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ULTRASONIC INSPECTION OF TEN RETREADED TIRES AND THIRTY-TWO CASINGS

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16. Abstract

TSC examined 42 tires ultrasonically. Of these, 10 reportedly had belt-edge separations which had been identified and measured prior to retreading (control group). The remaining 32 were reportedly used casings in good condition ready for retreading. The ultrasonic data were analyzed and numerical scores from 1 (poor) to 9 (excellent), were assigned to tread, belts, sidewalls, and carcass for each tire. The tires were ranked in in order of overall numerical scores. In the control group there were 5 tires with a belt score of 5; 4 tires with a belt score of 7 or less.

In the group of 32 casings the belt scores were as follows; 3 for one casing, 4 for two casings, 5 for one casing, 6 for five casings, 7 for five casings, 8 for eight casings, 9 for 10 casings. If the threshold score which separates defective casings from the remainder is taken to be 7 (on the basis that all tires in the control group had separations), then 16 tires of the 32 are suspect.

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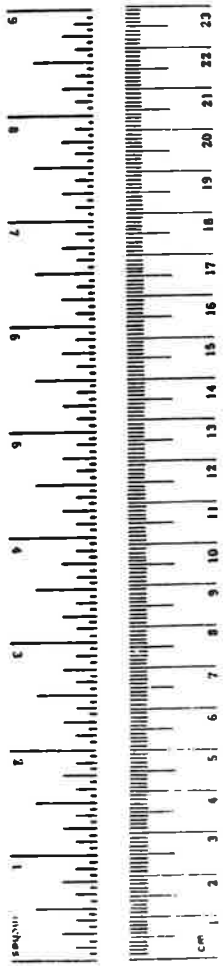
PREFACE

The work reported herein was done in cooperation with the Nevada Automotive Test Service which performed the tire road tests, under a task sponsored by M.J. Lourenco of NHTSA.

METRIC CONVERSION FACTORS

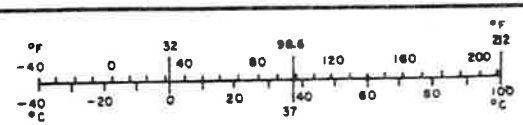
Approximate Conversions to Metric Measures

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

The objectives of the study were: (1) to perform ultrasonic nondestructive inspection of a group of 10 retreaded tires which had measured belt edge separations of the tire shoulders; (2) to perform a similar inspection of 32 tire casings which would then be shipped to Uniroyal for sectioning and comparison with the nondestructive inspection. This report describes the findings from the nondestructive inspection data.

2. SYSTEM DESCRIPTION

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 water where the tire is spun to remove bubbles and debris by high pressure water jets. It is then moved a further 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.

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

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

* These channels are of significance in the detection of belt edge separations.

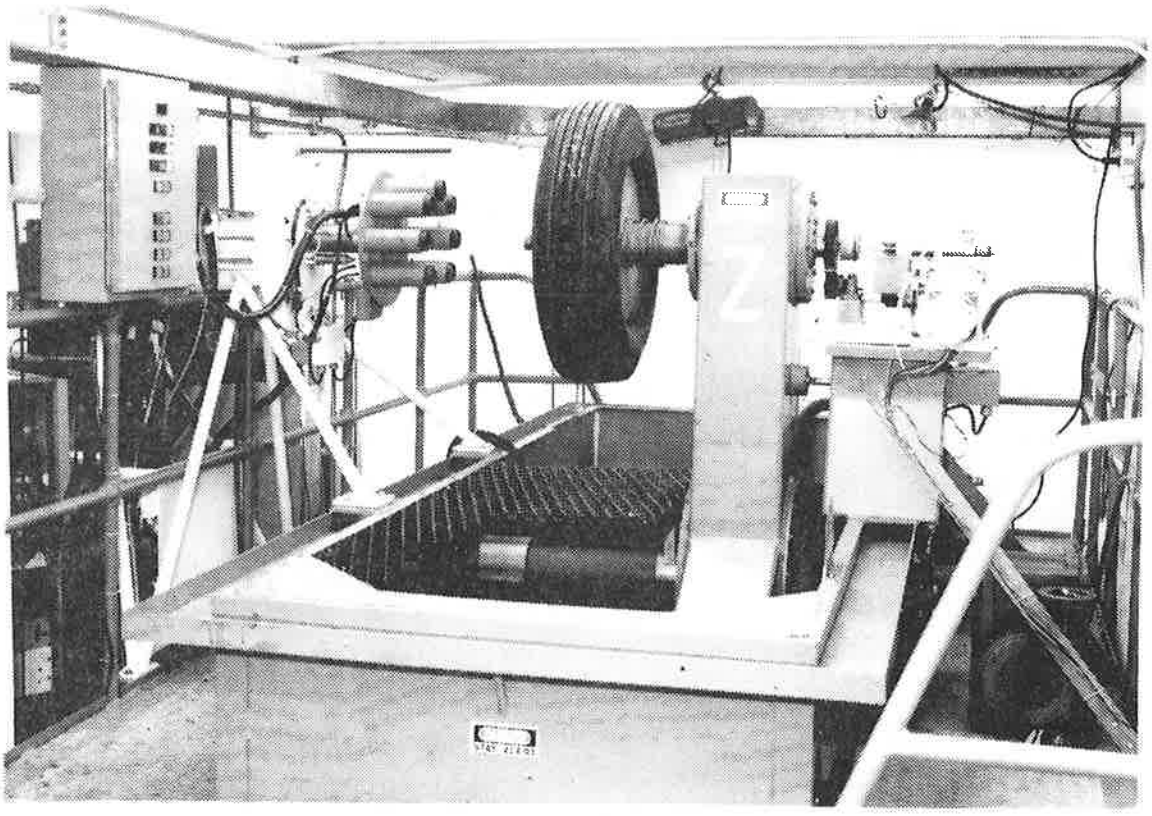


FIGURE 2-1. ULTRASONIC INSPECTION SYSTEM

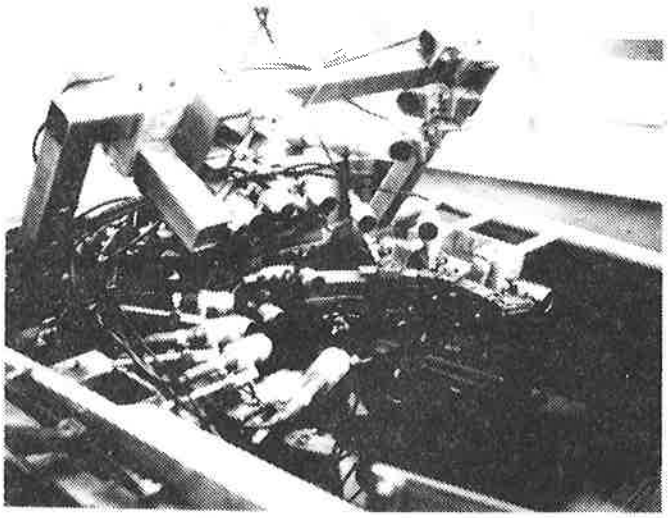


FIGURE 2-2. TRANSDUCER ARRAY

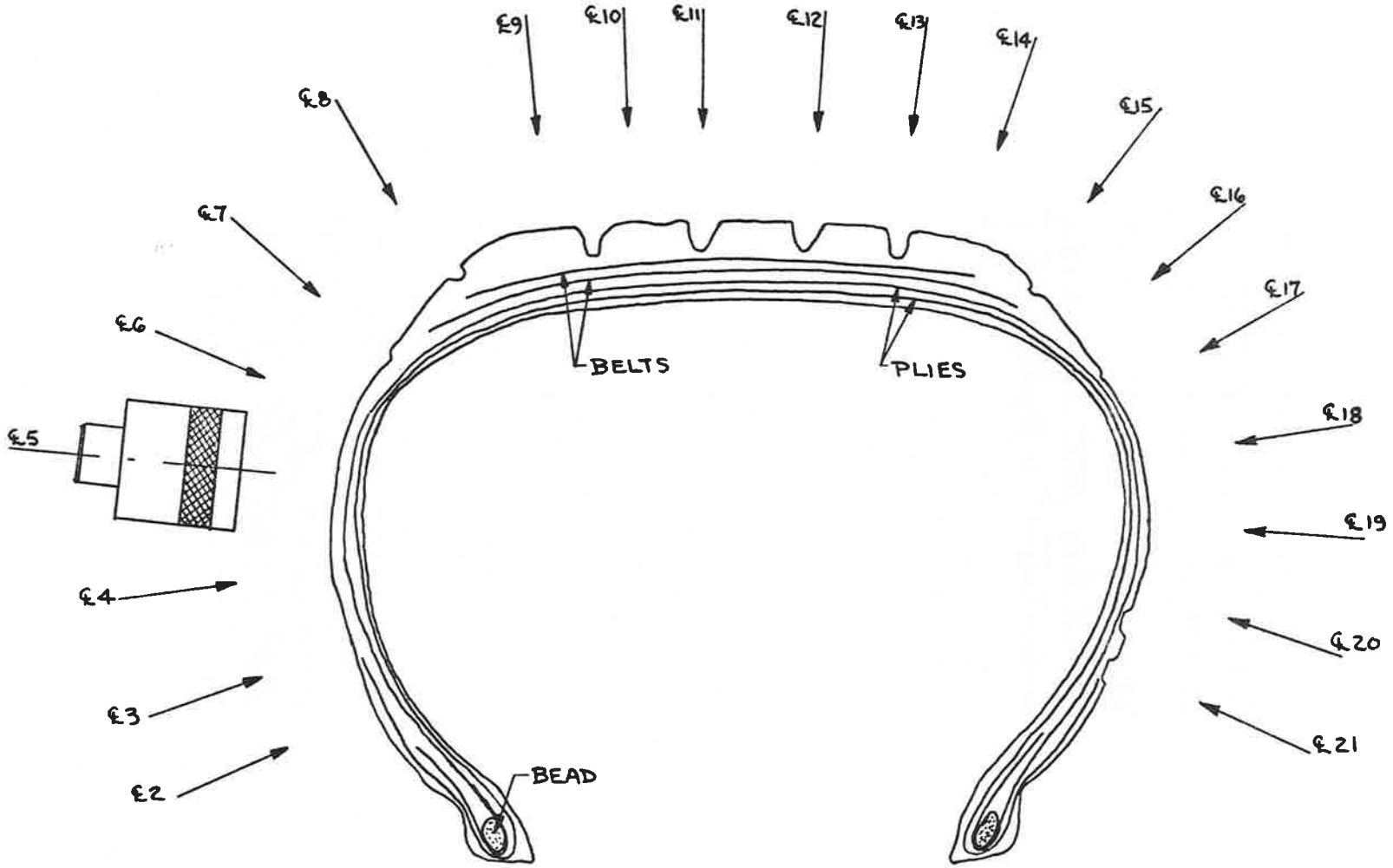


FIGURE 2-3. TRANSDUCER LOCATIONS

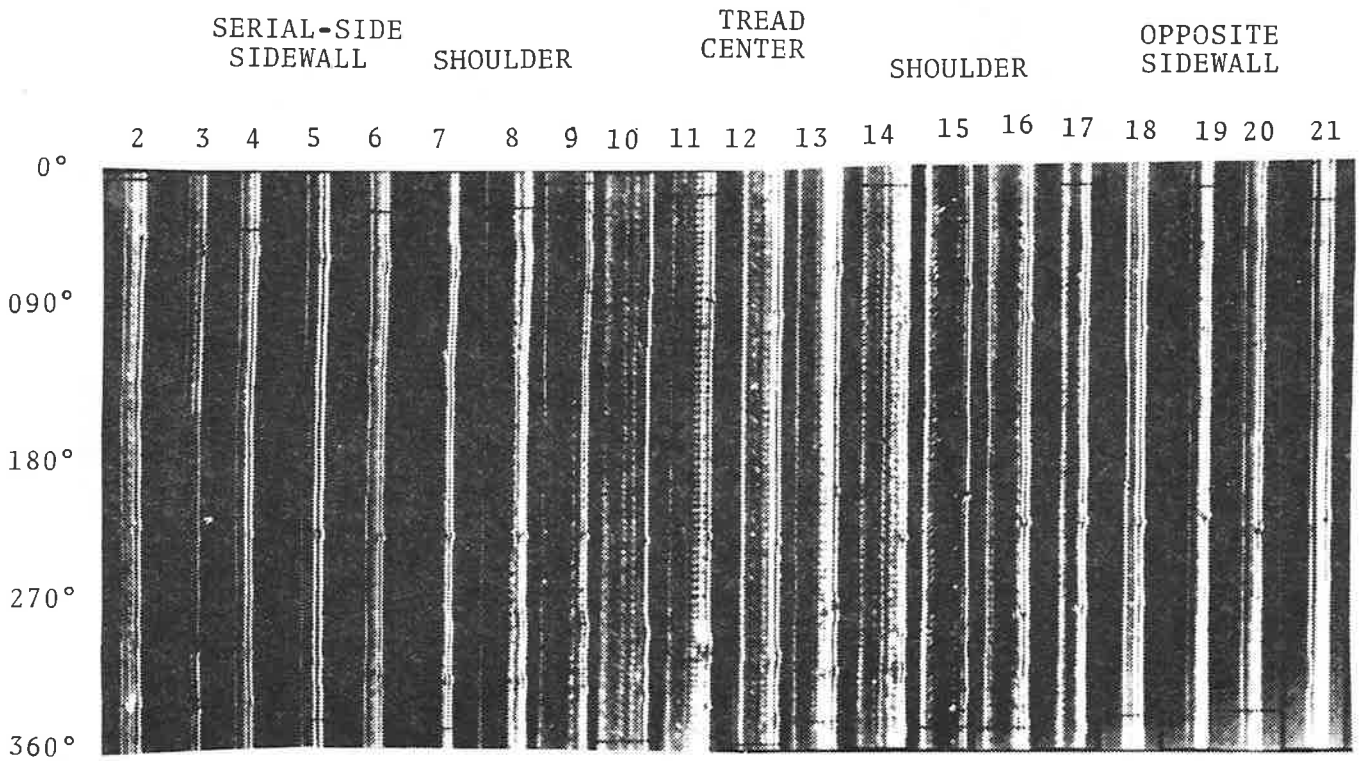


FIGURE 2-4. ULTRASONIC TIRE SCAN DISPLAY

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.

3. PROCEDURE FOR ANALYSIS OF NONDESTRUCTIVE INSPECTION DATA

The analysis of the printouts was performed by evaluators trained in data interpretation. A form (Figure 3-1) was completed for each tire. 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). The $\theta=0^{o}$ 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(See Figure 3-6), not to 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.

Singularity/Shadow (all channels)

A bright spot adjacent to a shadow (Figure 3-7). It is

TIRE NO.: CONSTRUCTION: BELT MATERIAL:

MANUFACTURER: PLY MATERIAL:

— CHANNELS —																			CHARACTERISTIC
2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
																				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	REGISTRATION	TREAD	BELTS	SIDEWALL	CARCASS	COMMENTS:

FIGURE 3-1. SCORING FORM

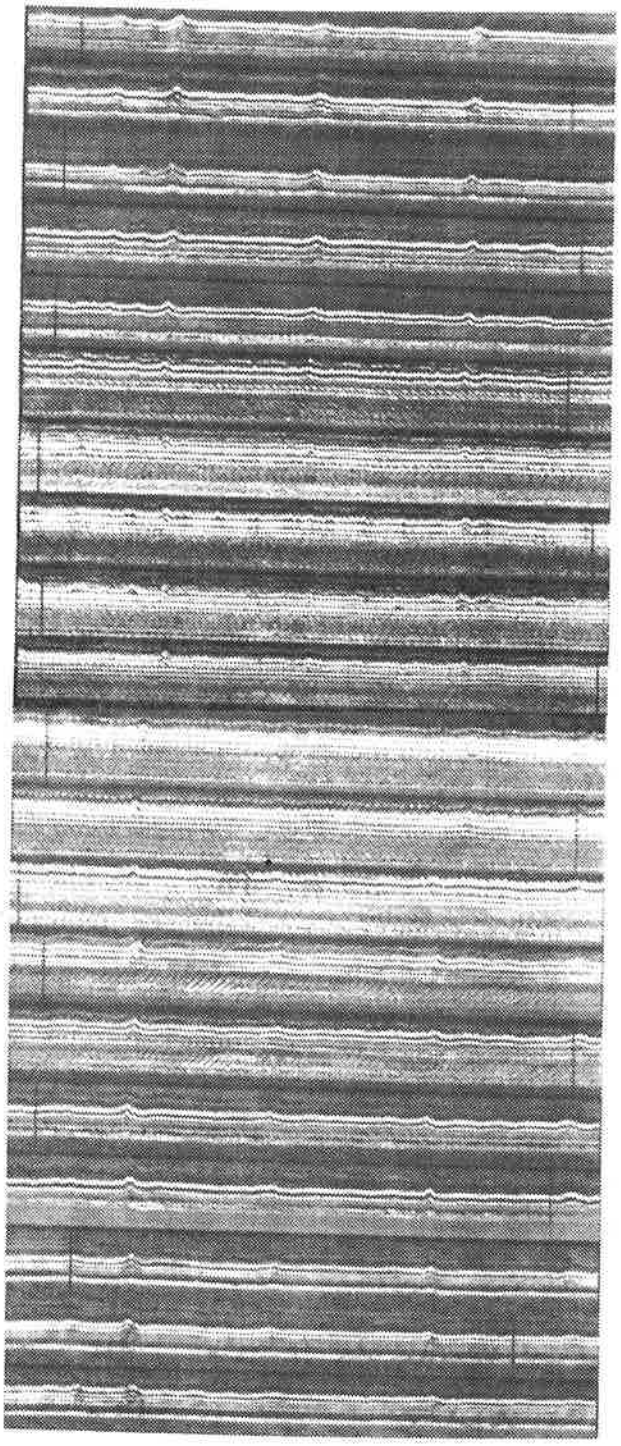


FIGURE 3-2. HIGH QUALITY DATA PRINTOUT

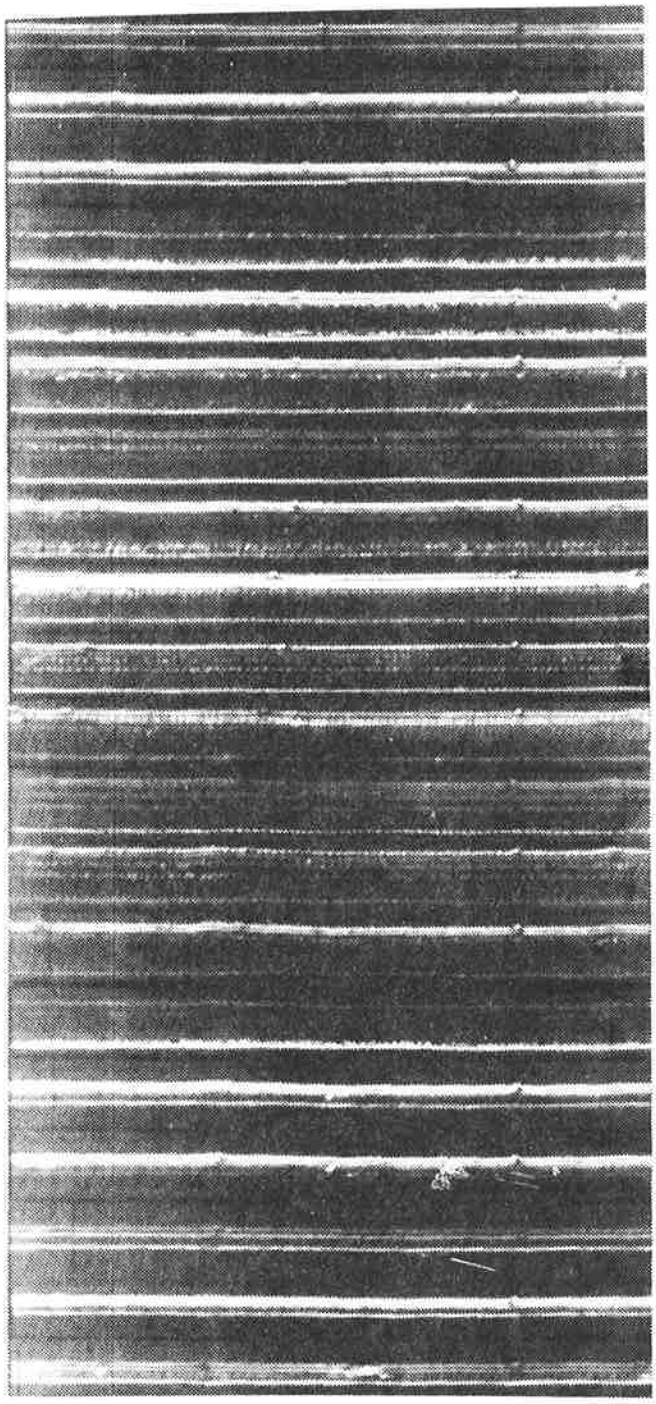


FIGURE 3-3. POOR QUALITY DATA PRINTOUT

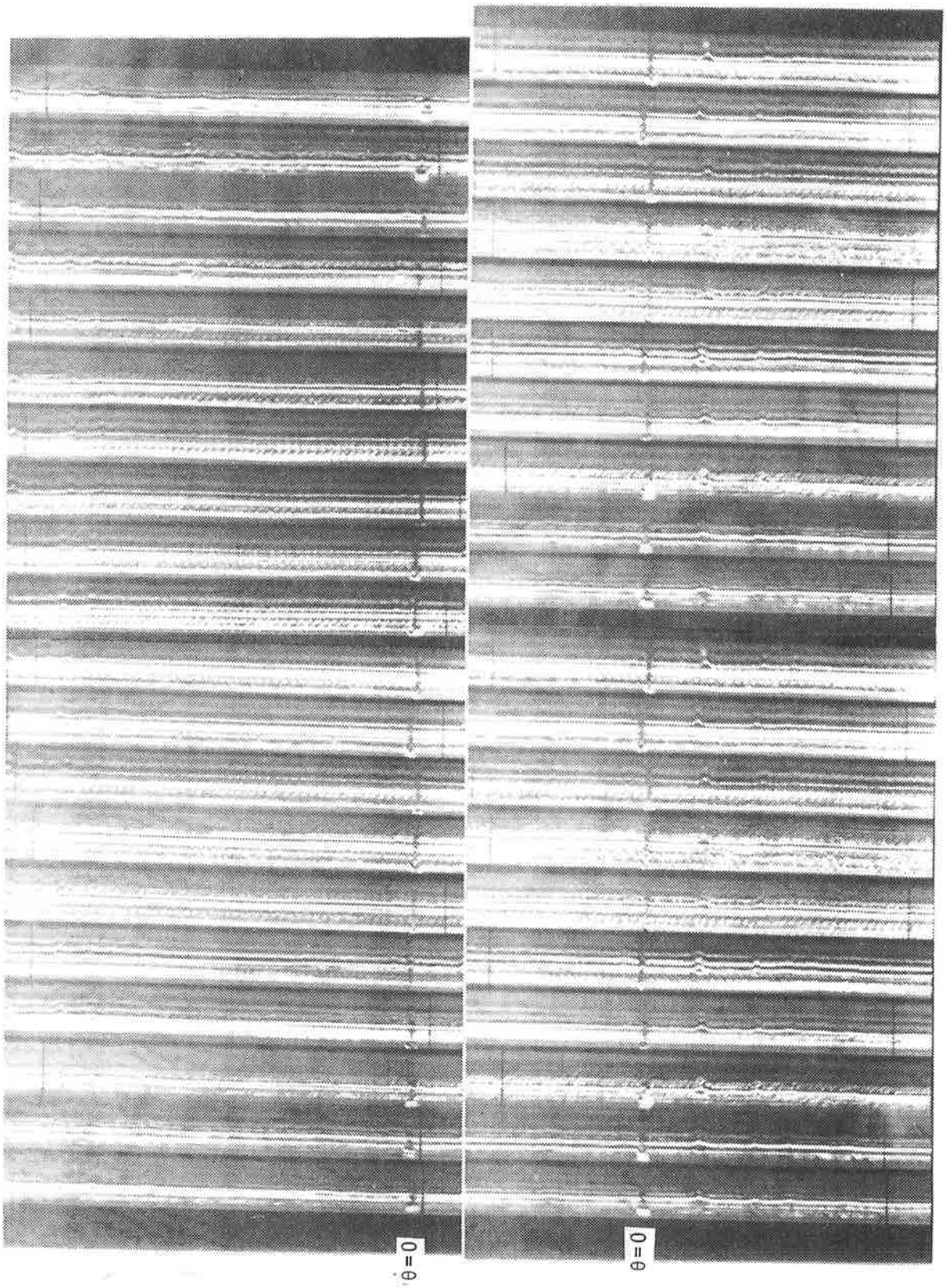
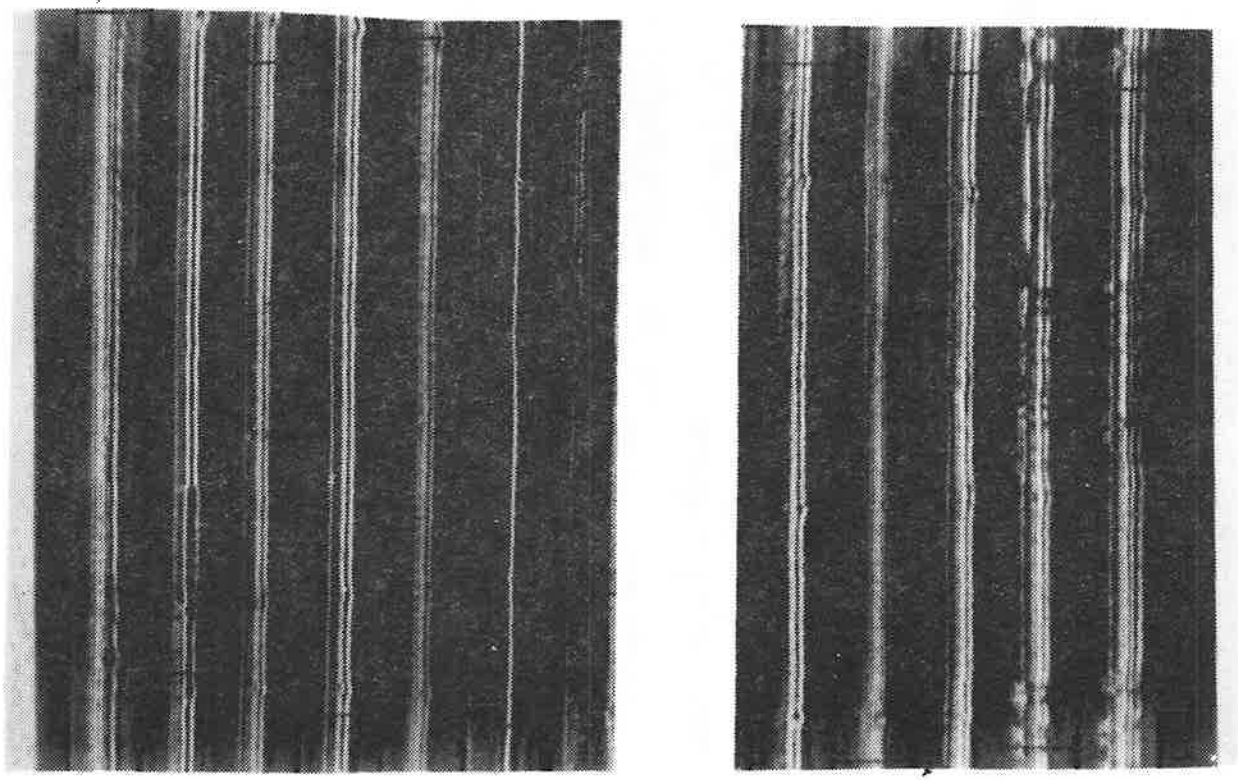


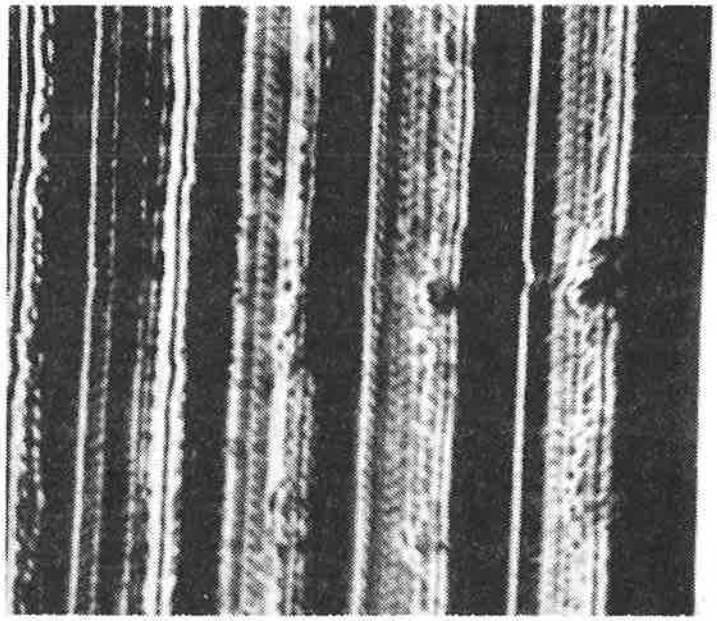
FIGURE 3-4. EXAMPLE OF POOR REGISTRATION



LITTLE OR NO
TURNUP MODULATION

SEVERE TURNUP
MODULATION

FIGURE 3-5. TURN-UP AREA



10

FIGURE 3-6. EXAMPLE OF INCLUSION

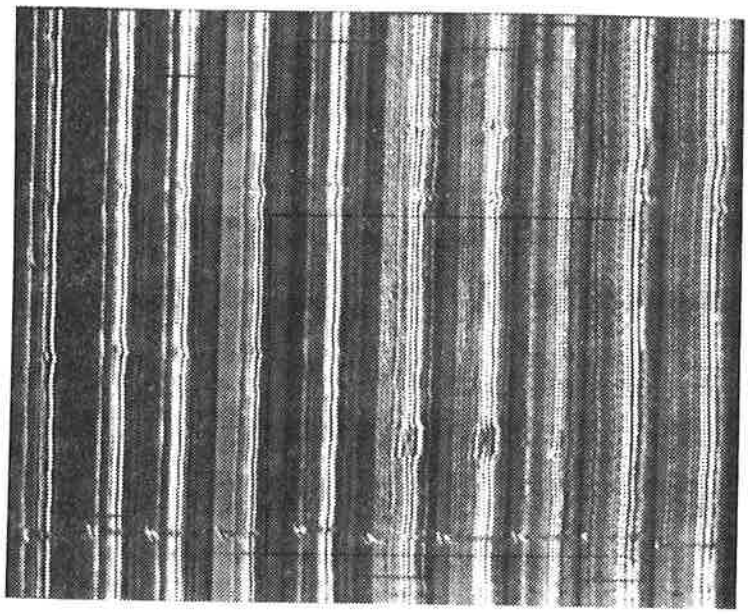


FIGURE 3-7. EXAMPLE OF SINGULARITY/SHADOW

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.

Lateral Runout (channels 5 and 18)

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

Intensity Change (all channels)

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

Trace Discontinuity (all channels)

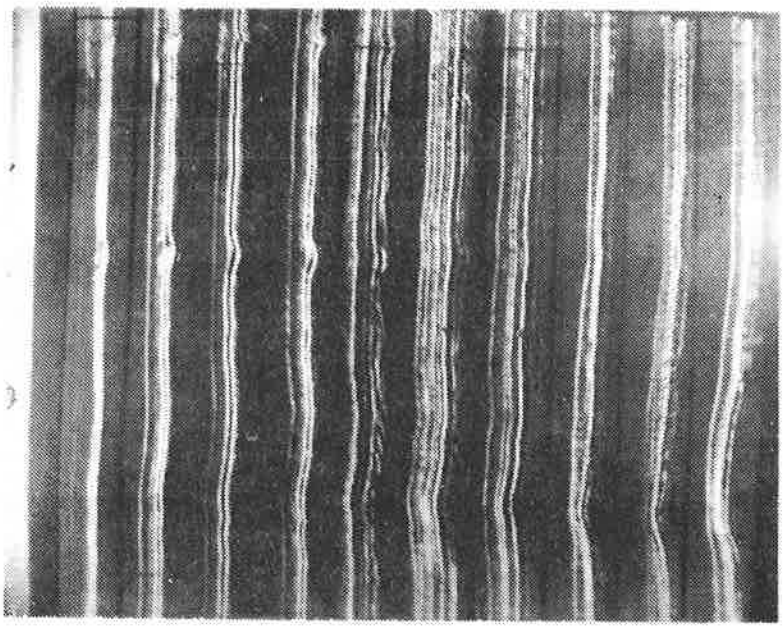
Interruption of a trace (Figure 3-11); not to be confused with an inclusion which is usually indicated in more than one channel. It is caused by abnormal displacement of material.

Shape Discontinuity (all channels)

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

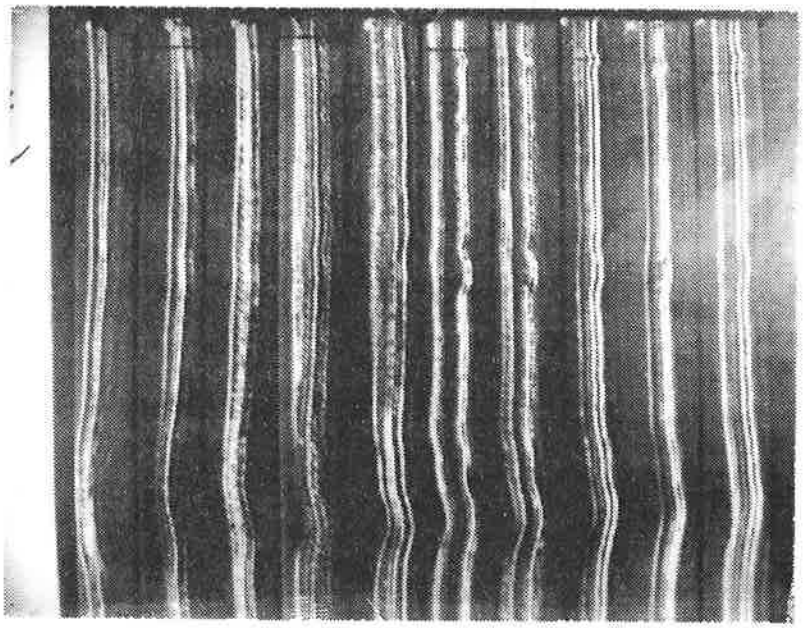
The scores for tread, belts, sidewall, and carcass are derived from the above inspection criteria, taking all factors known about the tire into account. An experienced tire inspector can readily be trained for this task.

*The figure shows an example of typical belt-edge separations in Channels 7 and 8.



5 10

FIGURE 3-8. RADIAL RUNOUT



12 18

FIGURE 3-9. LATERAL RUNOUT

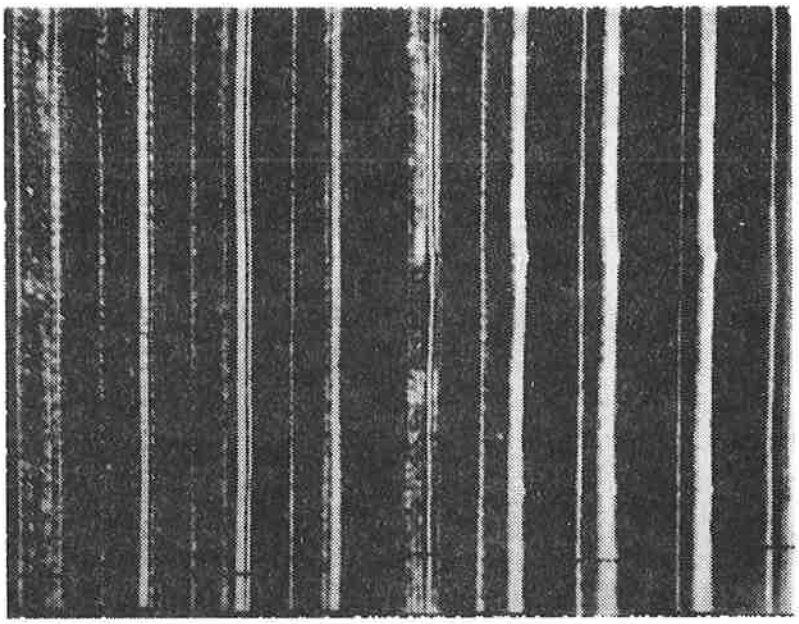


FIGURE 3-10. INTENSITY CHANGE

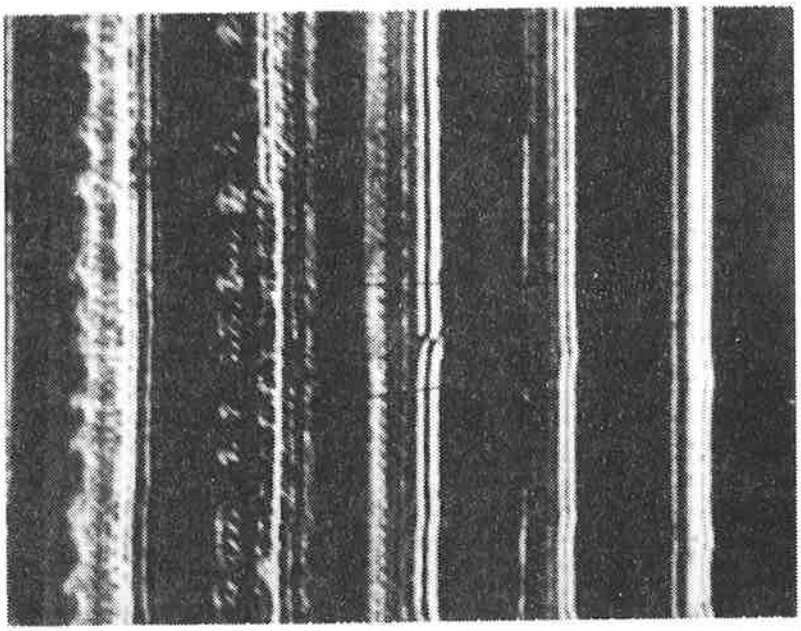


FIGURE 3-11. TRACE DISCOUNTINUITY

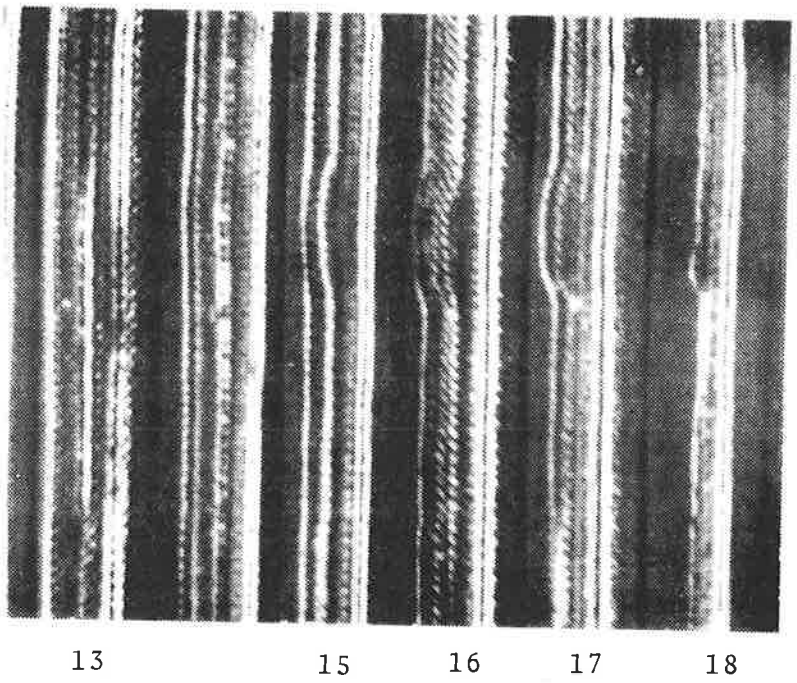


FIGURE 3-12. SHAPE DISCONTINUITY

4. ANALYSIS OF INSPECTION RESULTS

From the scoring forms prepared by the three evaluators the average scores for tread, belts, sidewalls and carcass and their sum(total) were obtained for each tire and tabulated. Also included in the tabulation were the tire number and the reported separation size (mm). For the control group, the data are presented in Table 4-1, ranked in decending order of total score. There was no unique correspondence between belt score and reported separation size; but three of the tires with low belt scores (5) had reported separations of 5 or 7 mm whereas only one tire with a higher belt score (6) had a separation longer than 3 mm.

For the 32 casings, the data are reported in Table 4-2. If we assign a belt-edge score of 7 or less as the threshold criterion which signifies a potential belt-edge separation based on the findings for the control group, then 16 casings are suspect. By lowering the threshold score to 6, 9 casings are suspect; by lowering it to 5, 4 casings are suspect. The validity of the methodology remains to be correlated with the results obtained from sectioning of the 32 casings.

TABLE 4-1. INSPECTION SCORES FOR THE CONTROL GROUP

TIRE NUMBER	TREAD	BELTS	SIDEWALLS	CARCASS	TOTAL	SEPARATION (millimeters)	RANK
2511	7	7	8	7	29	1	1
2515	7	6	8	7	28	7	2
2510	7	6	8	6	27	2	3
2512	6	6	8	6	26	3	4
2509	5	5	6	9	25	2	5
2514	6	5	7	6	24	7	6
2516	6	5	8	5	24	5	7
2517	6	6	7	5	24	3	8
2518	7	5	7	5	24	7	9
2513	6	5	7	5	23	5	10

TABLE 4-2. INSPECTION REPORT FOR THIRTY-TWO CASINGS

Tire No.	T	B	S	C	Total
2538	3	3	7	3	16
2527	5	4	8	5	22
2534	6	4	8	4	22
2535	8	5	8	5	26
2530	7	6	9	6	28
2532	8	9	6	6	29
2543	7	6	9	7	29
2529	8	7	8	8	31
2542	8	6	9	8	31
2525	9	7	8	8	32
2526	8	7	9	8	32
2528	9	7	8	8	32
2533	8	8	9	8	33
2536	9	6	9	9	33
2540	9	8	7	9	33
2544	9	6	9	9	33
2520	9	9	8	8	34
2523	9	9	8	8	34
2537	9	9	9	7	34
2539	9	8	8	9	34
2548	9	7	9	9	34
2522	9	8	9	9	35
2524	9	9	8	9	35
2541	9	9	8	9	35
2545	9	8	9	9	35
2546	9	8	9	9	35
2547	9	8	9	9	35
2550	9	8	9	9	35
2519	9	9	9	9	36
2521	9	9	9	9	36
2531	9	9	9	9	36
2549	9	9	9	9	36

T= tread, B= belts, S= sidewall
C= carcass

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