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ULTRASONIC DETECTION OF OVERBUFFING IN RETREADED TIRES

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INTERIM REPORT

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16. Abstract

A study was performed to determine the feasibility of non-destructive inspection by the reflection ultrasound for damage from overbuffing of retreaded tires. Following the introduction, the report briefly describes the principles of the method. Then, the details of the study are discussed. In Part I, comparison of inspection for overbuffing of two tires by X-rays and reflection ultrasound conclusively showed that the latter technique was superior. In Part II, flaws of varying severity, deliberately introduced in six tires were identified by reflection ultrasound, positively in 24 instances and tentatively in the remainder. Subsequent X-ray inspection proved negative. The report ends with a brief section of conclusions and recommendations.

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PREFACE

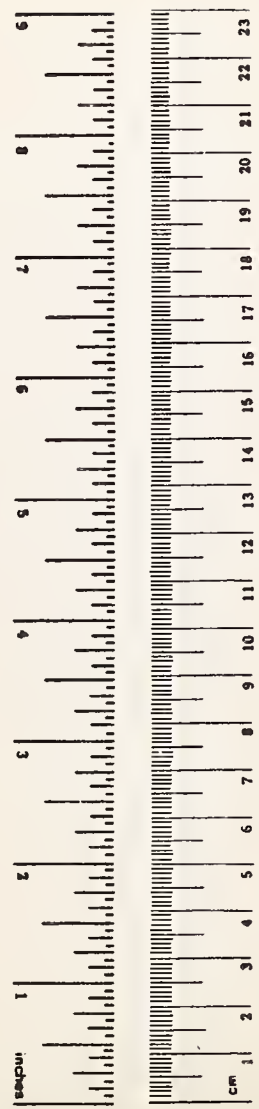
In the preparation of tires for retreading, a condition sometimes occurs where, in buffing off the remainder of the tread from the casing with a motorized rasp, the outer ply or belt layers are exposed or damaged. This is termed "overbuffing" and violates the provisions of FMVSS117.* To ensure compliance, NHTSA must inspect a population of tires from various retreaders throughout the country. Under the current inspection procedure, the tread layer is peeled back. This is destructive, time-consuming and costly.

*FMVSS117, "Retreated Pneumatic Tires--Passenger Cars."

METRIC CONVERSION FACTORS

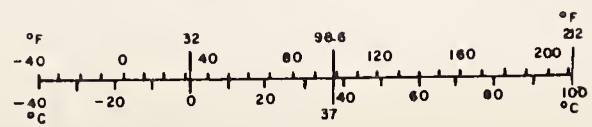
Approximate Conversions to Metric Measures

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



CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. DESCRIPTION OF THE METHOD

In tire inspection by reflection ultrasound, first demonstrated at TSC in 1975, narrow-band pulses of ultrasonic energy are coupled acoustically to a tire by a water envelope. This energy penetrates the tire and sends return reflections from lamina within the tire. The system in use at TSC is equipped with twenty-two transducers to obtain coverage of the complete tire. Reflection signals received at half-degree intervals from individual transponders during tire rotation are processed as two-dimensional channels. The complete display is a three-dimensional representation as shown in Figure 2.* Approximate location of the transducers is given in Table 1.

TABLE 1. LOCATION OF TRANSDUCERS WITH RESPECT TO THE TIRE

Transducers	Location
1	not used
2	Near Bead
3	Upper Sidewall Blackwall Side
4	Upper Sidewall Blackwall Side
5	Curb Strip Blackwall Side
6,7,8	Blackwall Shoulder
9	Tread
10	Tread Center
11,12	Tread
13,14,16	Whitewall Shoulder
15,17,18	Whitewall Shoulder
19	Whitewall Curb Strip
20	Whitewall Near Bead
21	not used
22	not used

* Figure 2 appears on page 6.

The vertical dimension of the figure represents rotation around the tire starting from the serial number at the top and continuing through 360 degrees of rotation at the bottom. Each of the twenty strips then contains information about the reflections within the tire. These reflections can be related to known tire characteristics. For example, the bumps (the lines of reflections in all channels between 180 and 270 degrees) represent splice systems within the tire plies. They are less apparent in the tread area (channels 9 through 17) but they exist. In channel 11, the evenly spaced gaps in one reflection line are tread-wear indicators at the groove bottom. Reflections from the lamina within a good tire are usually quite uniform and have a regular appearance. If, however, anomalies appear, this pattern breaks up and there is a definite disturbance in the orderly system of reflections from within the tire. It is this condition which occurs in over-buffed tires. Each bright line represents a reflection within the tire. However, when two lamina are close to one another, their reflections tend to interfere. Consider channel 14. The bright line on the left is the outer tread surface of the tire. The broken line slightly to the right of this and the dots within the area 3/8 inches to the right are all reflection patterns from the tread geometry. Alternate bright and dark lines then depict belts, ply layers and inner liner, successively. Sometimes the signals from adjacent plies interfere and the representation is not quite so straight-forward, but with a little experience one can become quite proficient at detecting anomalies within the structure of the tire.

The study was performed in two parts. Part 1 consisted of a demonstration of the superiority of ultrasound over x-ray in detecting severe buff-out of outer-ply layers on what was assumed to be the worst case from an inspection standpoint. Two bias tires were used. Part 2 was an attempt to establish the minimum degree of overbuff that could be detected on various tire types with reflection ultrasound. Six tires were used.

2. STUDY - PART I

Two tires were selected to demonstrate the feasibility of nondestructive inspection for overbuffing. Four-ply nylon tires were chosen as the worst case for two reasons; first, flaws in them are known to be difficult to detect with x-rays because of the low contrast between nylon and rubber; second, the rasp touch is not as destructive to the nylon ply system as it is to either glass, or steel, the other belt materials. In a four-ply bias tire, therefore, overbuff is the most difficult to detect by any means.

Figures 3 and 4 are photographs of tires 2312 and 2313 respectively. Tire 2312 was buffed with a rasp whose plane of rotation was parallel to the plane of the tire. Tire 2313 was buffed with a rasp whose plane of rotation was parallel to the tire axis with the rasp starting its cut on the left and leaving the tire on the right.

After buffing, the tires were retreaded by a reputable local manufacturer who used a conventional hot-cap process. The resulting tires had a very satisfactory appearance with no blow marks or blisters in the casing (usually seen where there is a series of separations within the tire lamina). The tires were then returned to TSC and a full inspection was made of the tires for the purposes of comparison of the nondestructive inspection results with the above photos.

Prior to ultrasonic inspection, the tires were inspected using the Picker X-ray system at TSC. As may be observed in the typical x-ray photograph (Figure 1 below), no pertinent information is readily available. Only a gradual dimming of the weave pattern in the fabric within the tire is dimly visible. All tires in this experiment were x-rayed but no cord overbuffing could be identified from x-ray display or from photographs, therefore photographs were not included. Next, ultrasonic inspection was performed. Figures 5 and 6 are ultrasonic images of the two

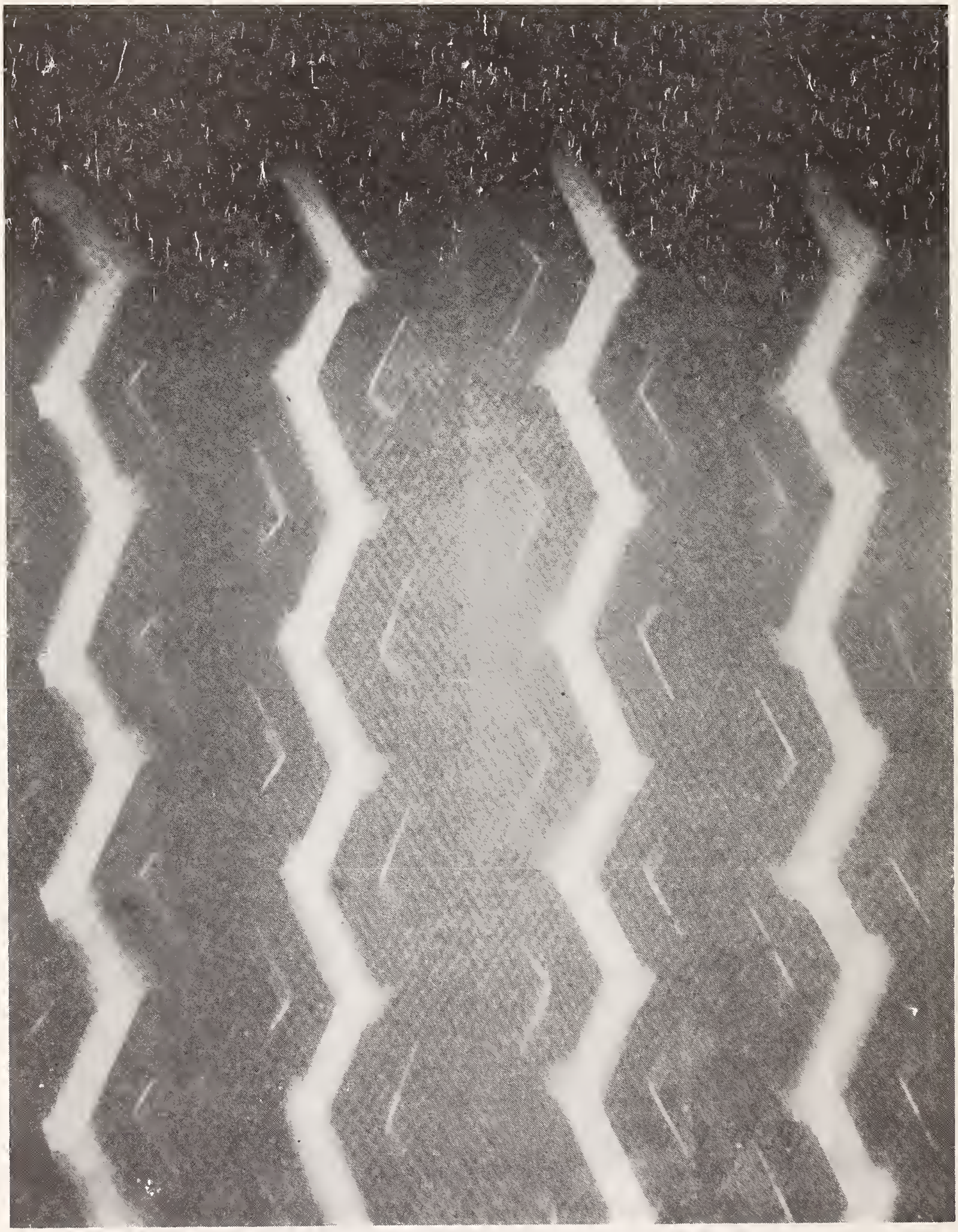


FIGURE 1. X-RAY OF TIRE SHOWING CORD STRUCTURE

biased-ply tires in question. Carefully observed, these images can show the extent and severity of the buffing damage. In Figure 5 (tire 2312), channel 11 shows an irregular pattern of damage starting at a rotation point of about 300 degrees and going to 30 degrees. Channel 12 shows a similar condition. Channel 13 was not aimed at the site of the damage and shows no flaw information. Channels 14, 15, and 16 show reflection systems of increasing severity and extent with severely reduced reflections from underlayers, always a clear signal that severe damage has occurred within the tire. In Figure 6 (Tire 2313), the damage is apparent in chanels 14, 15, 16, and 17, with extensive reflections at the outer ply surface running from 170 to 290 degrees.in rotational direction, with secondary disturbances in channel 16 completely around the tire. The disappearance of the reflected signal is even more apparent in this tire.

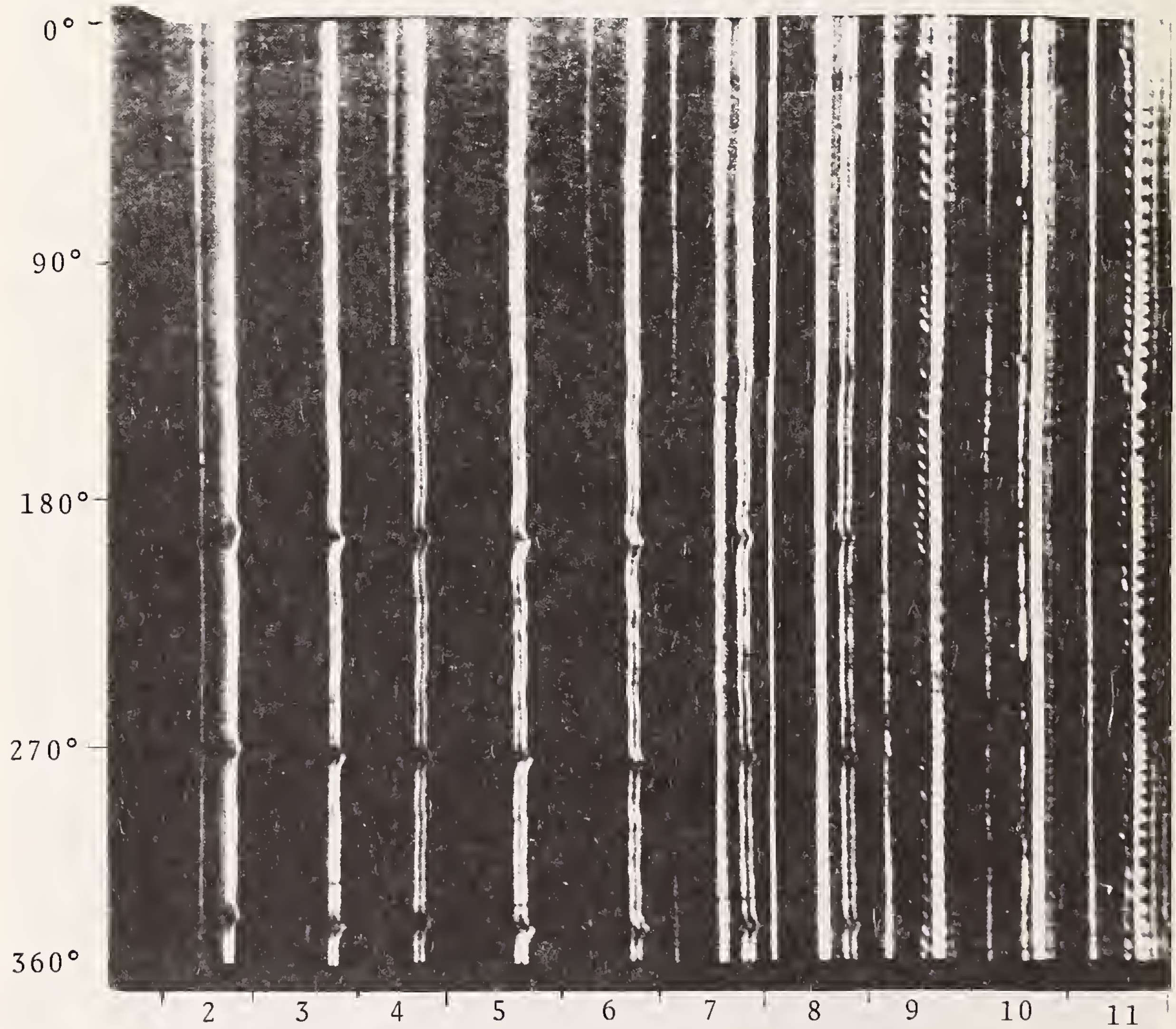


FIGURE 2. HARDCOPY PRINTOUT OF ULTRASONIC DISPLAY FOR A NORMAL TIRE

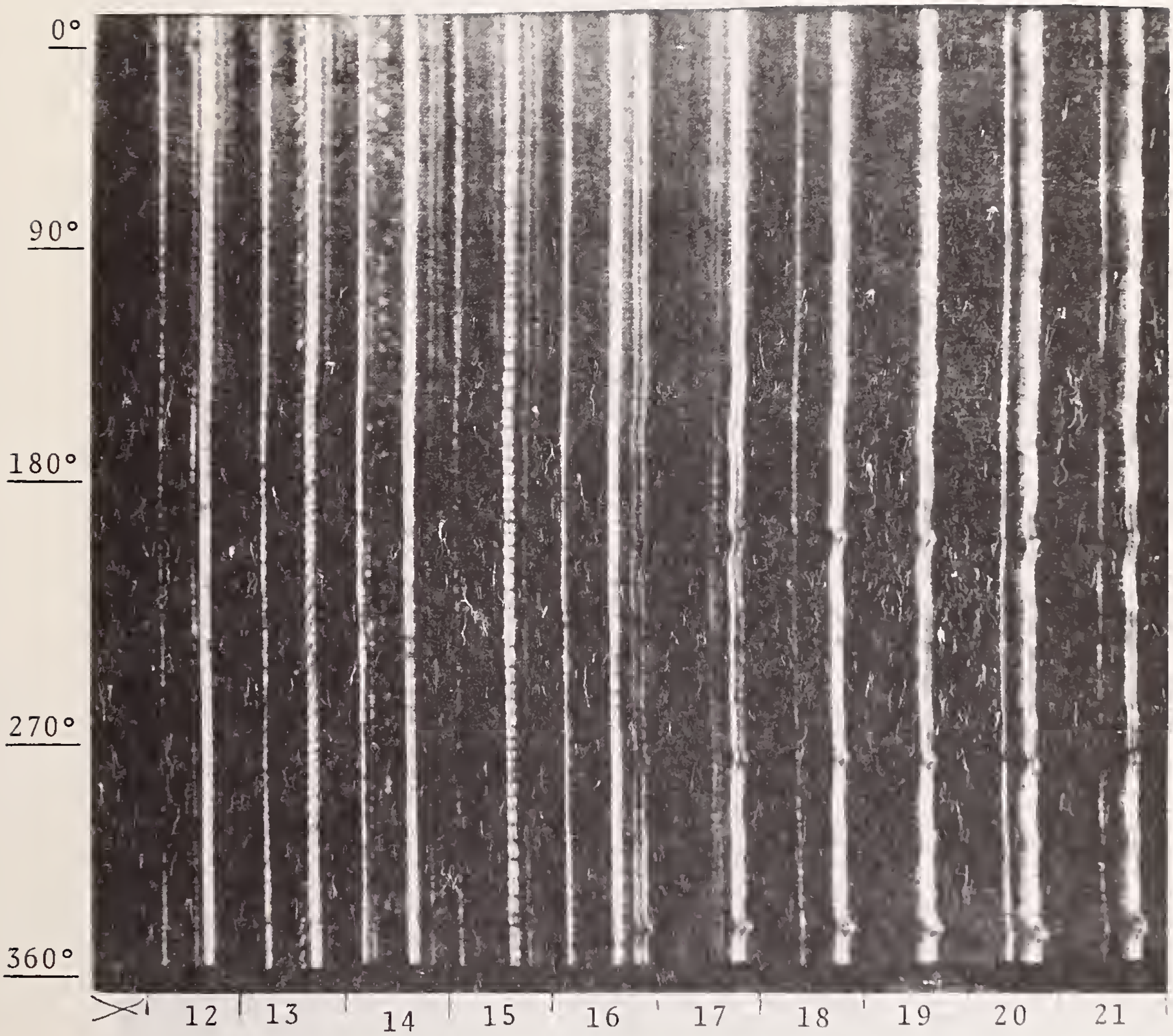


FIGURE 2. HARDCOPY PRINTOUT OF ULTRASONIC DISPLAY FOR A NORMAL TIRE (CONTINUED)

FIGURE 3. LONGITUDINALLY BUFFED CASING SHOWING BUFFING DAMAGE

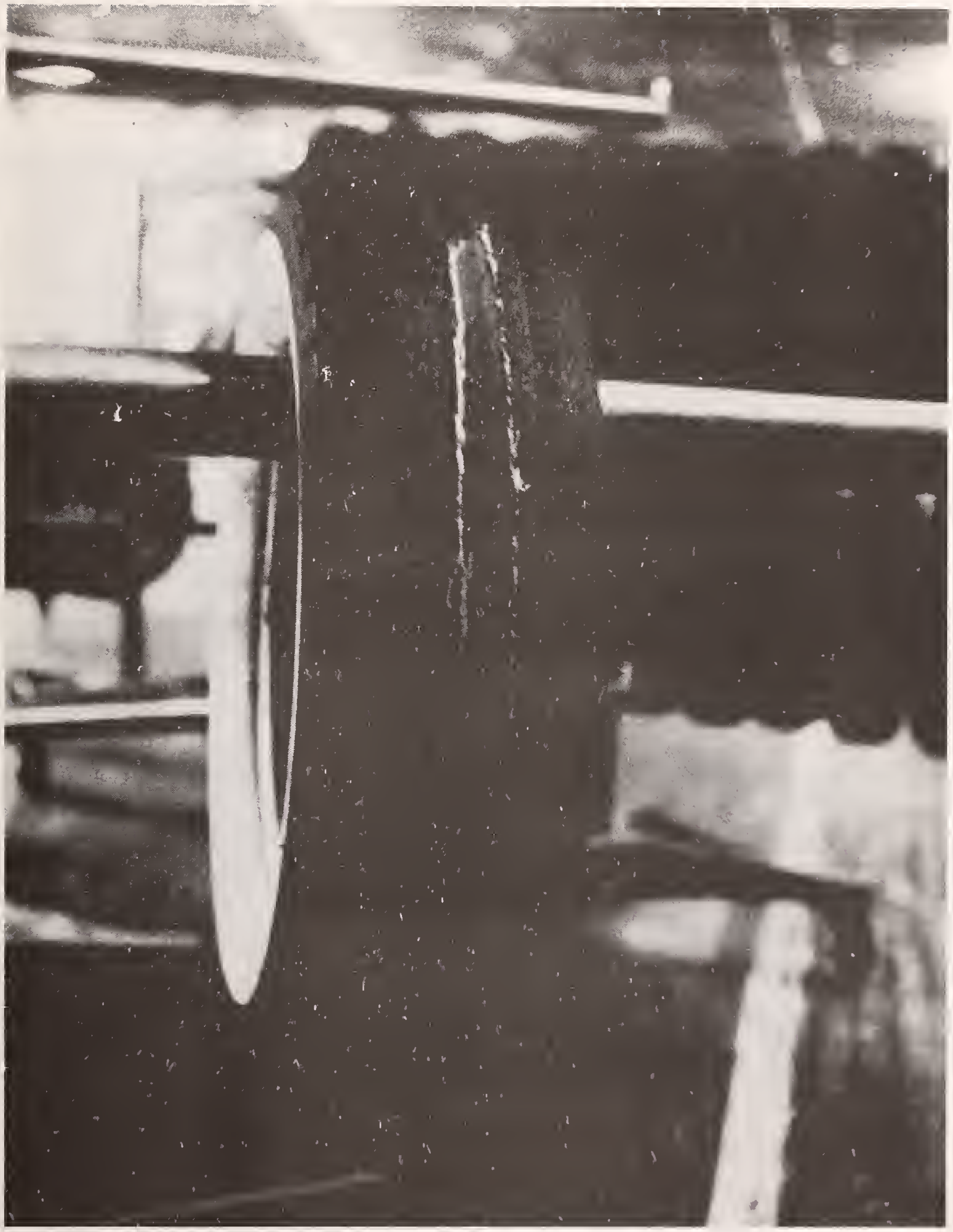


FIGURE 4. AXIALLY BUFFED CASING SHOWING BUFFING DAMAGE

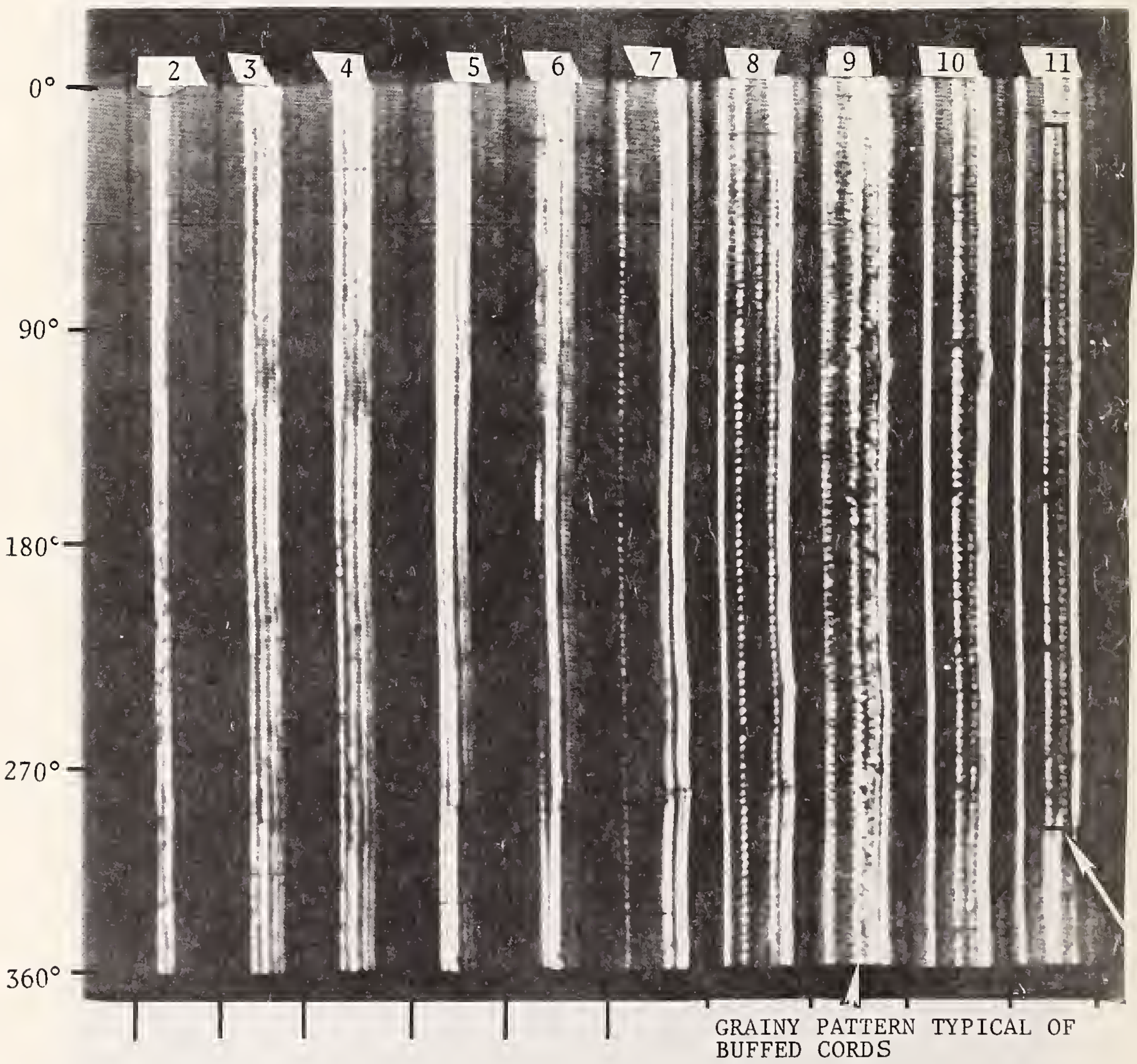


FIGURE 5. HARDCOPY DISPLAY OF RADIALLY BUFFED TIRE CASING

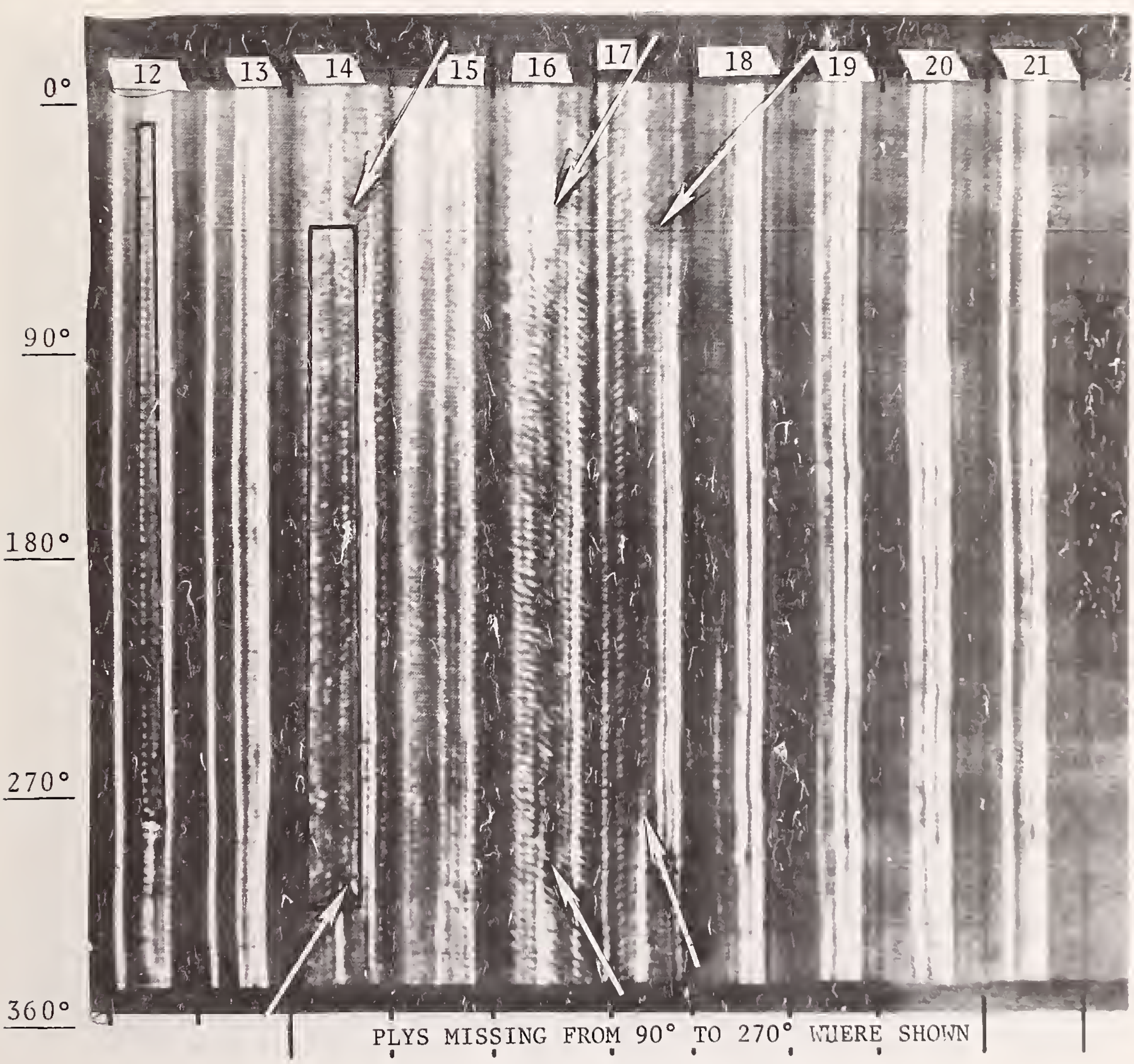


FIGURE 5. HARDCOPY DISPLAY OF RADIALLY BUFFED TIRE CASING (CONTINUED)

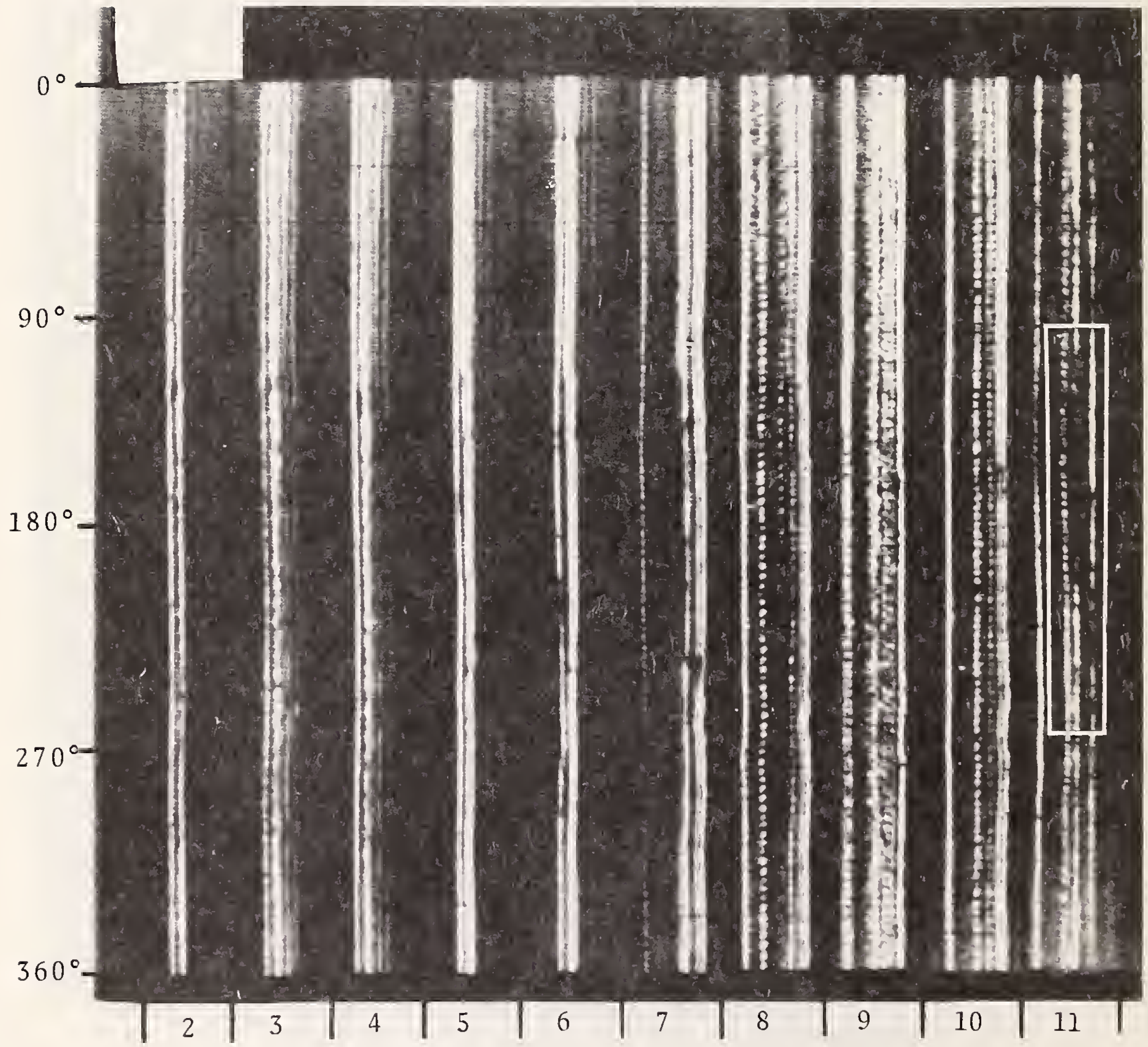


FIGURE 6. HARDCOPY DISPLAY OF AXIALLY BUFFED CASING

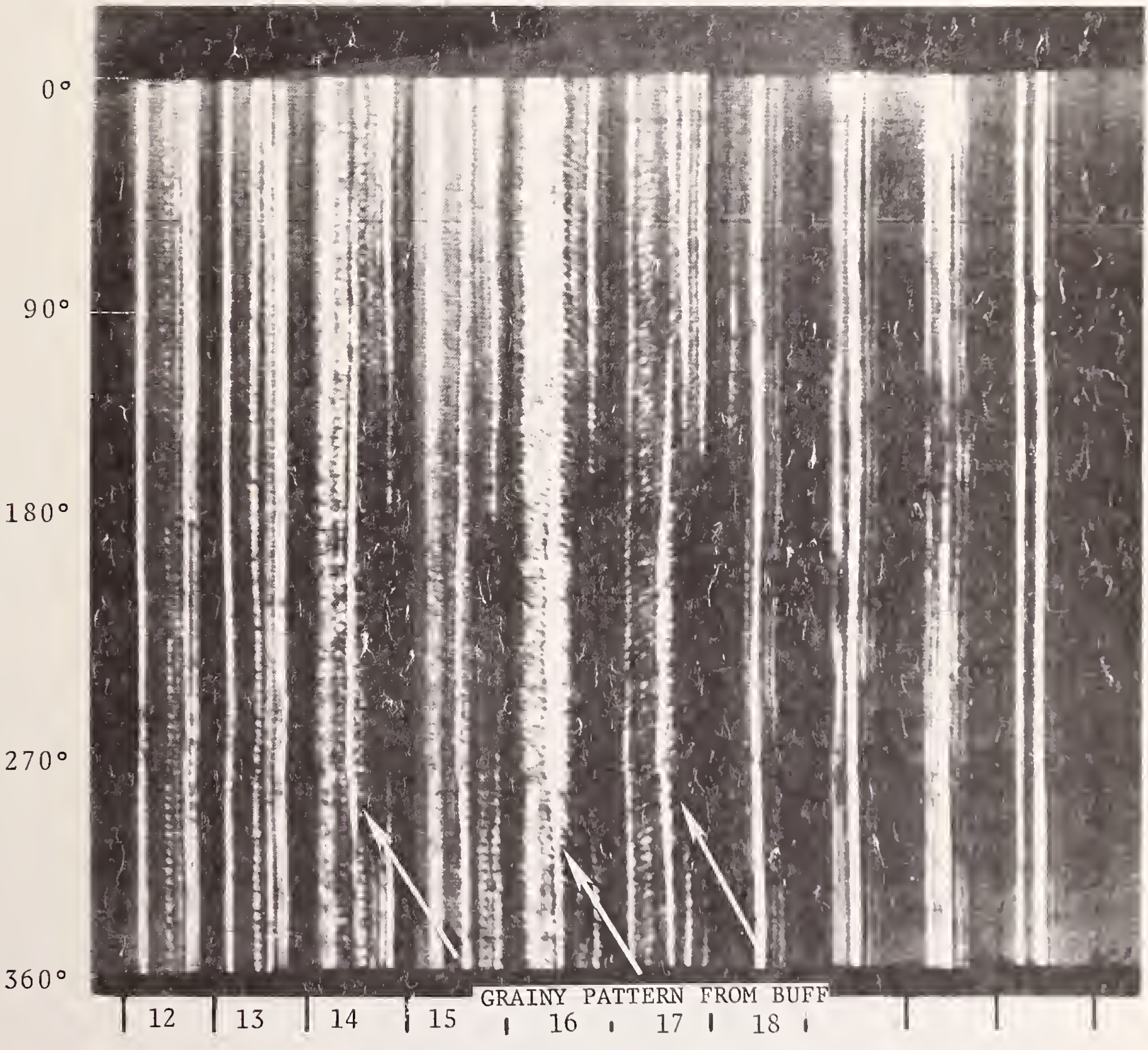


FIGURE 6. HARDCOPY DISPLAY OF AXIALLY BUFFED CASING (CONTINUED)

3. STUDY - PART II

Six tires were selected, buffed, and small flaws were introduced. The tires were then retreaded and inspected by ultrasound. They are listed in Table 2. The built-in flaws had the character of intentional minor repairs which might be attempted by a retreader in order to save a casing. Four flaws were built into each tire as follows. With the DOT Serial number as a starting point, a 4 x 1/2 inch section was skived out at tread center. Next, 90 degrees around in the clockwise direction facing the serial another one inch square section was removed. At 180 degrees a 1/2 x 4 inches section was removed at the serial side shoulder. At 270 degrees, a similar flaw was placed into the whitewall side shoulder. Figures 7, 8, and 9 show typical flaws in radial, belted and bias tires, respectively. An attempt was made to make these flaws of varying severity. That is, some flaws were made using a tack rasp in which sometimes multiple cords and sometimes single cords were removed. In other cases, only the top of the outer plies were touched by a carbide rasp.

In all cases the repair was cleaned up and stoned out. The tires were then sent to retreading. The retreading procedure was as follows: first, a small amount of tread stock was introduced into the void to build up the casing thickness. Next, the tires were retreaded using a conventional hot-cap process. After retreading, the tires were brought to TSC and inspected by reflection ultrasound. The displays for all six tires are shown in Figures 10, 11, 12, 13, 14 and 15. Table 2 also gives the results of inspection of these tires, with positive identification in 76 percent of the cases. Additional evidence of damage was also detected. In tire No. 3 there is damage and broken cords at 90 degrees at the blackwall shoulder and, in Tire No. 1, there is belt edge separation all along the white sidewall shoulder. The cause of these defects is not known. Subsequent x-ray inspection proved negative.

TABLE 2. TIRES WITH OVERBUFF

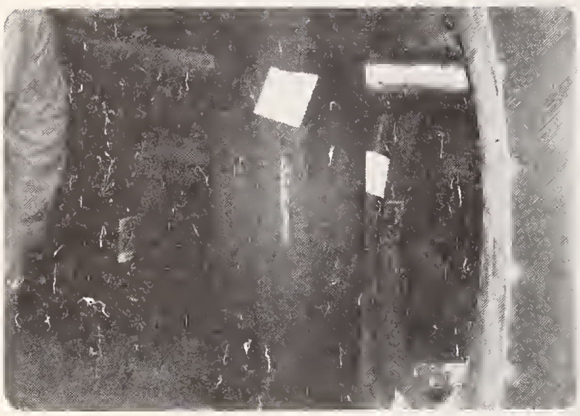
TIRE	TYPE	SERIAL	TYPE	FLAWS DETECTED SURE	PROBABLE
1	Steel Belted Radial 2+2	BRVW DR1035	B.F. Goodrich Lifesaver Radial	3	1
2	Bias Belted 2+2 Polyester Glass	MRB00633	Firestone	3	1
3	Bias Belted 2+2 Polyester Glass	VBVV004404 025B	Firestone Deluxe Champion	4	0
4	4 Ply Polyester 825-815-15	ALVVEEE215	Gillette Ambassador	4	0
5	4 Ply Polyester G78-15	WKVVVBF 415	Imperial Falcon	2	2
6	Steel Belted Radial 2+2	MKVWDRN453	Goodyear	2	1

TIRE # 1
BUFF AT 0°

BUFF AT 90°

BUFF AT 180°

FIGURE 7. TIRE NO. 1 BUFF AT 0, 90 AND 180 DEGREES



BUFF AT 0°

BUFF AT 90°

BUFF AT 180°

BUFF AT 270°

FIGURE 8. TIRE NO. 2 BUFF AT 0, 90, 180 AND 270 DEGREES

TIRE NO. 3 BUFF AT 0°

TIRE NO. 3 BUFF AT 90°

TIRE NO. 4 BUFF AT 180°

TIRE NO. 3 BUFF AT 270°

FIGURE 9. TIRE NOS. 3 AND 4 BUFFS AS NOTED

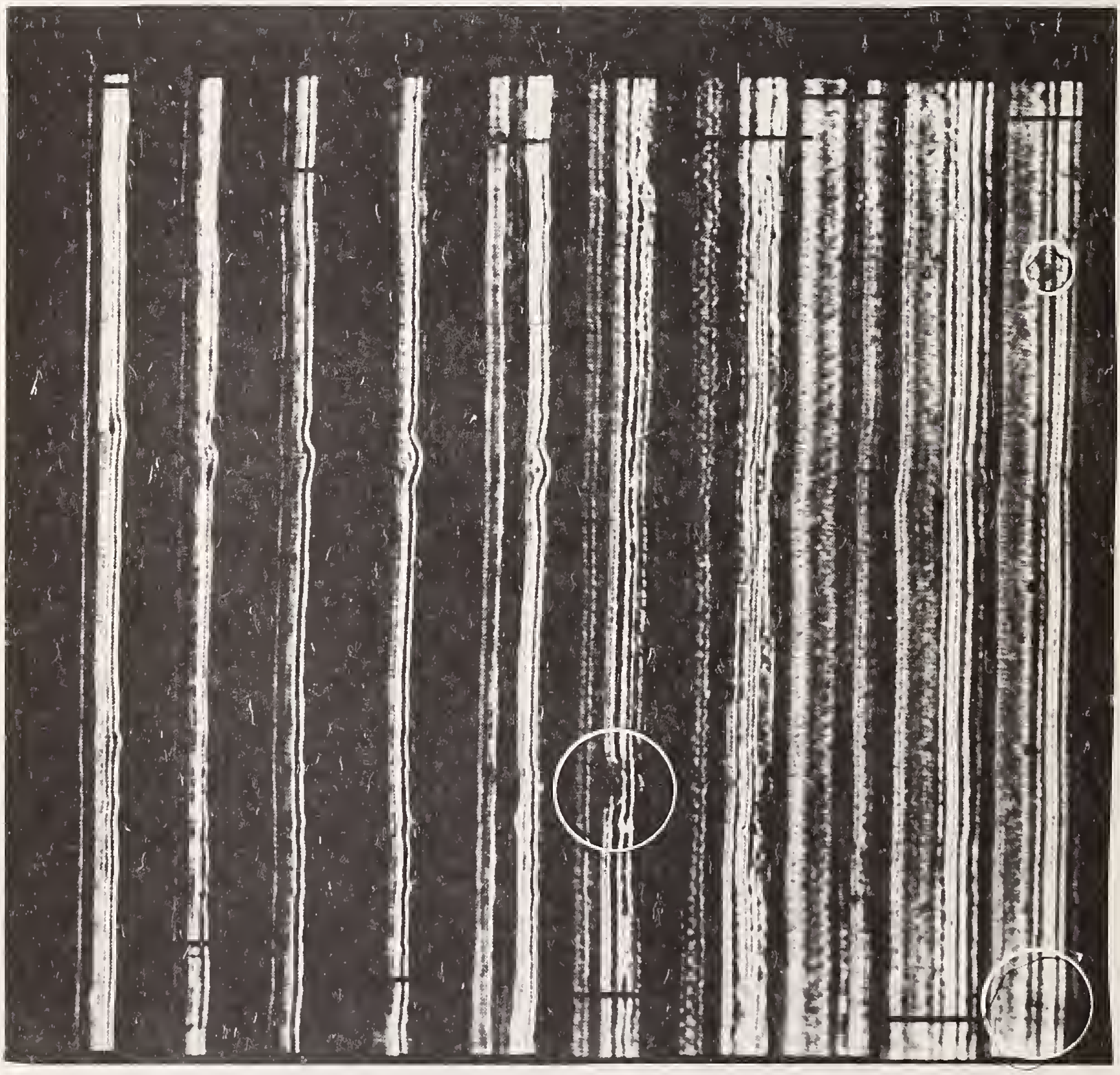


FIGURE 10. HARDCOPY DISPLAY OF TIRE NO. 1, STEEL BELTED RADIAL

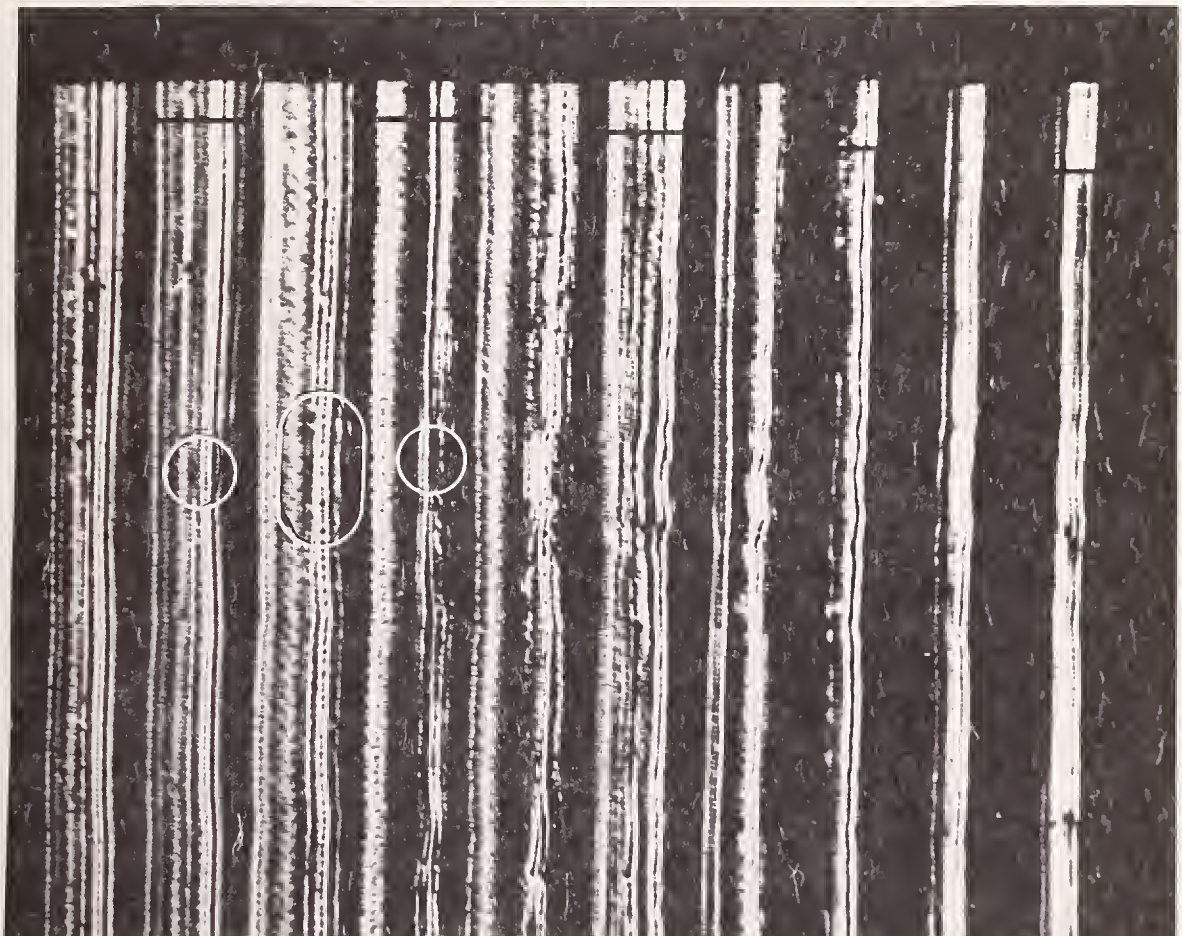


FIGURE 10. HARDCOPY DISPLAY OF TIRE NO. 1, STEEL BELTED RADIAL (CONTINUED)

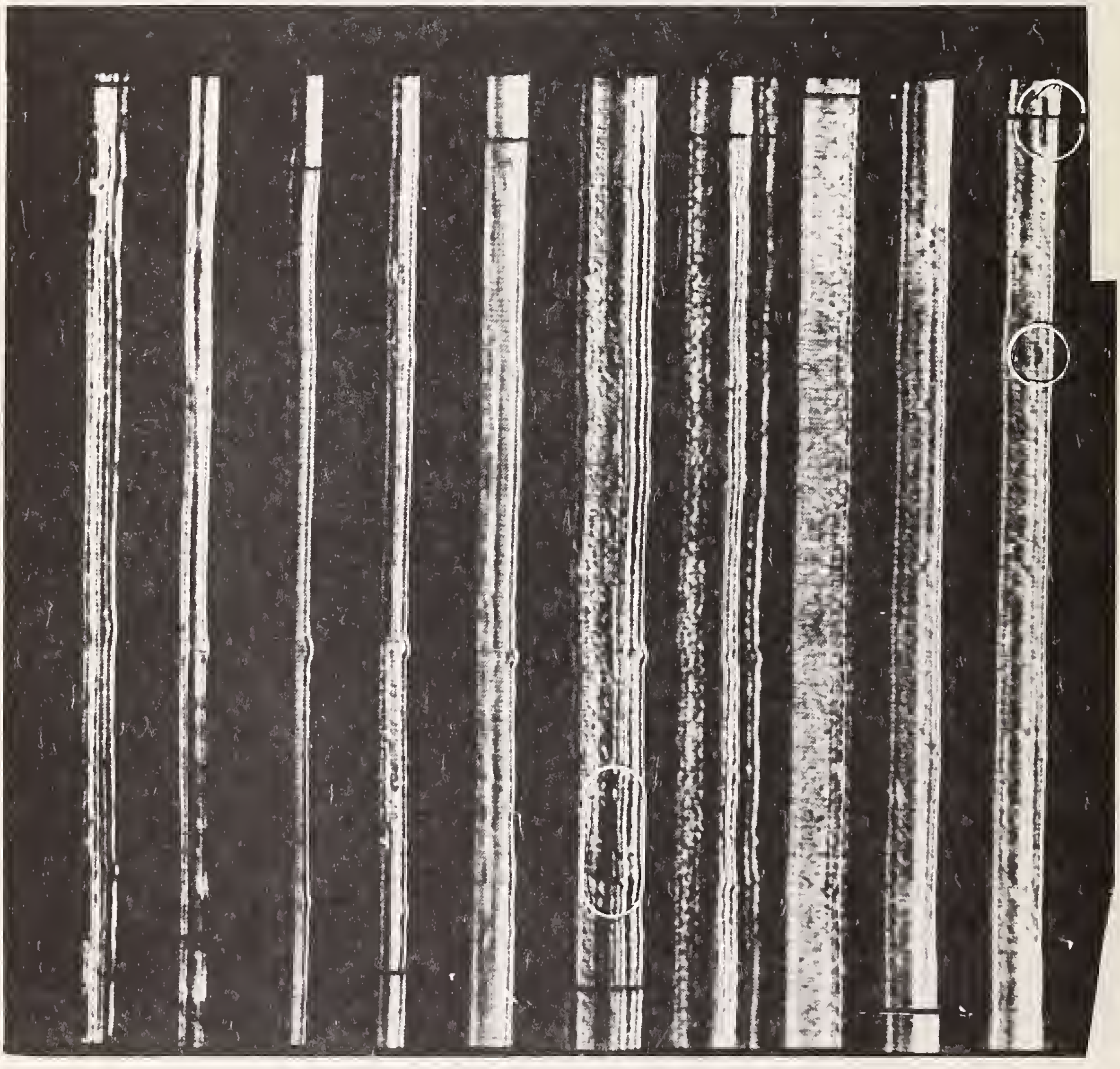


FIGURE 11. HARDCOPY DISPLAY OF TIRE NO. 2, GLASS BELTED BIAS

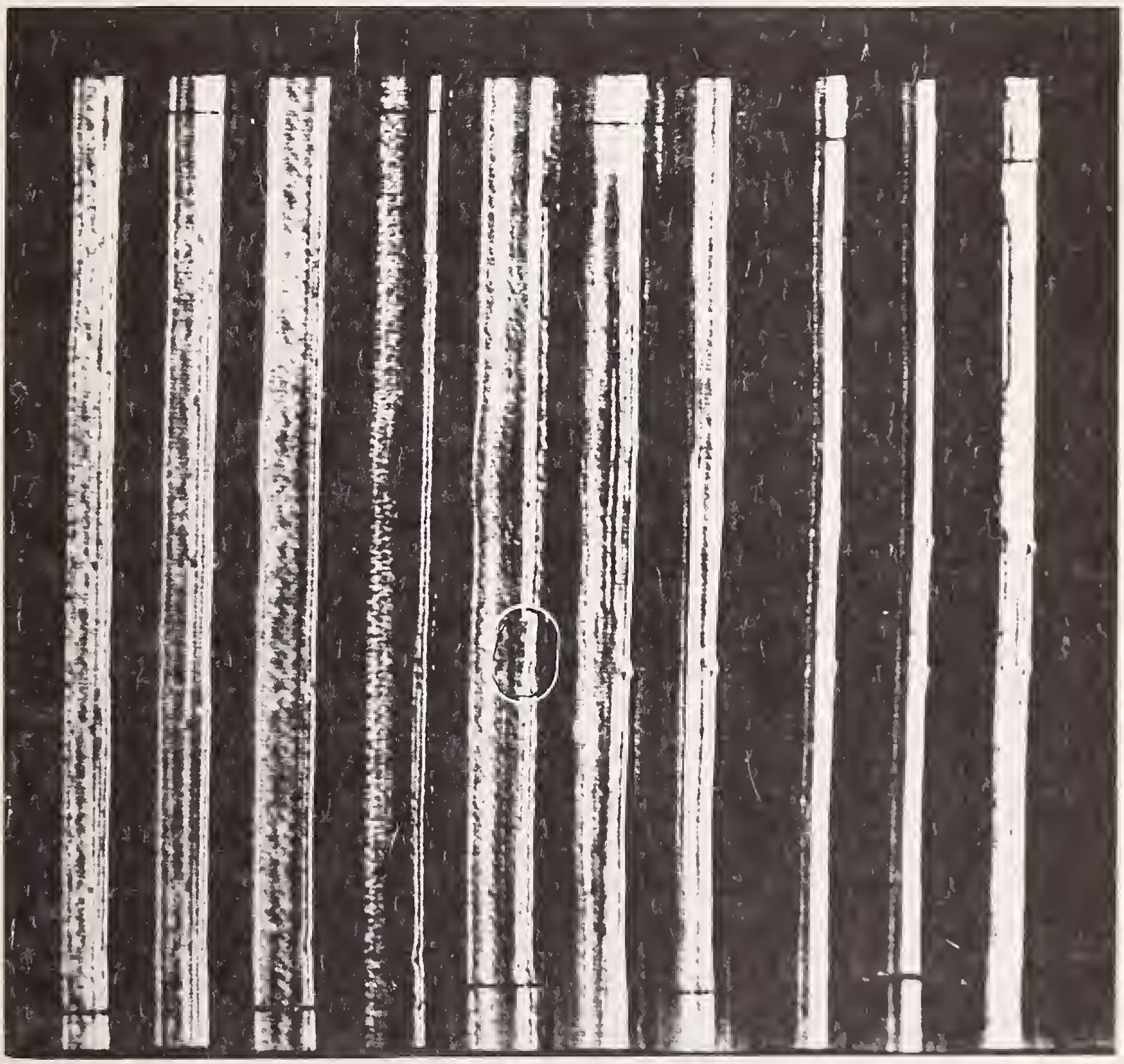


FIGURE 11. HARDCOPY DISPLAY OF TIRE NO. 2, GLASS BELTED BIAS (CONTINUED)

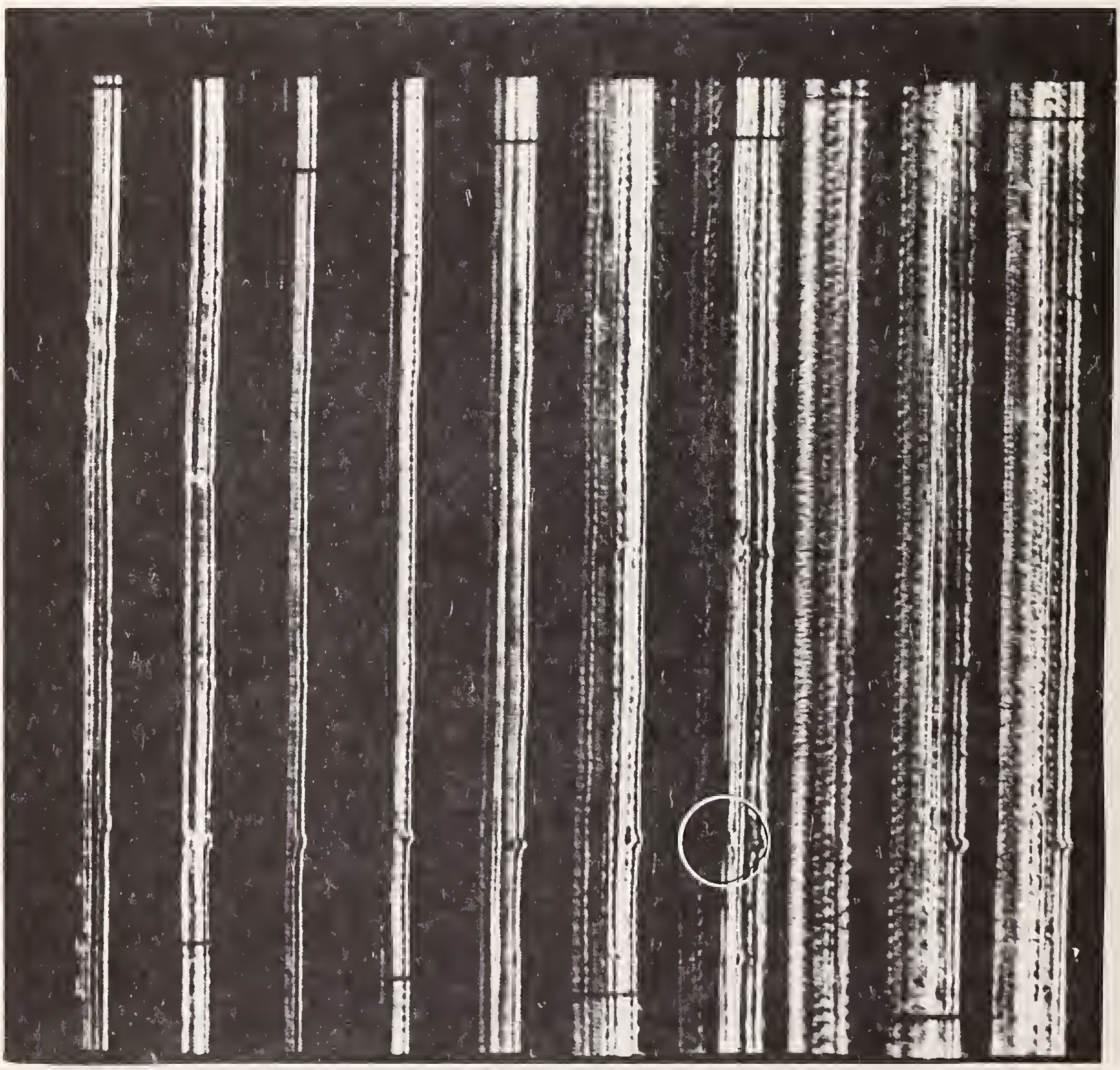


FIGURE 12. HARDCOPY DISPLAY OF TIRE NO. 3, BIAS BELTED

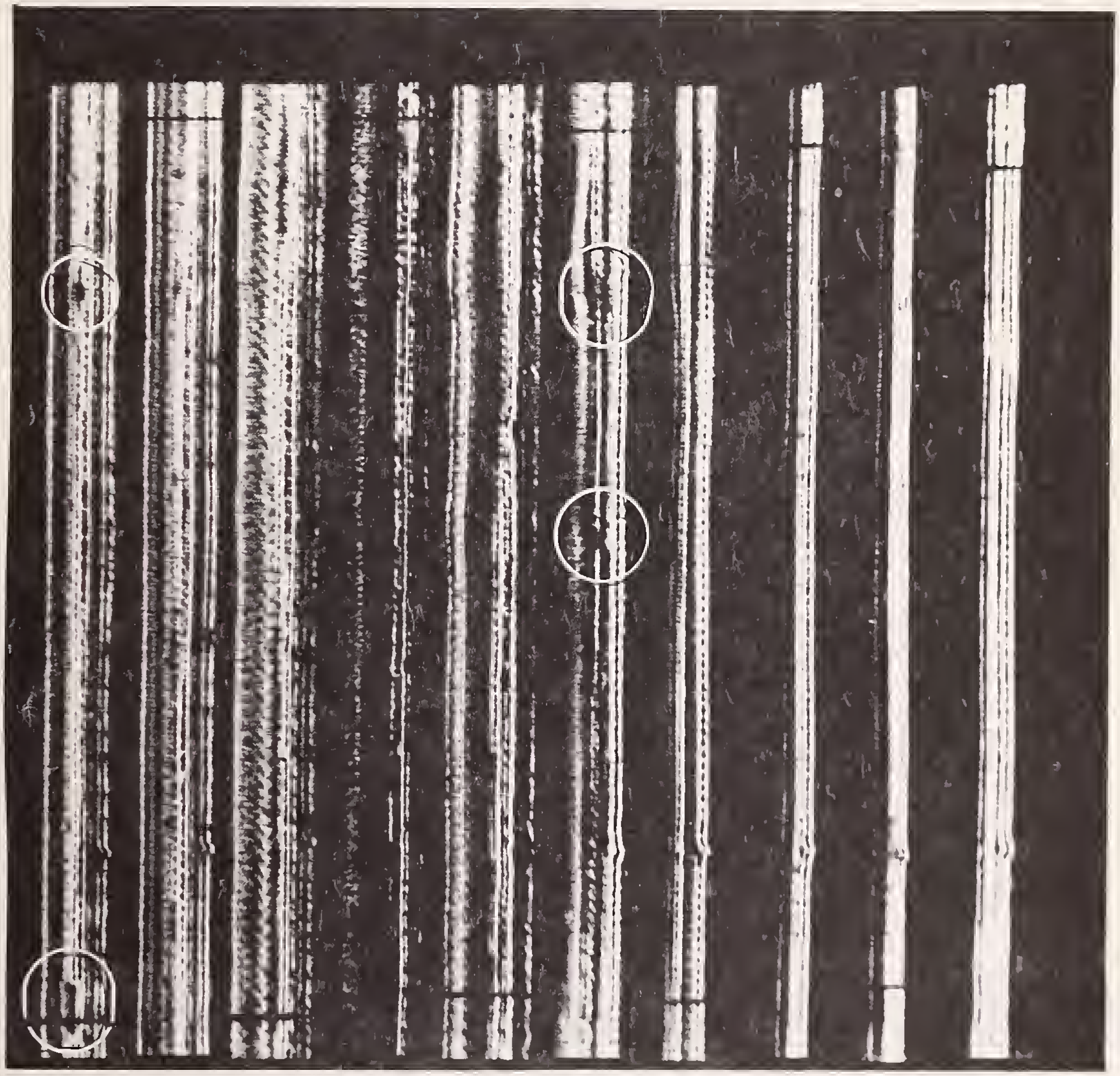


FIGURE 12. HARDCOPY DISPLAY OF TIRE NO. 3, BIAS BELTED (CONTINUED)

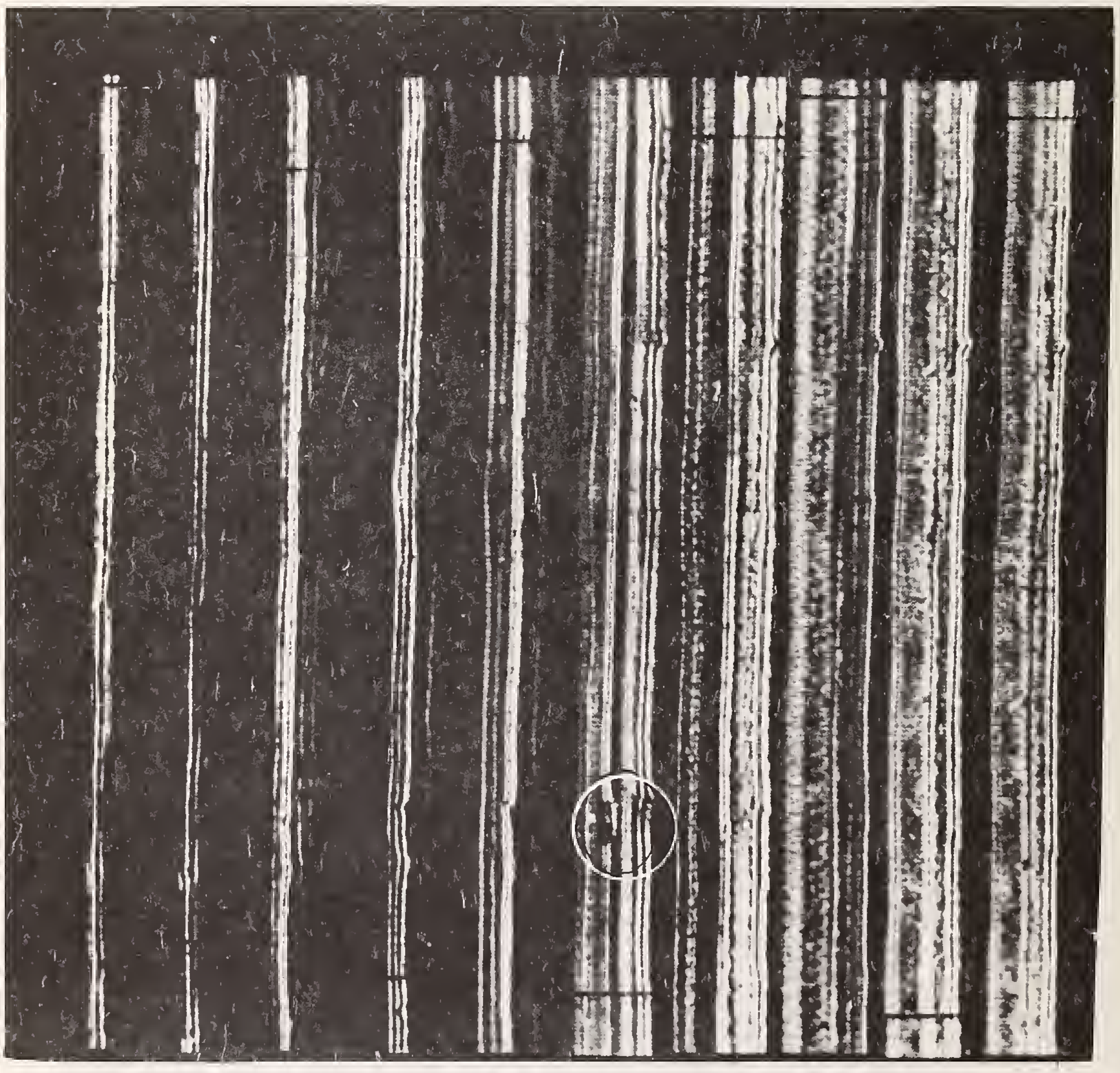


FIGURE 13. HARDCOPY DISPLAY OF TIRE NO. 4, BIAS BELTED

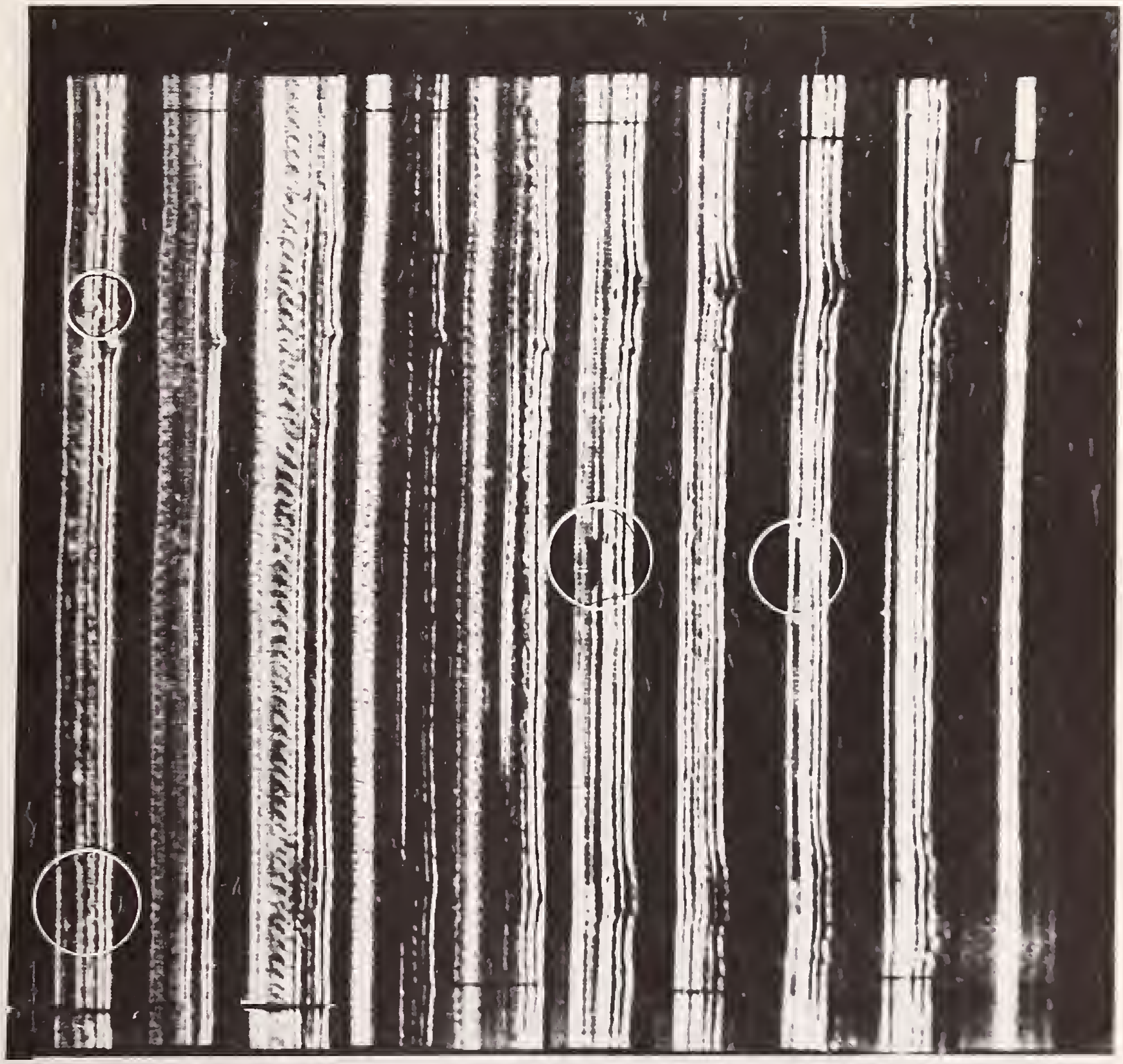


FIGURE 13. HARDCOPY DISPLAY OF TIRE NO. 4, BIAS BELTED (CONTINUED)

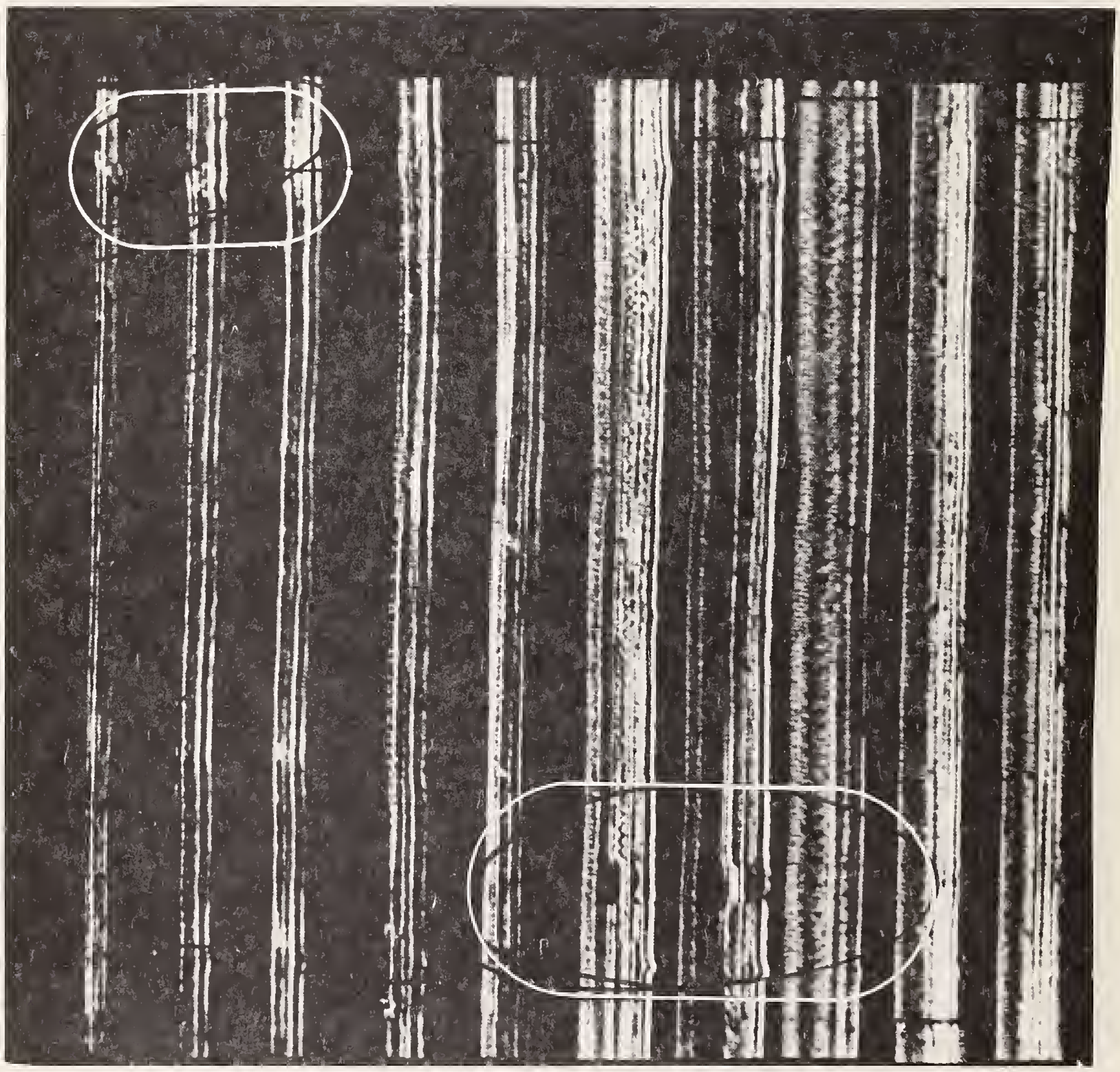


FIGURE 14. HARDCOPY DISPLAY OF TIRE NO. 5, 4-PLY POLYESTER

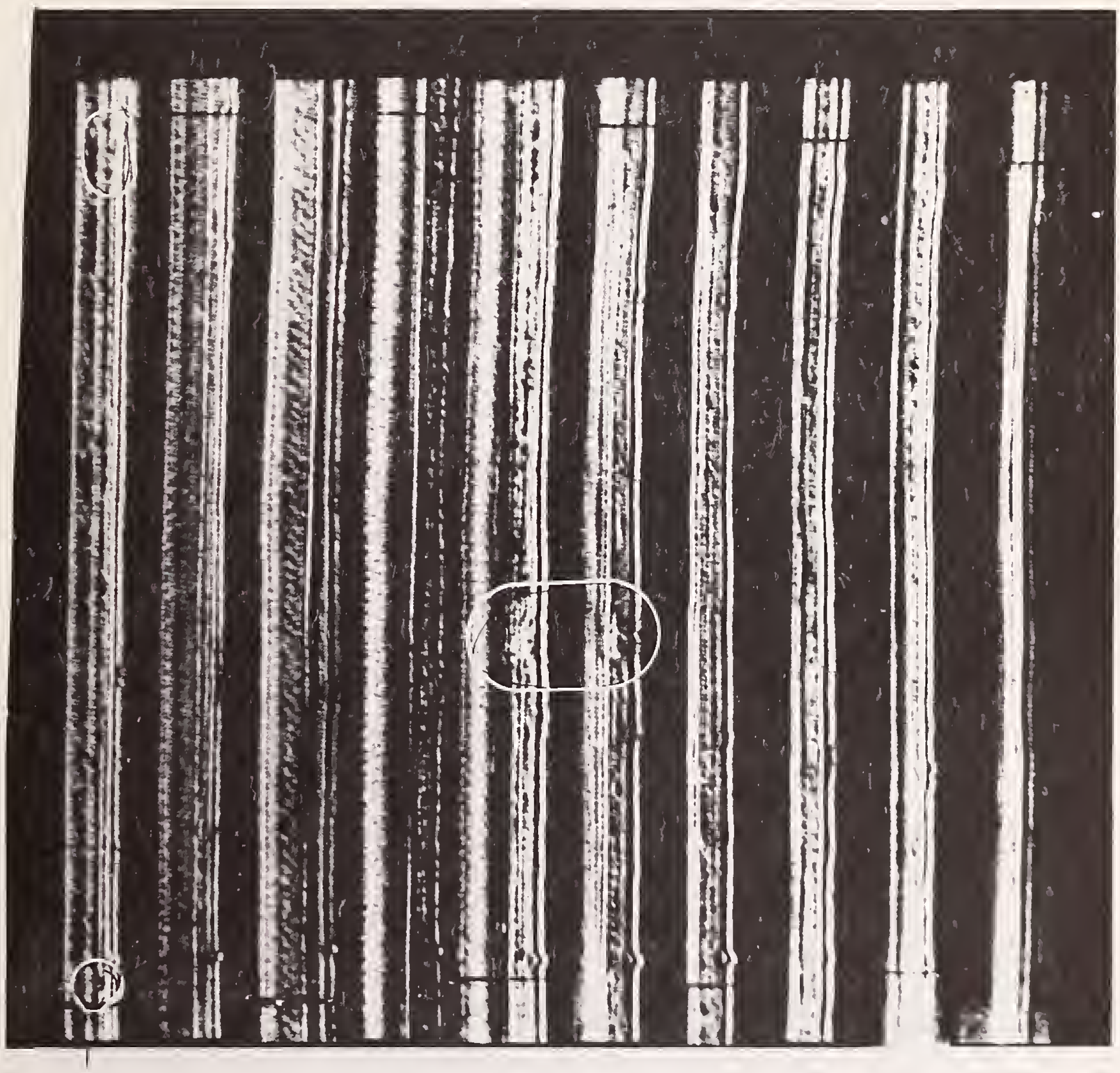


FIGURE 14. HARDCOPY DISPLAY OF TIRE NO. 5, 4-PLY POLYESTER (CONTINUED)

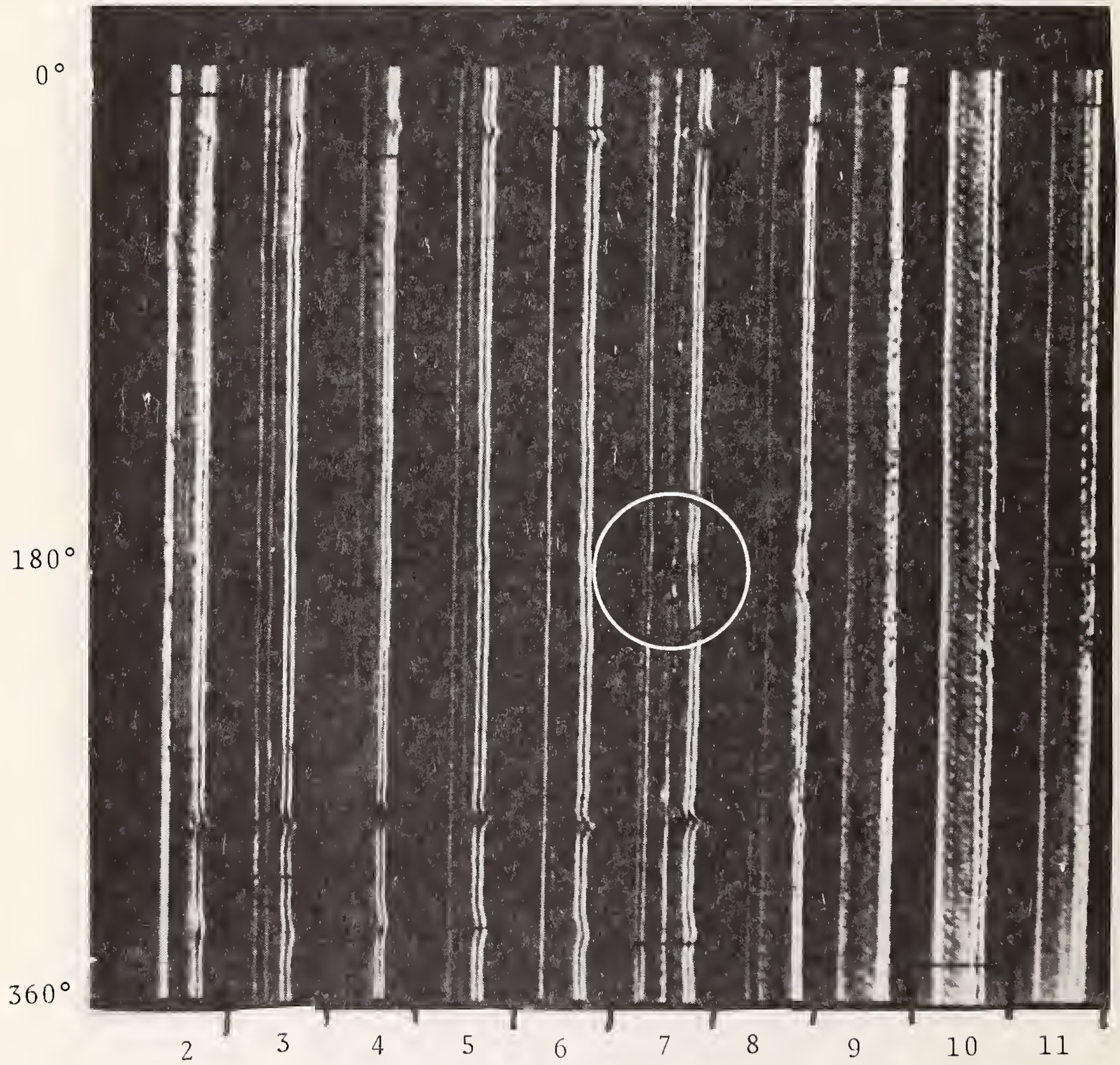


FIGURE 15. HARDCOPY DISPLAY OF TIRE NO. 6 , 4-PLY POLYESTER

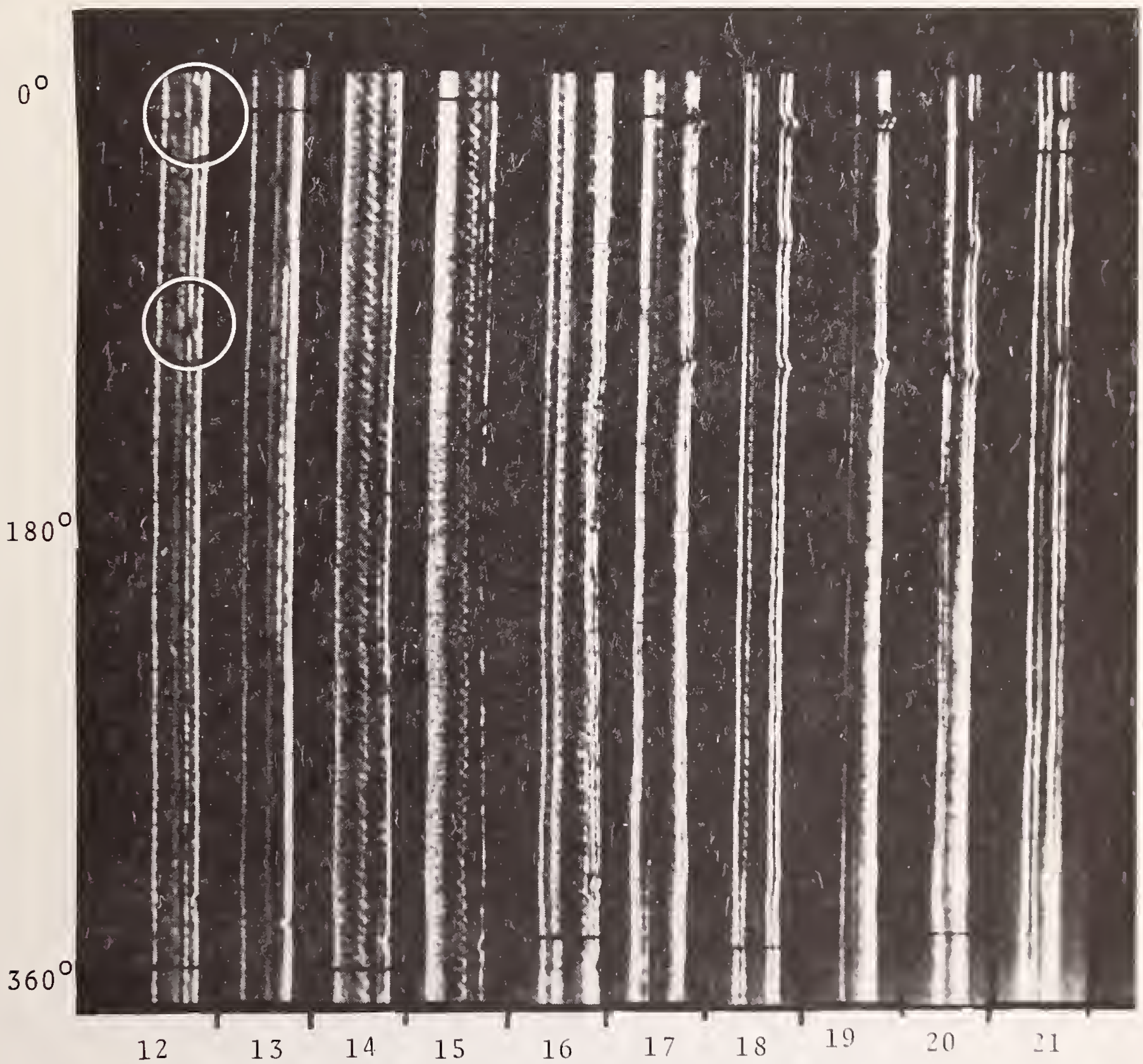


FIGURE 15. HARDCOPY DISPLAY OF TIRE NO. 6 , 4-PLY POLYESTER (CONTINUED)

4. CONCLUSIONS

a. Ultrasonic inspection for damage from overbuffing is reliable and cost effective even though the sample size is small. Such damage is identified positively in 20 of the 26 instances where it is known to be present and tentatively in all but one of the remainder.

b. Identification by X-ray of damage from overbuffing can only be accomplished when cords have been completely removed (severe damage), but not when cords have only been exposed or partially removed (slight damage).

c. This report describes the results of a study, which demonstrates that inspection by reflection ultrasound is feasible. Since this technique is nondestructive, faster and cheaper, it constitutes a viable alternative to retread inspection under FMVSS117.

5. RECOMMENDATIONS

It is recommended that NHTSA should:

a. Initiate a follow-up program to validate any of the uncertainties due to small sample size or degree of overbuffing.

b. Redesign and test a simplified but versatile overbuffing reflection ultrasonic system (transportable and low cost) for use in compliance acceptance. System cost should be sufficiently low to develop acceptance by the industry if system versatility lends itself to casing inspection and selection.

c. Develop a data base to support inclusion of NDT*(ultrasonic detection of overbuffing) as a test technique in FMVSS 117 "Retreaded Pneumatic Tires--Passenger Cars."

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*NDT = Nondestructive Testing

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