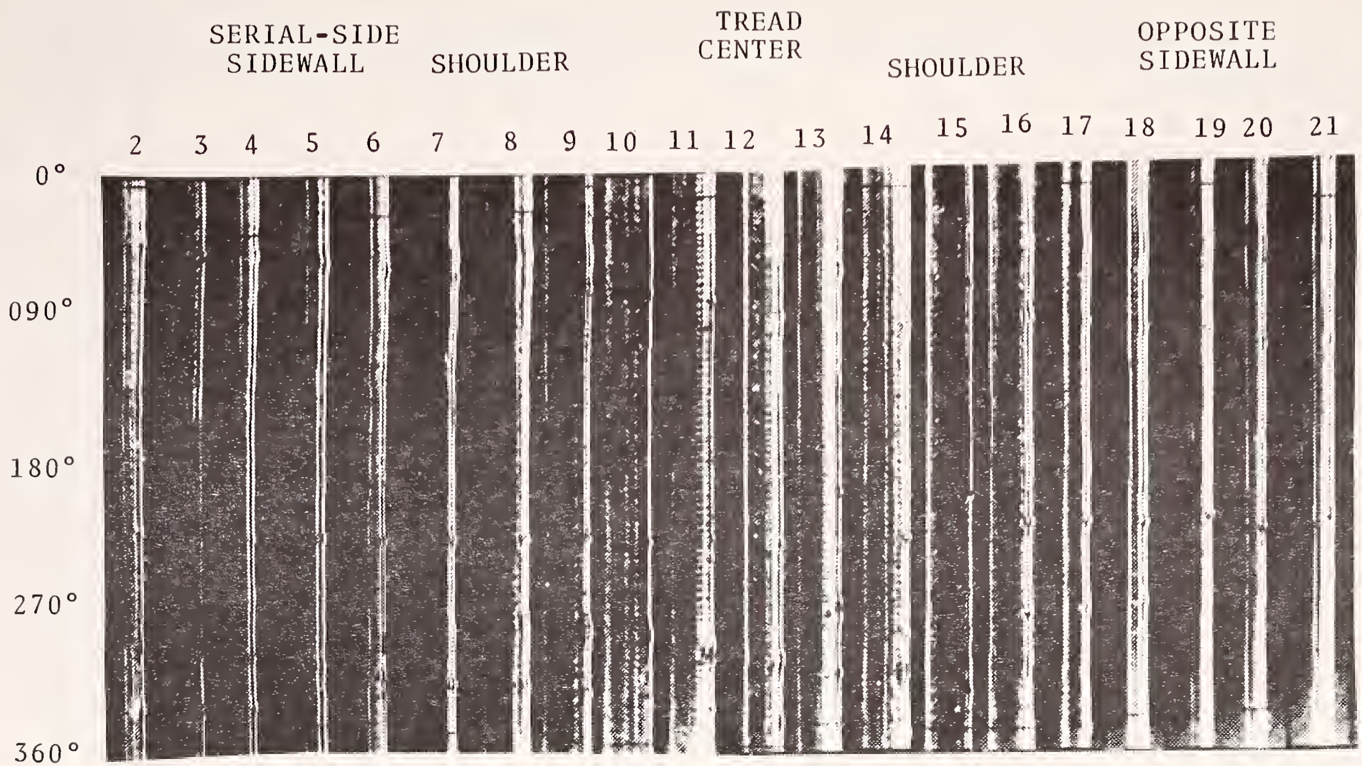


FIGURE 2-4. ULTRASONIC TIRE SCAN DISPLAY

3. PROCEDURE FOR ANALYSIS OF NONDESTRUCTIVE INSPECTION DATA

The analysis of the printouts was performed by individuals trained in data interpretation but having no knowledge of tire technology. A form (Figure 3-1) was then completed for each tire in the population. It lists the identification number, manufacturer, construction, ply material, and belt material. Across the top of the form, numbers 2 to 21 correspond to the 20 transducer channels on the printout. On the right side of the form are ten inspection criteria. Some of these criteria apply to individual channels, others apply to combinations of channels. A whole-number scoring value from 1 = poor to 9 = excellent is entered into the appropriate blocks by the evaluator. The inspection criteria and transducer channels to which they apply are defined below:

Data Quality (combination of all channels)

Degree of clarity and focus of traces, black and white detail and gray shades (good quality - Figure 3-2; poor quality, Figure 3-3).

Registration (combination of all channels)

The line-up accuracy of the 20 data channels. The complete printout consists of two pages placed side by side, channels 2 - 11 on the first page, channels 12 - 21 on the second page (Figure 3-4). $\theta = 0^{\circ}$ location is different on the two traces, thereby preventing superposition for comparison purposes (poor registration).

Turnup Modulation (channels 2 and 21)

Abrupt brightness change (Figure 3-5). It is caused by overlapping or separation of material near the tire beads.

Inclusion (all channels)

A reflection from several depths and generally present in more than one channel (Figure 3-6), not be confused with a single trace separation or fading of a trace. It is caused by a hole or foreign material in the tire structure.

TIRE NO.: CONSTRUCTION: BELT MATERIAL:

MANUFACTURER: PLY MATERIAL:

— CHANNELS —																				
2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	CHARACTERISTIC
																				TURNUP MODULATION CHANNELS 2&21
																				INCLUSIONS
																				SINGULARITY SHADOW
																				RADIAL RUNOUT CHANNEL 10
																				LATERAL RUNOUT CHANNELS 5&18
																				INTENSITY CHANGE
																				TRACE DISCONTINUITY
																				SHAPE DISCONTINUITY

DATA QUALITY	REGIS-TRATION	TREAD	BELTS	SIDEWALL	CARCASS	COMMENTS:

FIGURE 3-1. SCORING FORM

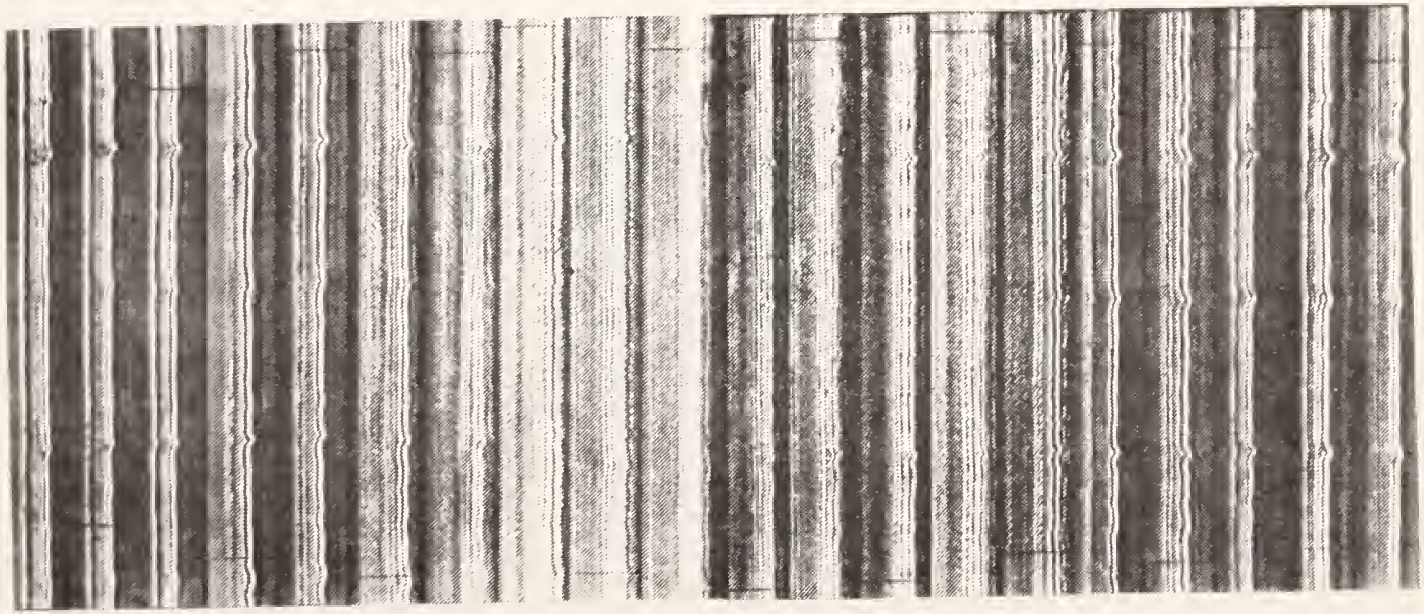


FIGURE 3-2. HIGH QUALITY DATA PRINTOUT

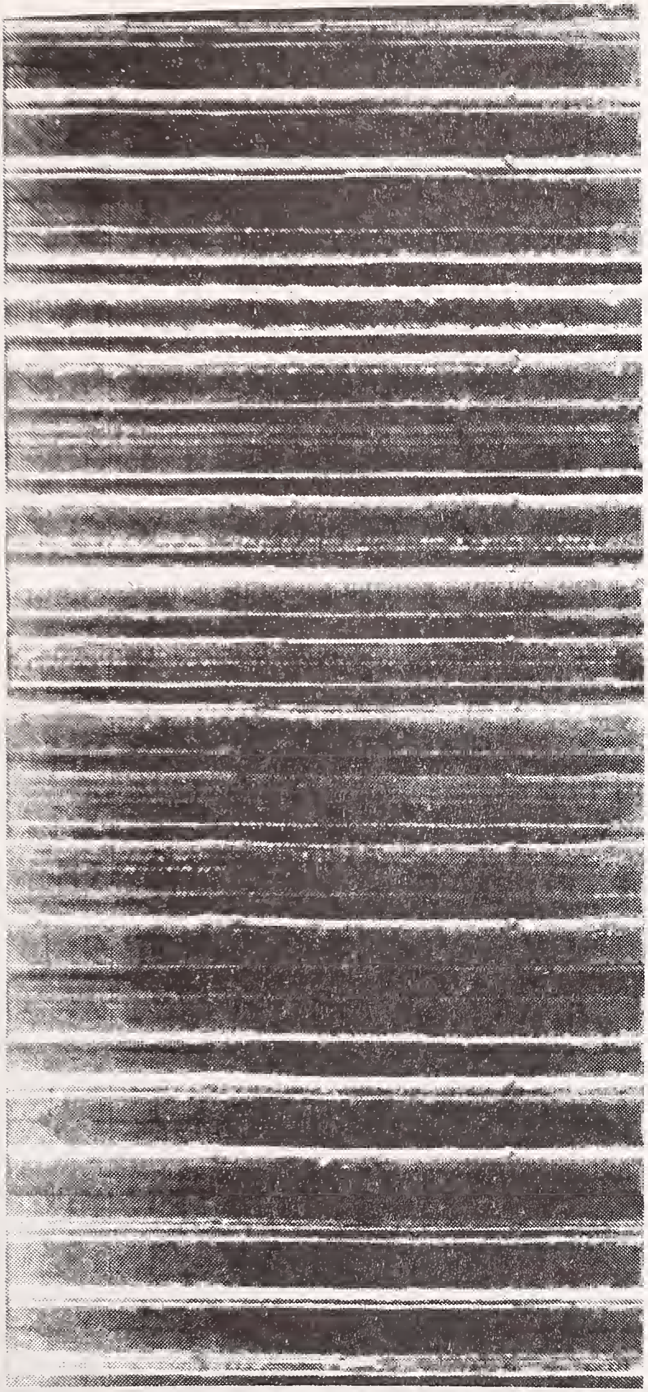


FIGURE 3-3. POOR QUALITY DATA PRINTOUT

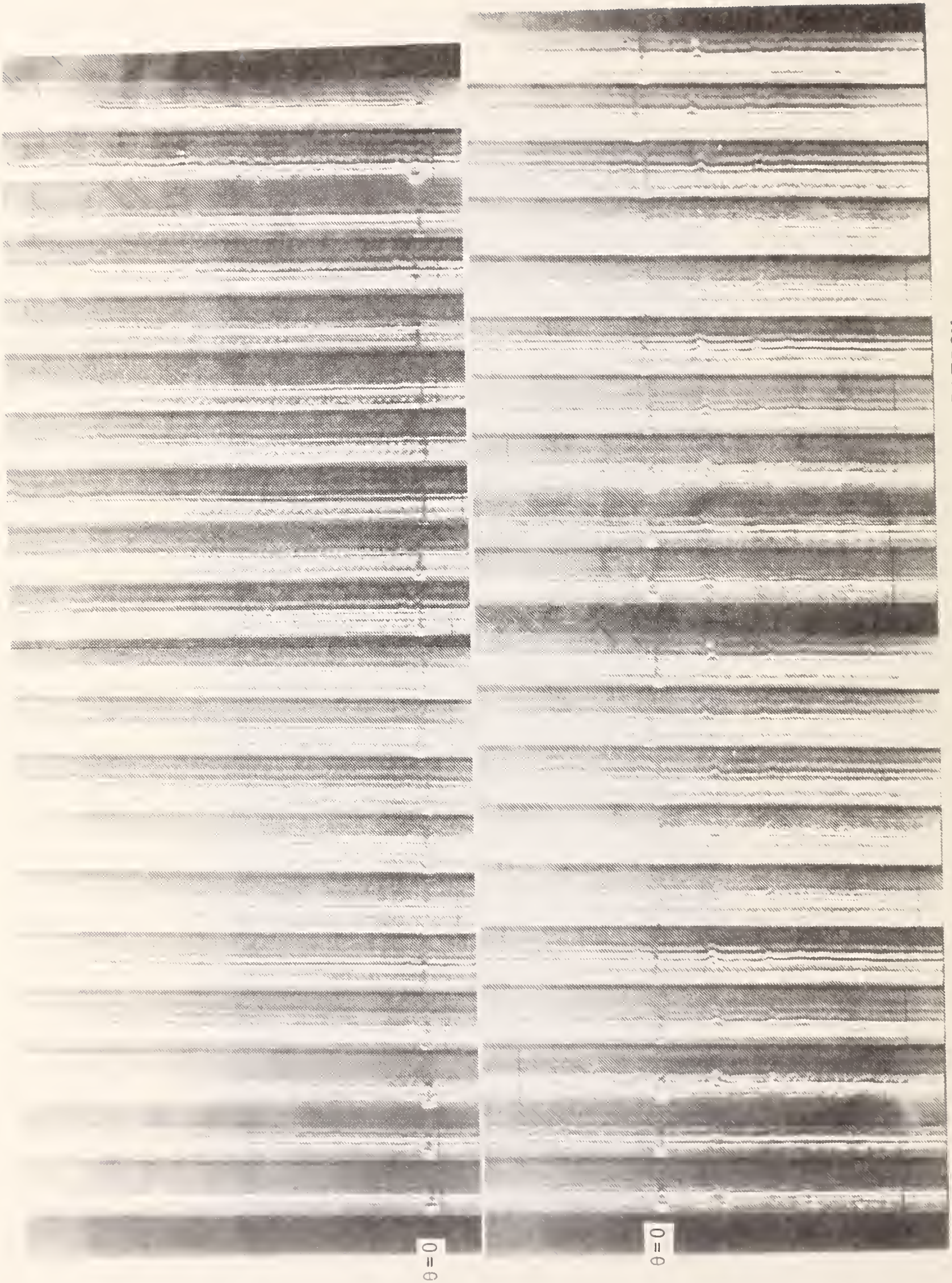
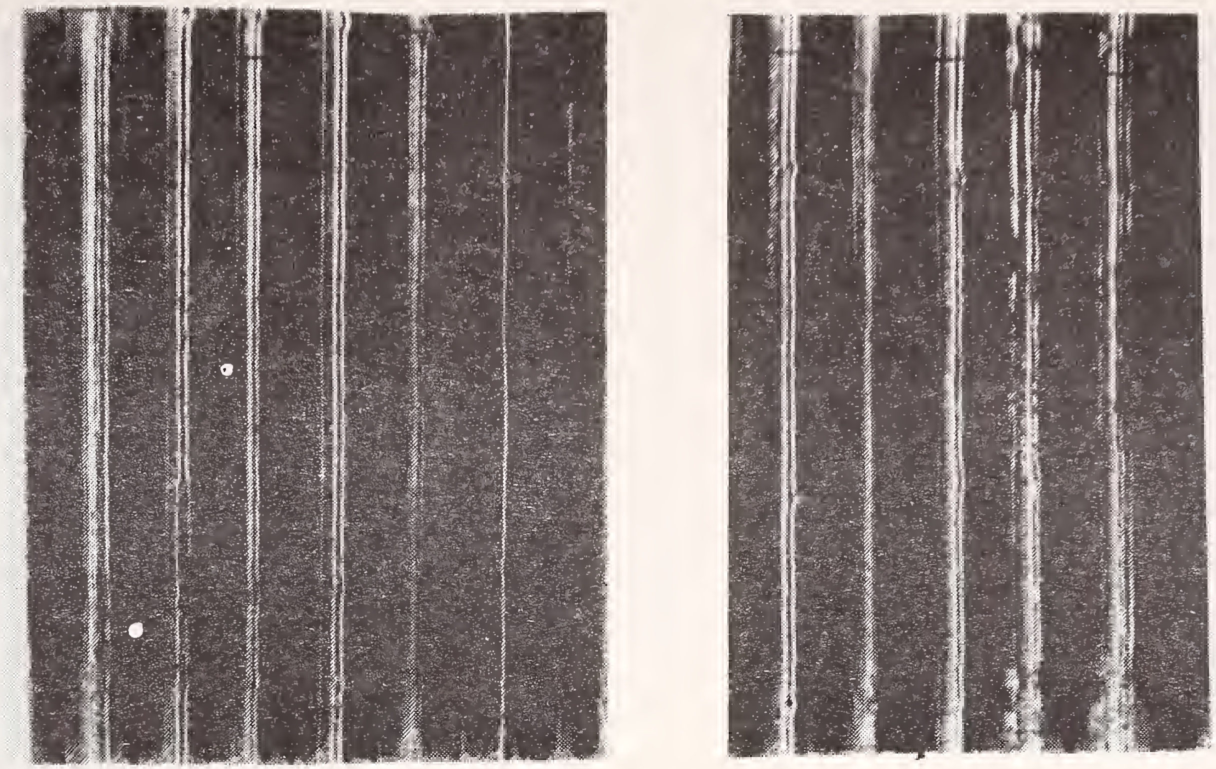


FIGURE 3-4. EXAMPLE OF POOR REGISTRATION



LITTLE OR NO
TURNUP MODULATION

SEVERE TURNUP
MODULATION

FIGURE 3-5. TURN-UP AREA

FIGURE 3-6. EXAMPLE OF INCLUSION

Singularity/Shadow (all channels)

A bright spot adjacent to a shadow (Figure 3-7). It is caused by a separation or other discontinuity.

Radial Runout (channel 10)

Skewed or wavy trace (Figure 3-8). Caused by "out of roundness": the resulting "high spot" passes closer to transducer #10 than the remainder of the tire scanned in Channel #10.

Lateral Runout (channels 5 and 18)

Wavy trace (Figure 3-9). Caused by a change in tire width.

Intensity Change

Abrupt brightness change (Figure 3-10). Caused by a change of material thickness.

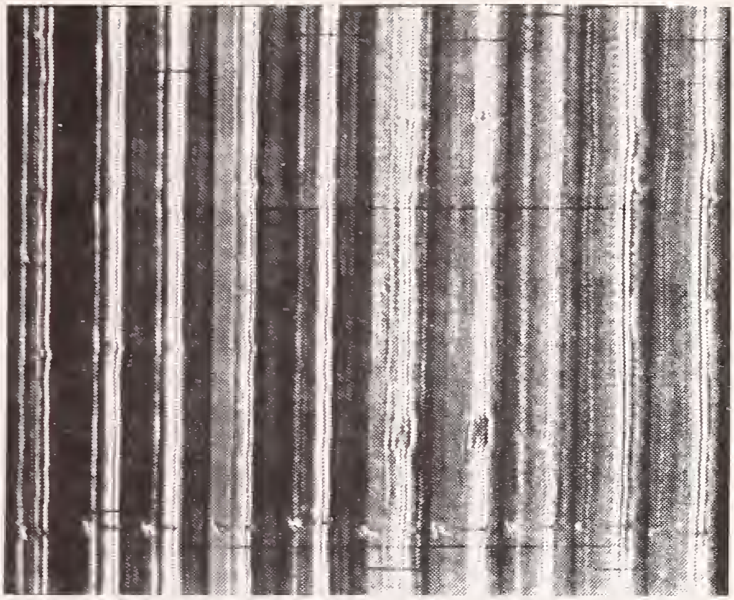


FIGURE 3-7. EXAMPLE OF SINGULARITY/SHADOW

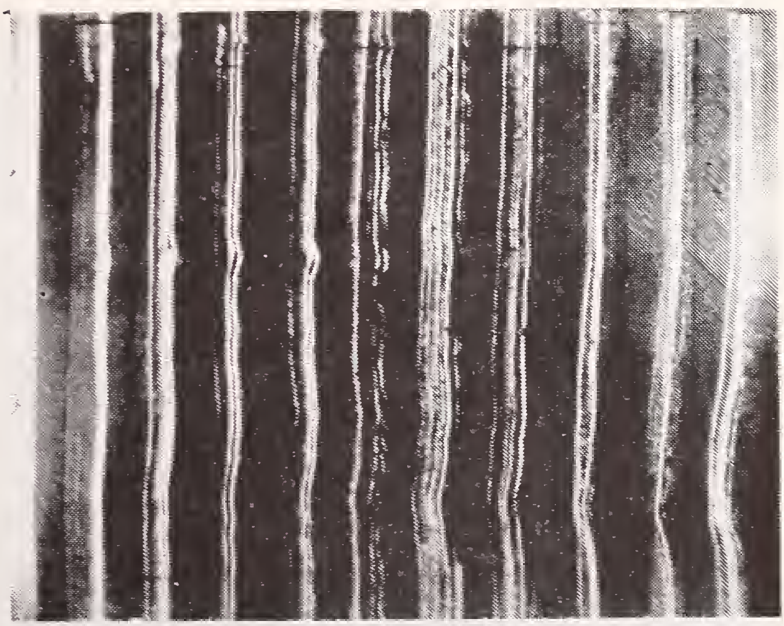
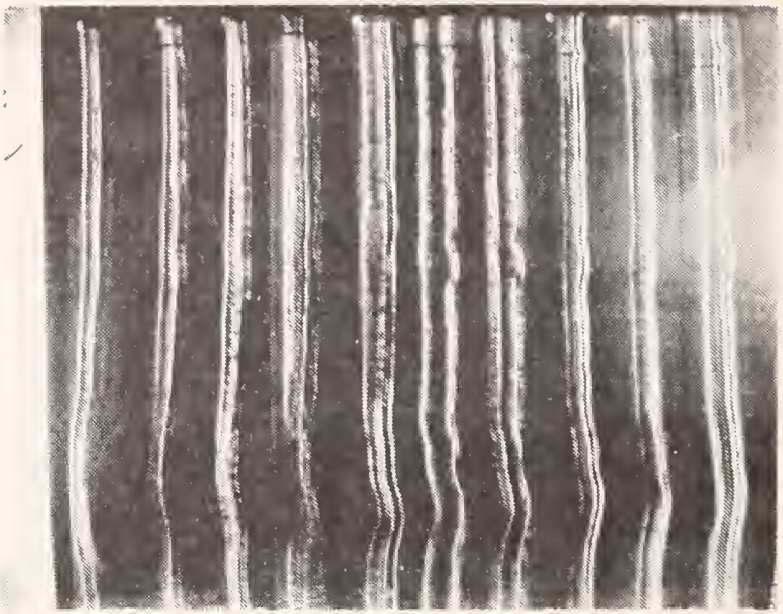


FIGURE 3-8. RADIAL RUNOUT



12 18

FIGURE 3-9. LATERAL RUNOUT

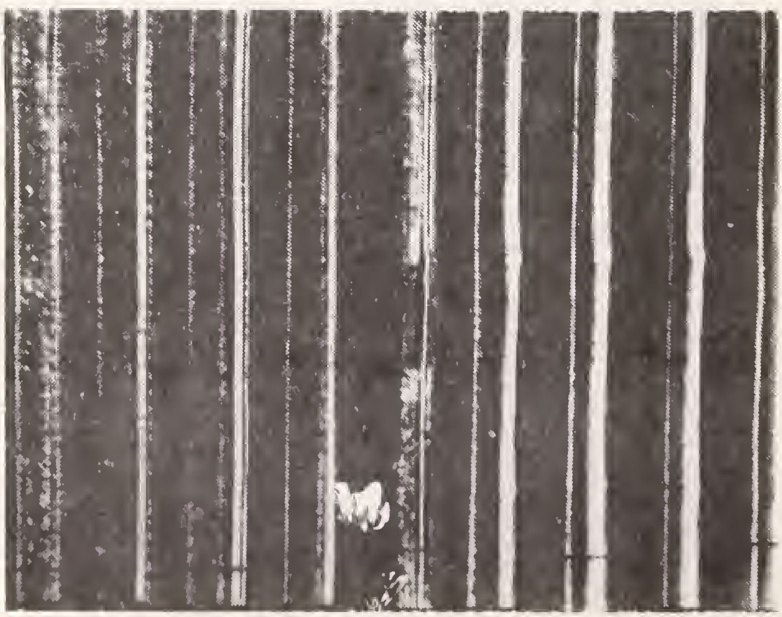


FIGURE 3-10. INTENSITY CHANGE

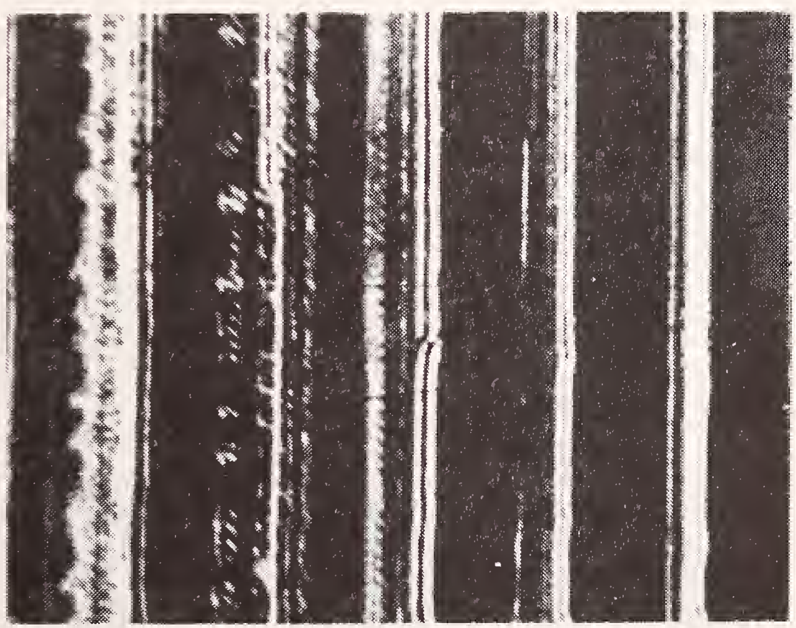
Trace Discontinuity (all channels)

Interruption of a trace (Figure 3-11); not to be confused with an inclusion which is usually indicated in more than one channel. It is caused by abnormal displacement of material.

Shape Discontinuity (all channels)

Abrupt change of shape of trace (Figure 3-12). It is caused by excess of material or distorted ply structure.

The scores for tread, belts, sidewall, and carcass are derived from the above inspection criteria, taking all factors known about the tire into account. An experienced tire inspector can readily be trained for this task.



17

FIGURE 3-11. TRACE DISCOUNTINUITY

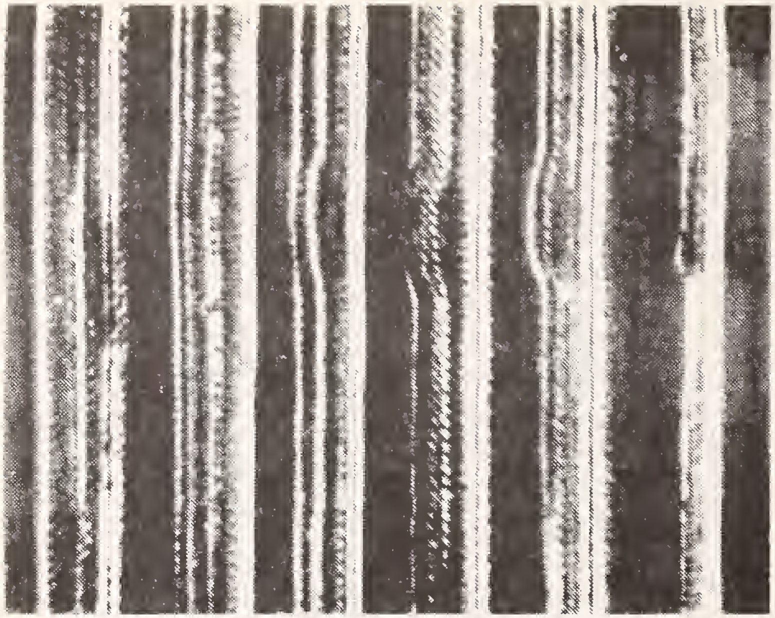


FIGURE 3-12. SHAPE DISCONTINUITY

4. TIRE DESCRIPTION

Name	Quantity	Construction	Size
Goodrich Custom Long Miler	21	2 Polyester and 2 Glass	H78-15
Uniroyal Tiger Paw	21	4 Ply Polyester	H78-15
Firestone Radial "500"	21	2 Polyester and 2 Steel	HR78-15
Cooper Lifeliner "78"	21	2 Polyester and 2 Glass	H78-15
Goodyear Power Cushion 78	21	4 Ply Polyester	H78-15
Goodyear Poly-steel Radial	29	2 Polyester and 2 Steel	HR78-15

5. SUMMARY OF COMPARATIVE ANALYSIS

The printouts from nondestructive inspection before and after road test were compared on a side by side basis. Of the 6 groups tested 9 tires revealed considerable degradations. Other tires in the groups showed some minor changes.

Five of the nine tires, (all Goodrich Custom Long Miler) developed Radial Runout or shape discontinuities in the sidewall. Shoulder variations were found in the remaining four tires. See Section 7 for a commentary describing degradations in each tire, along with possible cause.

The scores of the nine tires are given in Table 5-1.

Of the six groups investigated, 4 groups had only one tire which showed degradations; one group had five tires with degradations; one group had no degradation in any tire.

TABLE 5-1. LIST OF DEGRADED TIRES WITH SCORES BEFORE AND AFTER ROAD TEST

Name	Serial Number	SCORES Before T	B	S	C*	After T	B	S	C
Goodrich Custom Long Miler (Glass Belts)	T8X2119	9	8	7	8	7	6	7	7
	T8X2122	7	8	6	7	7	7	6	7
	T8X2123	7	7	7	7	7	7	7	7**
	T8X2124	8	8	7	8	6	7	7	7
	T8X2125	9	7	7	7	9	7	7	7**
Uniroyal Tiger Paw (4-Ply)	T7X2199	9	NA	6	7	6	NA	6	7
Firestone Radial "500" (Steel Belts)	T7X2236	8	7	7	8	6	7	7	8
Goodyear Power Cushion 78 (4-ply)	T8X2270	7	NA	6	5	7	NA	5	5
Goodyear Poly Steel Radial	T8X2302	9	9	8	8	7	8	7	7

* T - Tread
  B - Belts
  S - Sidewalls
  C - Carcass

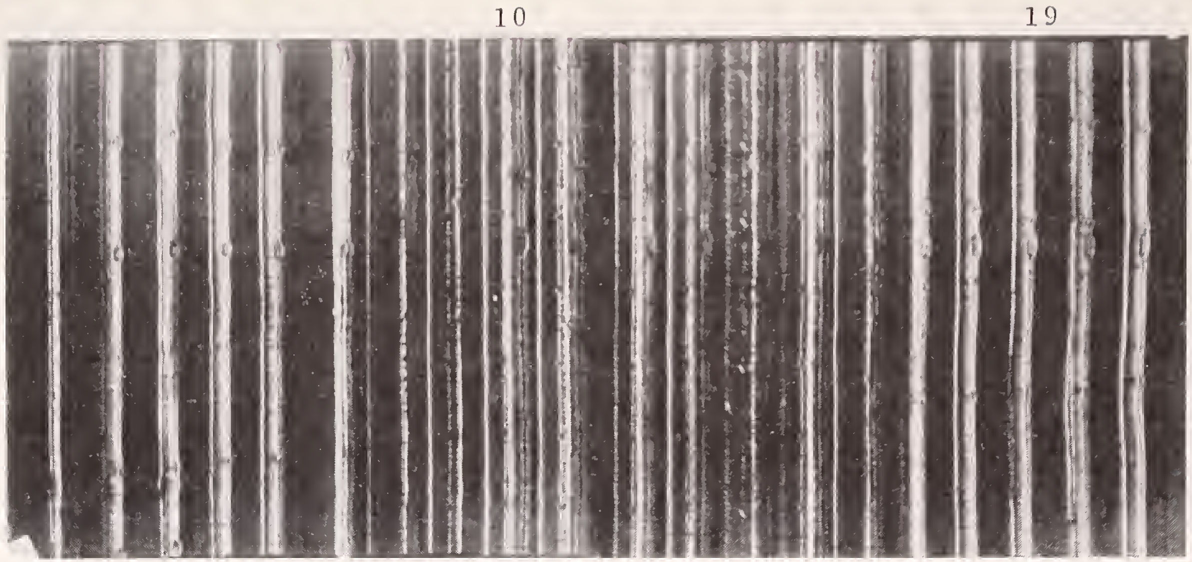
** For degradation, see Figures 7-3 and 7-5.

6. ANNOTATED HARD COPY PRINTOUTS

Figures 6-1 through 6-9 are copies of the primary hardcopy ultrasonic data. The upper image was obtained before the road test and the lower after road test. The titles explain conditions observed in the tires.

T8X
2119

BEFORE ROAD TEST



AFTER ROAD TEST

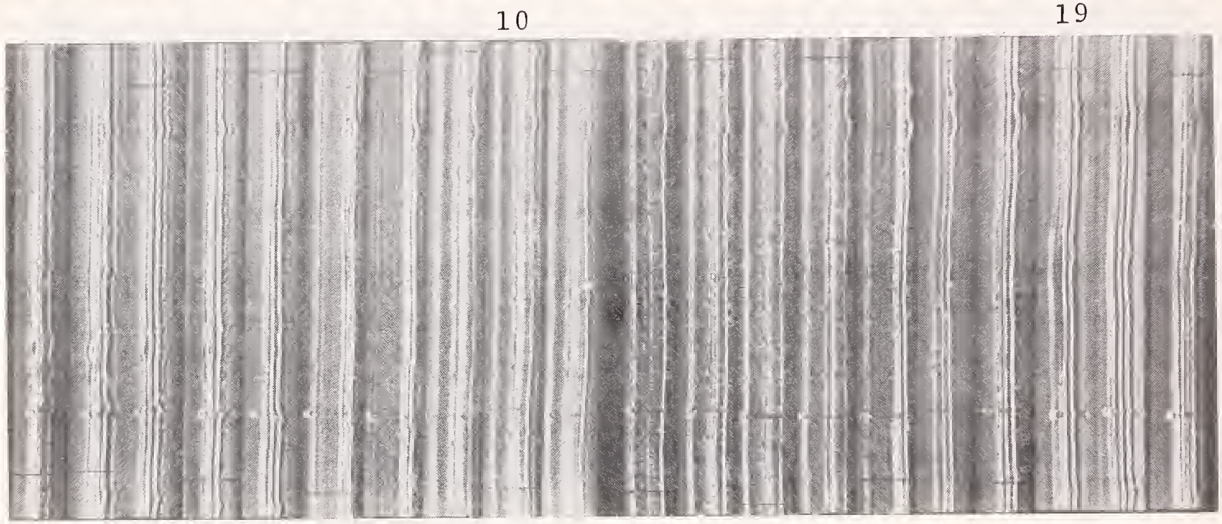


FIGURE 6-1. GOODRICH CUSTOM LONG-MILER —— RADIAL RUNOUT IN CHANNEL 10. IT DID NOT APPEAR BEFORE ROAD TEST. POSSIBLE SEPARATION ? CHANNEL 19 ALSO HAS SOME SHAPE DISCONTINUITY, BULGING OF OUTER SURFACE. DOES NOT APPEAR IN NEIGHBORING CHANNELS. POSSIBILITY OF EXCESS RUBBER.

T8X
2122

BEFORE ROAD TEST

AFTER ROAD TEST

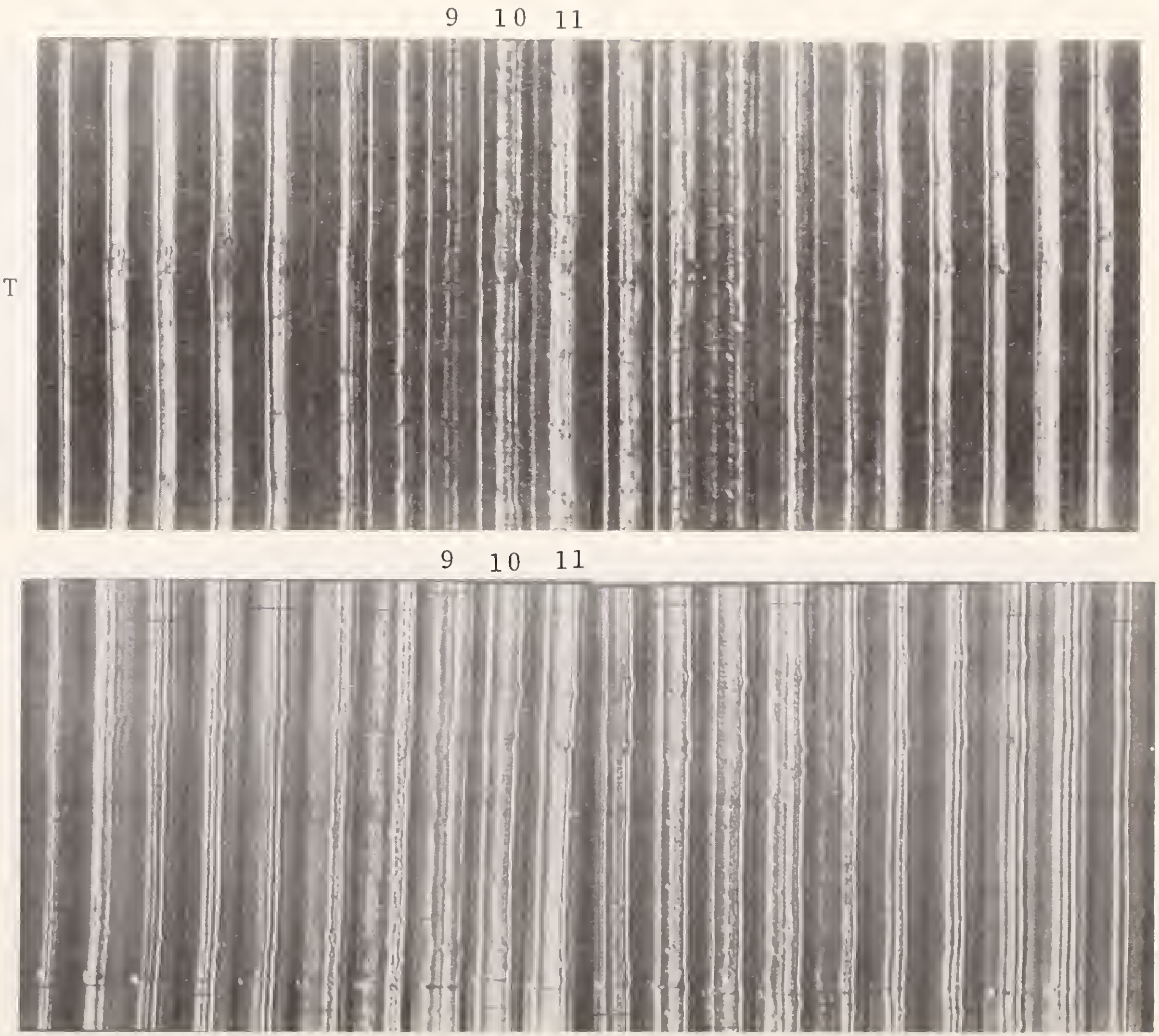
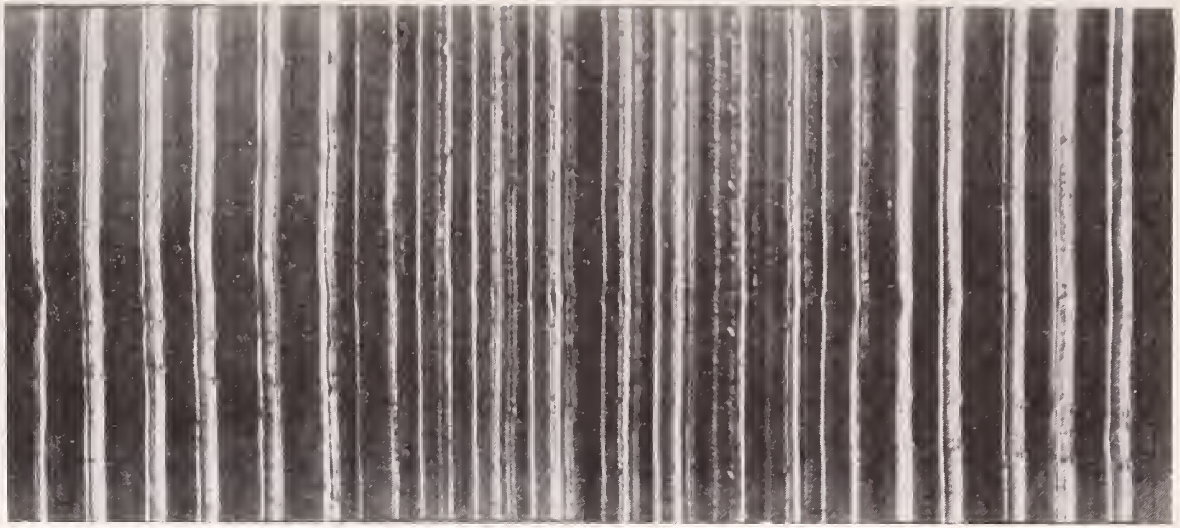


FIGURE 6-2. GOODRICH CUSTOM LONG-MILER —— APPARENT TREADWEAR IN SHOULDER AREA. DARK LINER TRACES IN CHANNEL 9 ARE SUSPICIOUS. PELTS SEEM TO HAVE SHIFTED SLIGHTLY IN CHANNELS 9,10, and 11.

T8X
2123

BEFORE ROAD TEST



AFTER ROAD TEST

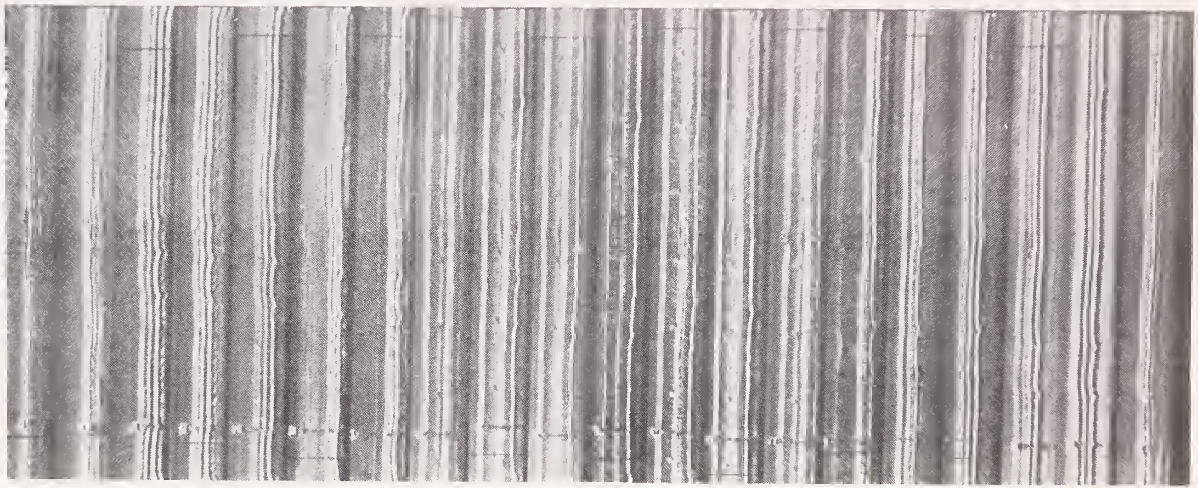
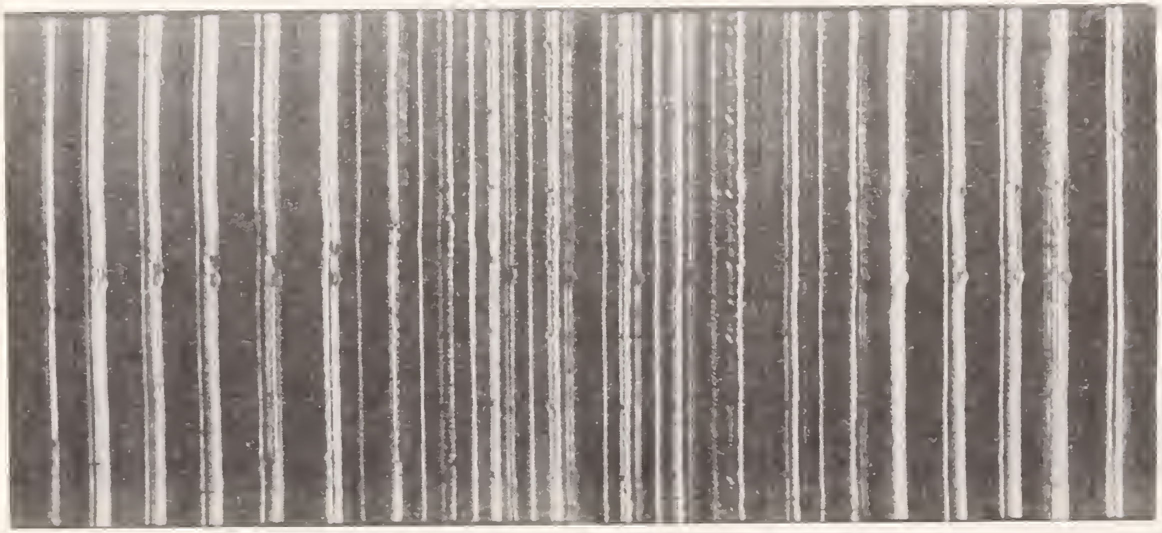


FIGURE 6-3. GOODRICH CUSTOM LONG-MILER —— SOME TREAD MODULATION; MAY OR MAY NOT BE SERIOUS. BELTS ARE NOT EVEN, SOME LATERAL RUNOUT INDICATED.

T8X
2124

8 9

BEFORE ROAD TEST



8 9

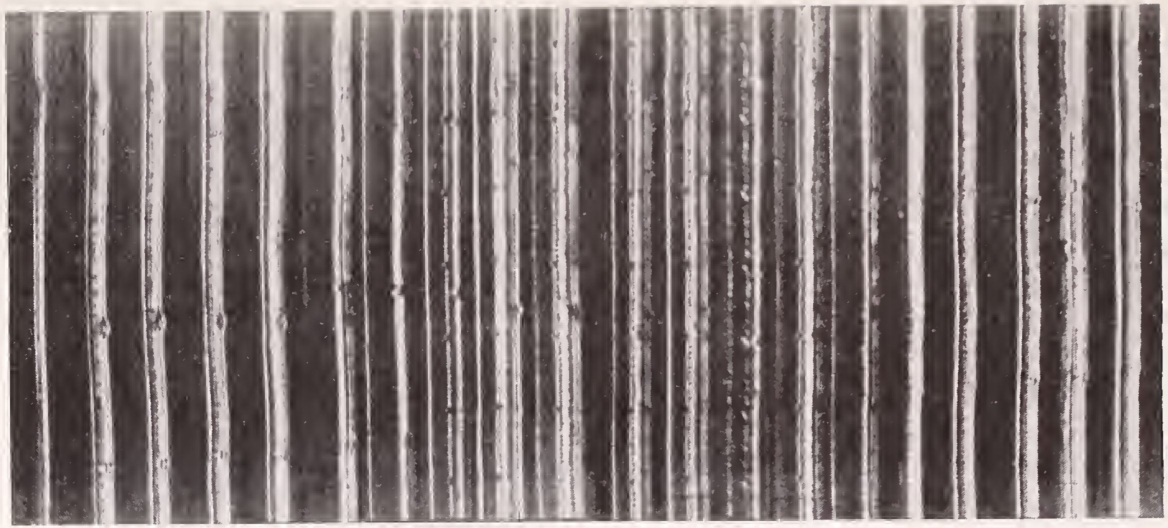
AFTER ROAD TEST

FIGURE 6-4. GOODRICH CUSTOM LONG-MILER —— HEAVY SPLICE IN CHANNELS 8&9 CAUSING BULGING EFFECT ON SURFACE OF SHOULDER. THIS CAUSES OUT-OF-ROUNDNESS AND IRREGULAR WEAR. SPLICE APPEARS TO BE MORE SEPARATED AFTER ROAD TEST.

T8X
2125

BEFORE ROAD TEST

15



AFTER ROAD TEST

15

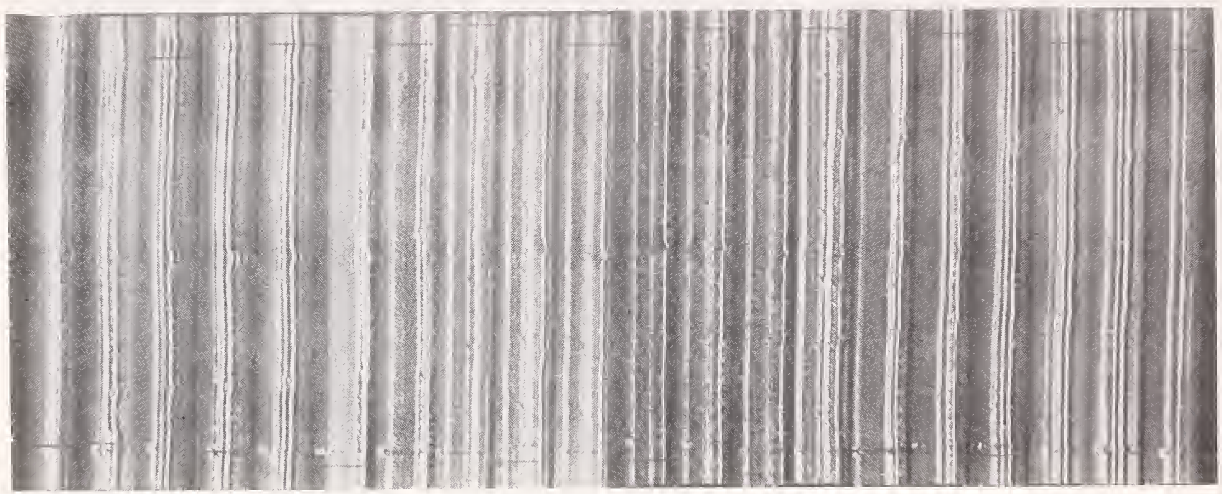
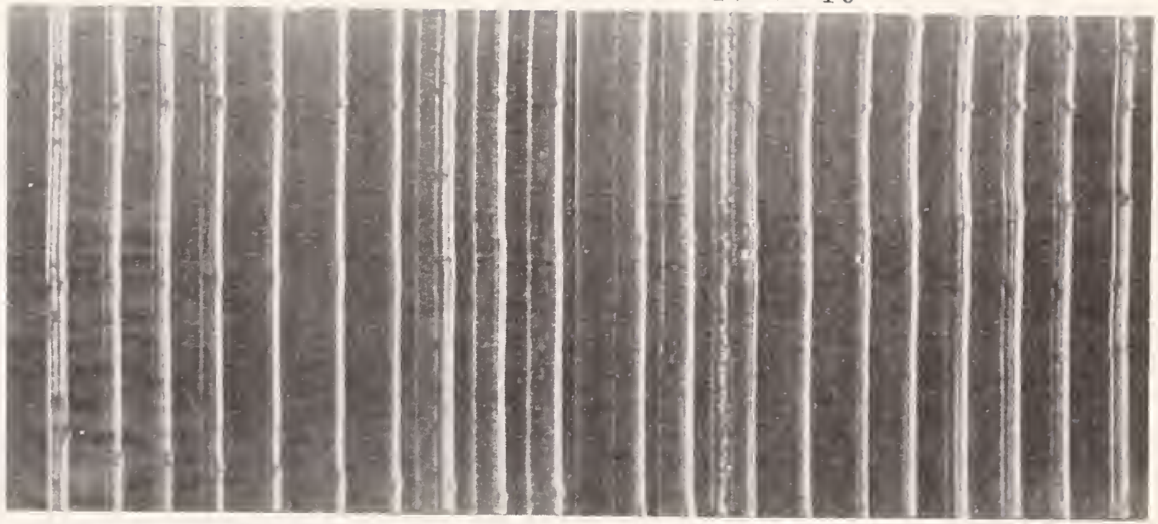


FIGURE 6-5. GOODRICH CUSTOM LONG-MILER —— BULGING OF OUTER SURFACE DUE TO BELT PROBLEM. BELTS IN CHANNEL 15 SEEM TO HAVE DISCONTINUITIES. WOULD SUSPECT A POSSIBLE SEPARATION TO BE PRESENT. UNEVEN BELT SPLICES ARE KNOWN TO CAUSE UNEVEN TREADWEAR.

T8X
2199

14 15 16

BEFORE POAD TEST



14 15 16

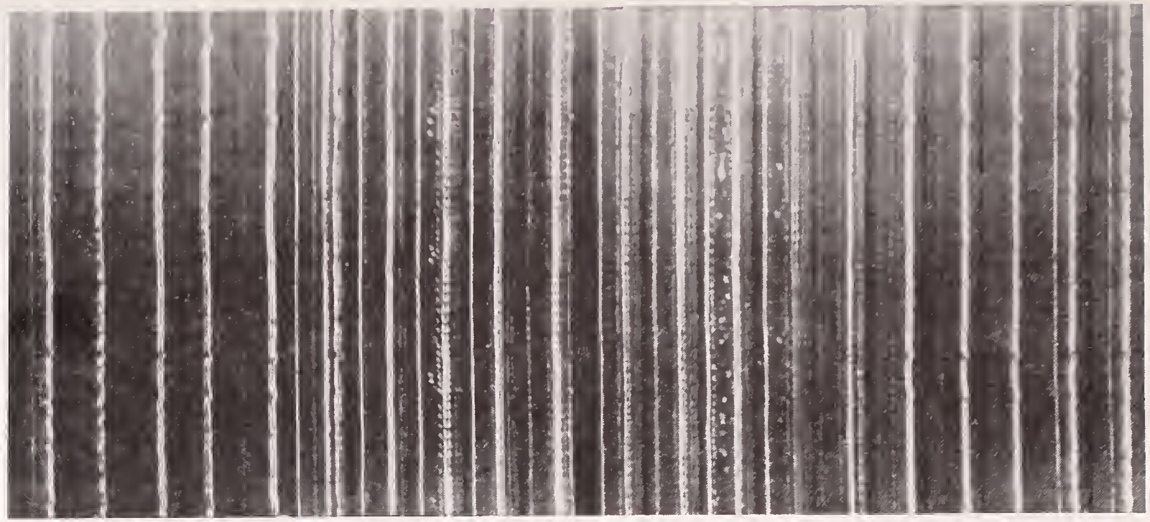
AFTER POAD TEST

FIGURE 6-6. UNIROYAL TIGER PAW INCLUSIONS OBSERVED IN CHANNELS 14 AND 16 BEFORE ROAD TEST ARE OBSERVED IN CHANNELS 15 AND 16 AFTER ROAD TESTS.

T8X
2236

BEFORE ROAD TEST

15 16



AFTER ROAD TEST

15 16

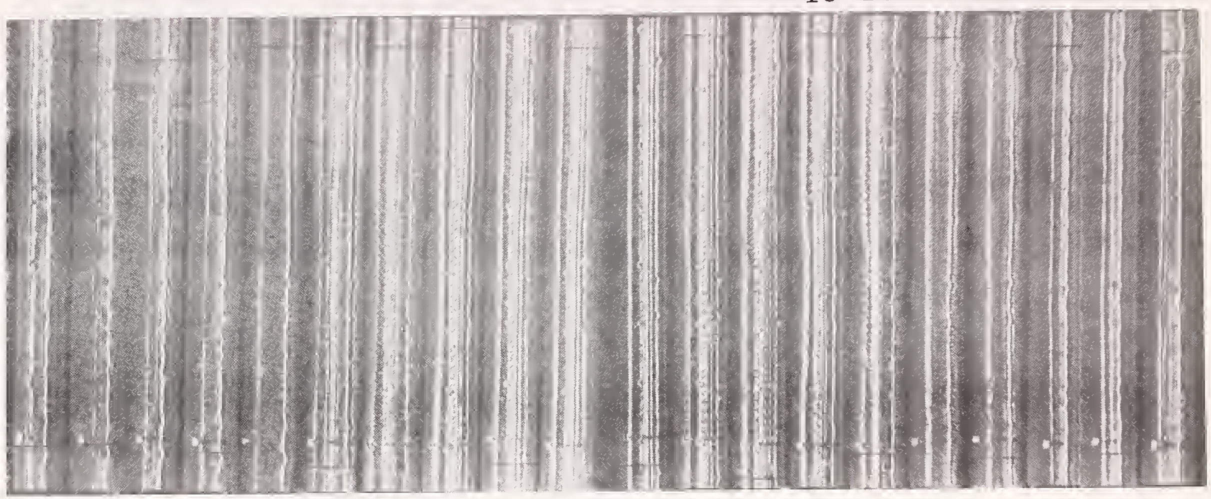
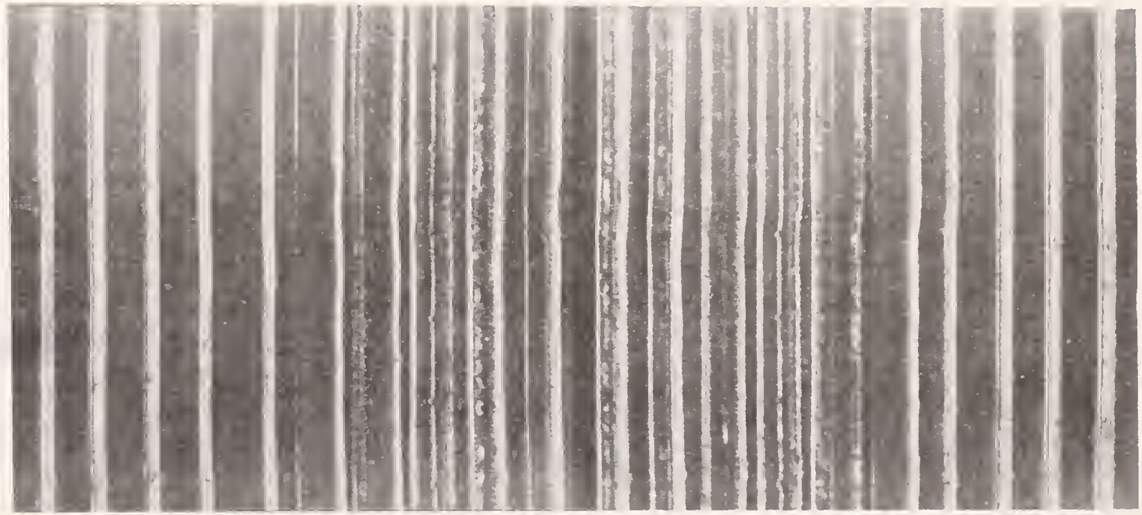


FIGURE 6-7. FIRESTONE #500 —— DEFINITE CHANGE IN SHAPE IN CHANNELS 15 and 16. NOTICEABLE TREADWEAR. CAUSE DOES NOT SEEM TO BE ASSOCIATED WITH BELTS OR INNER SURFACE.

T8X
2270

BEFORE ROAD TEST



AFTER ROAD TEST

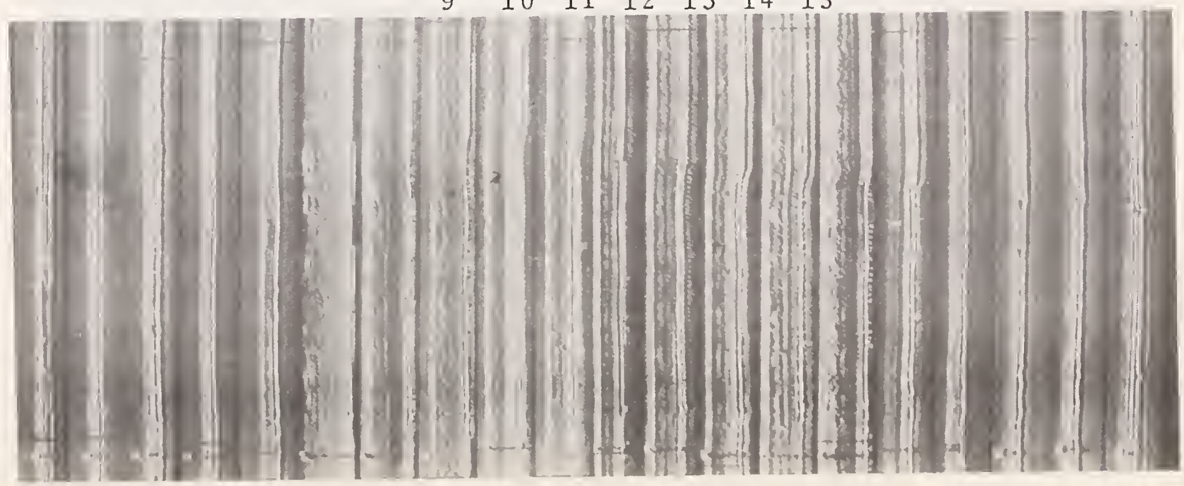
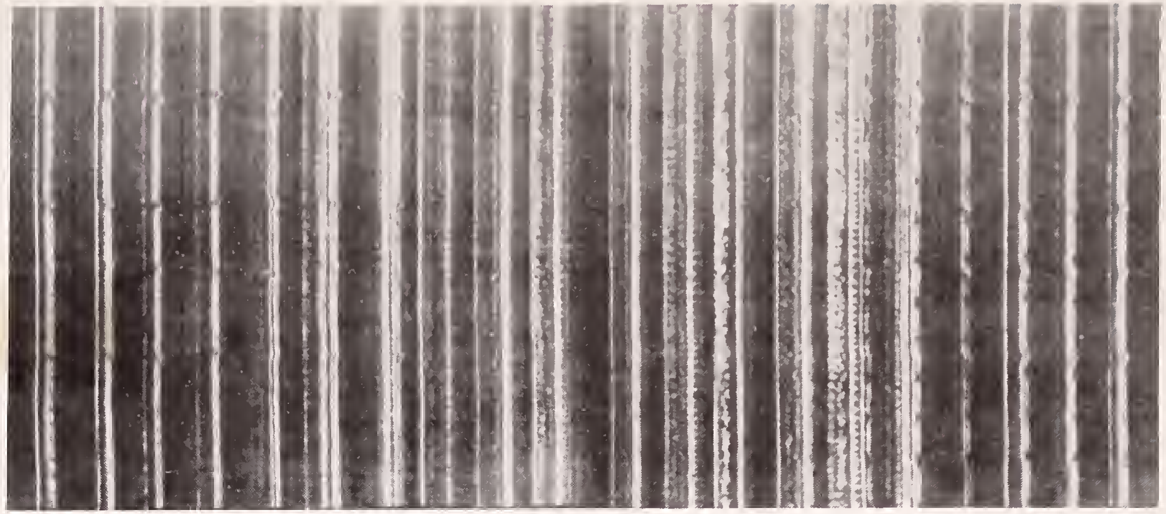


FIGURE 6-8. GOODYEAR POWER CUSHION 78 —— SEVERE RUNOUT (CHANNELS 9-15). CAUSES CIRCUMFERENTIAL OUT-OF-ROUNDNESS WHICH LEADS TO UNEVEN TREADWEAR.

T8X
2302

15

PEFORE ROAD TEST



15

AFTER ROAD TEST

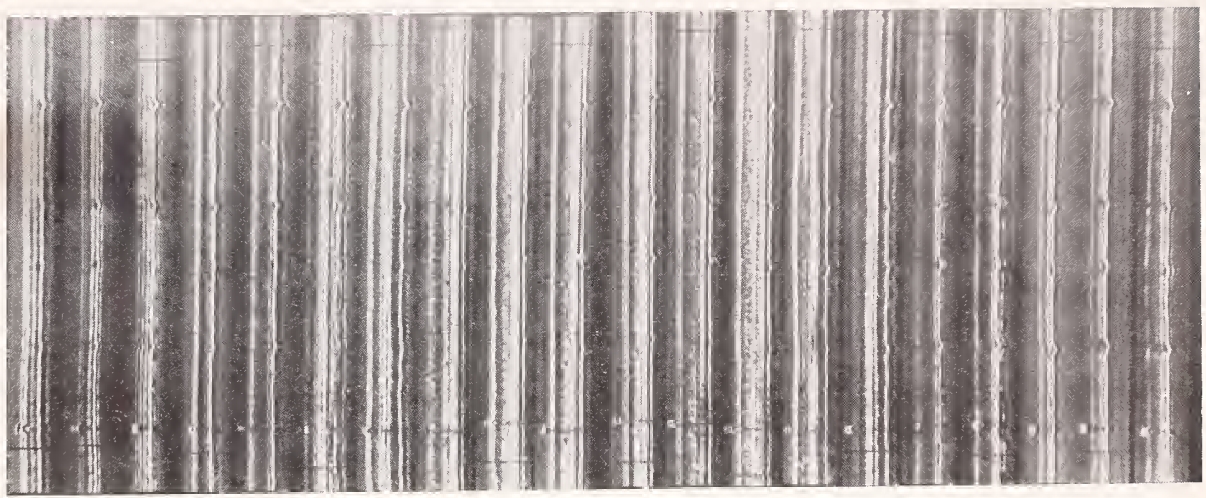


FIGURE 6-9. GOODYEAR POLY STEEL RADIAL—— CHANNEL 15 INDICATES SOME SHAPE DISCONTINUITY AFETR THE ROAD TEST. THIS WAS PROBABLY CAUSED BY A WEAK BOND BETWEEN TREAD AND CARCASS WHICH RESULTS IN HIGH SPOTS ON THE SURFACE.

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