AIRCRAFT GROUND-FLOTATION INVESTIGATION

PART XI — DATA REPORT ON TEST SECTION 10

W. BRABSTON and W. HILL, JR.

FOREWORD

The investigation described herein constitutes one phase of studies conducted during 1964 and 1965 at the U. S. Army Engineer Waterways Experiment Station (WES) under U. S. Air Force Project No. 410-A, MIPR No. AS-4-177, "Development of Landing Gear Design Criteria for the CX-HLS Aircraft." (The CX-HLS is now designated C-5A.) This program was sponsored and directed by the Landing Gear Group, Air Force Flight Dynamics Laboratory, Research and Technology Division, Mr. R. J. Parker, Project Engineer.

These tests were conducted by personnel of the WES Flexible Pavement Branch, Soils Division, under the general supervision of Messrs. W. J. Turnbull, A. A. Maxwell, and R. G. Ahlvin, and the direct supervision of Mr. D. N. Brown. Other personnel actively engaged in this study were Messrs. C. D. Burns, D. M. Ladd, W. N. Brabston, H. H. Ulery, Jr., and W. J. Hill, Jr. This report was prepared by Messrs. Brabston and Hill.

Directors of WES during the conduct of this investigation and preparation of this report were Col. Alex G. Sutton, Jr., CE, and Col. John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

Publication of this technical documentary report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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ABSTRACT

This data report describes work undertaken as part of an overall program to develop ground-flotation criteria for the C-5A aircraft. A test section was constructed to a width adequate for two test lanes. Each lane was divided into two items having different subgrade CBR values and different traffic surfaces. Item 1 was surfaced with modified T11 aluminum landing mat and item 2 with M8 steel landing mat. Both traffic lanes were subjected to traffic of a single-wheel load assembly consisting of one 56x16, 32-ply aircraft tire inflated to 250 psi. A 50,000-lb load was used on one lane and a 75,000-lb load on the other lane.

The information reported herein includes layout of the test lanes, characteristics and print dimensions of the load assembly tires, and data collected on soil strengths, surface deformations and deflections, and drawbar pull. The traffic-coverage level is given at which each test item was considered failed.

CONTENTS

ILLUSTRATIONS AND TABLES

SUMMARY

Tests on Section 10 are one phase of a comprehensive research program to develop ground-flotation criteria for heavy cargo-type aircraft. Section 10 was laid out to accommodate two test lanes, lanes 23A and 23B, each of which was divided into two items having different subgrade CBR values and different traffic surfaces (figure 9). Item 1 was surfaced with modified T11 aluminum landing mat and item 2 with M8 steel landing mat. Both lanes were subjected to traffic of a single-wheel load assembly consisting of one 56x16, 32-ply aircraft tire inflated to 250 psi. A 50,000-lb load was used on lane 23A and a 75,000-lb load was used on lane 23B. Figure 11 gives pertinent tire-print dimensions and tire characteristics.

The lanes were trafficked to failure in accordance with criteria designated in Part I of this report. Data were recorded throughout testing to give a behavior history of each item. Using the test criteria mentioned above, it was possible to directly compare the effects of trafficking with different loads on a single-wheel assembly. Basic performance data are summarized in the following paragraphs.

Lane 23A

Item 1

The item was considered failed due to roughness at 32 coverages. The rated CBR of the item was 3.0.

Item 2

The item was considered failed due to roughness at 2 coverages. The rated CBR of the item was 3.8.

Lane 23B

Item 1

The item was considered failed due to roughness at 4 coverages. The rated CBR of the item was 3.5.

Item 2

The item was considered failed due to roughness after 2 passes of the load vehicle. The rated CBR of the item was 3.9.

AIRCRAFT GROUND-FLOTATION INVESTIGATION

PART XI DATA REPORT ON TEST SECTION 10

SECTION I: INTRODUCTION

The investigation reported herein is one phase of a comprehensive research program being conducted at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., as part of U. S. Air Force Project No. 410-A, MIPR No. AS-4-177, to develop ground-flotation criteria for the C-5A, a heavy cargo-type aircraft. Specifically, the tests reported herein were conducted to compare the trafficking effect on landing mat surfaces of a single-wheel landing-gear assembly carrying different test loads.

Prosecution of this investigation consisted of constructing two similar traffic lanes and subjecting them to traffic of a single-wheel tracking assembly with test loads of 50,000 and 70,000 lb.

This report presents a description of the test section and wheel assembly, and gives results of traffic. Equipment used, types of data and method of recording them, and general test criteria are summarized in this part; more complete explanations and illustrations appear in Part I of this report.

SECTION II: DESCRIPTION OF TEST SECTION AND LOAD VEHICLE

Description of Test Section

Test Section 10 (figure 9) was constructed within a roofed area in order to allow control of the subgrade CBR (California Bearing Ratio) in the test items. In construction of the test section, an 80- by 36-ft area was excavated to a depth of 24 in. and then backfilled in five compacted lifts witn a heavy clay soil (buckshot; classified as CH according to the Unified Soil Classification System, MIL-STD-619). The fill material used was a local clay with a plastic limit of 27, liquid limit of 58, and plasticity index of 31. Gradation and classification data for the subgrade material are given in Part I.

Two traffic lanes, each divided into two items, were constructed in the test section. Different subgrade strengths were obtained in the items (figure 9) by controlling the water content and compaction effort. Item 1 was surfaced with modified T11 aluminum landing mat and item 2 with M8 steel landing mat (figure 10). The landing mats used are described and illustrated in Part I.

Load Vehicle

The load vehicle used for trafficking Section 10 is shown in figure 2. Load cart construction, details of linkage between the load compartment and prime mover, and method of applying load are explained in Part I. For trafficking lanes 23A and 23B, a single-wheel assembly was used with 50,000- and 75,000-lb loads, respectively. A 56x16, 32-ply aircraft tire with a 250-psi tire inflation pressure was used on both lanes. Tire-print data and pertinent tire characteristics are given in figure 11.

SECTION III: APPLICATION OF TRAFFIC, FAILURE CRITERIA, AND DATA COLLECTED

Application of Traffic

The load vehicle was operated to produce uniform traffic coverage on the test lanes. The load cart was driven forward and backward along the same track, then shifted laterally and the forward-backward operation repeated. In this manner, two coverages of traffic were applied to the test lane as the vehicle progressed from one side of the lane to the other. Figure 1 is representative of the general method of applying uniform coverages to the test lanes.

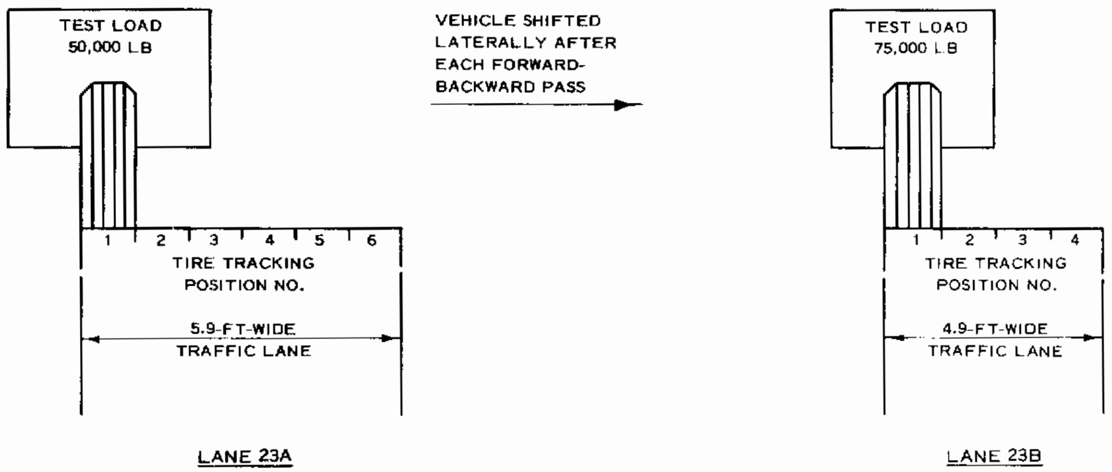


Figure 1. Application of traffic on Test Section 10

Failure Criteria and Data Collected

Failure criteria used in this investigation and descriptive terms used in presentation and discussion of data in all parts in this report are presented in Part I. A general outline of types of data collected is given in the following paragraphs. Details on apparatus and procedure for obtaining specific measurements are given in Part I.

CBR, water content, and dry density

CBR, water content, and dry density of the subgrade were measured for each test item prior to application of traffic, at intermediate coverage levels, and at failure. After traffic was concluded on an item, a measure of subgrade strength termed "rated CBR" was determined. Rated CBR is generally the average CBR value obtained from all the determinations made in the top 12 in. of soil during the test life of an item. In certain instances, extreme or irregular values may be ignored if the analyst decides that they are not properly representative.

Surface roughness, or differential deformation

Surface roughness, or differential deformation, measurements were made using a 10-ft straightedge at various traffic-coverage levels on all items. Dishing effects of individual mat panels were recorded.

Deformations

Deformations, defined as permanent cumulative surface changes in cross section or profile of an item, were charted by means of level readings at pertinent traffic-coverage levels.

Deflection

Deflection of the test surface under an individual static load of the tracking assembly was measured at various traffic-coverage levels. Level readings on the item surface on each side of the load wheel and on a pin and cap device directly beneath the load wheel provided deflection data. All mat deflection was for practical purposes recoverable, i.e. total deflection equaled elastic (spring-back) deflection. The pin and cap device for measuring deflection directly beneath load wheels was applied to the subgrade through a hole (existing or cut) in the mat.

Rolling resistance

Rolling resistance, or drawbar pull, measurements were performed with the load vehicle over each test item at designated coverage levels. Three types of drawbar measurements were taken: (a) maximum force required to overcome static inertia and commence forward movement of the load cart, termed "initial DBP"; (b) average force required to maintain a constant speed once the load vehicle is in motion, termed "rolling DBP"; and (c) maximum force obtained during the constant speed run, termed "peak DBP."

Mat breaks

Mat breaks were inspected, classified by type, and recorded at various coverage levels.

SECTION IV: BEHAVIOR OF ITEMS UNDER TRAFFIC AND TEST RESULTS

Lane 23A

Behavior of items under traffic

Item 1. Figure 3 shows item 1 prior to traffic. During the first 2 coverages, a large number of center-line rivets sheared. Traffic was continued to 32 coverages at which time the item was considered failed due to roughness (figure 4). The rated CBR for the item was 3.0.

Item 2. Figure 5 shows item 2 prior to traffic. The item deformed rapidly under traffic and at 2 coverages was considered failed due to roughness (figure 6). The rated CBR for the item was 3.8.

Test results

Results of trafficking lane 23A are summarized in table 1. Soil test data are given in table 2. Table 1 contains drawbar pull values for the load vehicle operated over an asphalt-paved strip for comparison with drawbar pull values recorded on the test lane.

Item 1. Item 1 was considered failed due to roughness at 32 coverages. A large number of center-line rivet failures occurred with trafficking. The following information was obtained from traffic tests on item 1.

a. Roughness. Table 1 shows differential deformation measurements at 2 and 32 coverages. At failure the average transverse, diagonal, and longitudinal differential deformations were 3.09, 2.40, and 1.03 in., respectively. Dishing of individual mat panels averaged 0.36 in. at failure.

b. Deformations. Figure 12 shows average cross-section deformations at 2 and 32 coverages for each of two typical mat runs. Figure 13 shows a profile plot of the item at the same coverage levels. Severe transverse differential deformations are evident and were the principal roughness factor contributing to failure.

c. Deflection. Average elastic mat deflections under static load of the load wheel assembly for three positions of the assembly relative to mat end joints are plotted in figure 14. Deflection at 32 coverages was greatest for each position. Elastic soil deflection at failure was 1.6 in.

d. Rolling resistance. Drawbar pull values recorded at 2 and 32 coverages are shown in table 1. No significant change in drawbar value occurred with trafficking.

e. Mat breaks. The number and type of mat breaks resulting from trafficking are given in table 1. A large number of center-line rivet failures were recorded at failure.

Item 2. Item 2 was considered failed due to roughness at 2 coverages. The following information was obtained from traffic tests on item 2.

a. Roughness. Table 1 shows differential deformations a 2 coverages. Average values at failure were 1.22, 2.00, and 1.81 in. for transverse, diagonal, and longitudinal measurements, respectively. Dishing of individual mat panels was slight and averaged 0.25 in. at failure.

b. Deformations. Average cross-section deformations at 2 coverages for two typical mat runs are plotted in figure 12. A very significant factor in cross-section deformations was the mat uplift along both sides of the lane. Figure 13 shows the longitudinal irregularities that contributed to early failure of the item.

c. Deflection. Average elastic mat deflections under static load of the wheel assembly are plotted in figure 14 for three positions of the assembly relative to mat end joints.

d. Rolling resistance. Drawbar pull values measured at 2 coverages are shown in table 1.

e. Mat breaks. No mat breaks were observed after the item failed. The M8 mat conformed to the shape of the deformed subgrade without breaking.

Lane 23B

Behavior of items under traffic

Item 1. Figure 3 shows item 1 prior to traffic. The mat surface deformed and many rivet failures occurred with initial coverages. The item was considered failed due to roughness at 4 coverages with the primary failure factor being excessive transverse differential deformations (figure 7). The rated CBR for the item was 3.5.

Item 2. Figure 5 shows item 2 prior to traffic. The subgrade was severely deformed with the first pass of the load vehicle. The item was considered failed due to roughness after 2 passes (figure 8). The rated CBR for the item was 3.9.

Test results

Results of trafficking lane 23B are summarized in table 1. Soil test data are given in table 2. Table 1 contains drawbar pull values for the load vehicle operated over an asphalt-paved strip for comparison with drawbar pull values recorded on the test lane.

Item 1. Item 1 was considered failed due to roughness at 4 coverages. A large number of center-line rivet failures occurred with trafficking. The following information was obtained from traffic tests on item 1.

a. Roughness. Table 1 shows the differential deformations that existed at failure of the item. The principal roughness factor was transverse differential deformation which averaged 3.47 in. at failure. Diagonal and longitudinal differential deformations averaged 3.19 and 1.03 in., respectively. Dishing of individual mat panels was slight, averaging 0.25 in. at failure.

b. Deformations. Figure 12 shows average cross-section deformations at 4 coverages for two typical mat runs. Mat uplift at the lane edges contributed to the cross-section deformation. No profile deformation data were obtained on this item.

c. Deflection. Average elastic mat deflections under static load of the wheel assembly for three positions of the assembly relative to mat end joints are plotted in figure 14. Only small differences in deflection occurred for the different positions.

d. Rolling resistance. Drawbar pull values at 4 coverages are shown in table 1.

e. Mat breaks. The number and type of mat breaks resulting from traffic are shown in table 1. Center-line rivet failures far exceeded other types of mat breaks.

Item 2. Item 2 was considered failed due to roughness after 2 passes of the load vehicle.

a. Roughness. Table 1 shows maximum and average values of transverse differential deformation at 2 passes. The average measurement was 2.37 in. No measurements were made of longitudinal and diagonal differential deformations.

b. Deformations, deflection, and rolling resistance. No measurements were made of cross-section and profile deformations, deflections, or rolling resistance.

c. Mat breaks. No breaks occurred in the M8 mat with trafficking.

SECTION V: PRINCIPAL FINDINGS

From the foregoing discussion, the principal findings relating test load, wheel assembly, tire inflation pressure, surface type, subgrade CBR, and traffic coverages are as follows:

Load, Wheel Assembly, and Tire Pressure	Type of Surface	Rated Subgrade CBR	Coverages at Failure
50,000-lb load; single-wheel assembly; 56x16, 32-ply tire with 250-psi inflation pressure	Modified T11 aluminum mat	3.0	32
	M8 steel landing mat	3.8	2
75,000-lb load; single-wheel assembly; 56x16, 32-ply tire with 250-psi inflation pressure	Modified T11 aluminum mat	3.5	4
	M8 steel landing mat	3.9	2 passes

TABLE 1

SUMMARY OF TRAFFIC DATA, TEST SECTION 10

Test Item	Cover-ages	Rated CBR	No. of Mat Breaks*					Differential Deformation (in.)						Dishing (in.)		Drawbar Pull (kips)			Average Total Deflection (in.) with Center Line of Assembly Located on			Elastic Subgrade Deflection (in.)	Remarks
			A	B	C	D	E	Longitudinal Max	Longitudinal Avg	Transverse Max	Transverse Avg	Diagonal Max	Diagonal Avg	Max	Avg	Initial	Peak	Rolling	Quarter Point of Panel	Half Point of Panel	Joint of Panel		
Lane 23A																							
1 Modified T11 aluminum landing mat	2	3.0	--	7	93	--	--	0.63	0.59	0.88	0.72	0.75	0.65	0.38	0.31	8.7	4.1	2.4	1.6	1.4	2.0	--	Failed due to roughness at 32 coverages
	32		5	67	226	7	--	1.13	1.03	3.38	3.09	2.75	2.40	0.44	0.36	8.7	5.3	2.9	1.9	2.2	3.0	1.6	
2 M8 steel landing mat	2	3.8	--	--	--	--	--	2.25	1.81	1.50	1.22	2.25	2.00	0.25	0.25	7.7	5.8	4.7	3.3	2.2	2.5	1.9	Failed due to roughness at 2 coverages
Asphalt test strip			--	--	--	--	--	--	--	--	--	--	--	--	--	7.1	3.1	1.0	--	--	--	--	
Lane 23B																							
1 Modified T11 aluminum landing mat	4	3.5	--	24	249	26	2	1.13	1.03	4.00	3.47	3.50	3.19	0.25	0.25	12.1	8.9	6.1	2.7	2.7	2.9	2.0	Failed due to roughness at 4 coverages
2 M8 steel landing mat	2 passes	3.9	--	--	--	--	--	--	--	3.00	2.37	--	--	--	--	--	--	--	--	--	--	--	Failed due to roughness at 2 passes
Asphalt test strip			--	--	--	--	--	--	--	--	--	--	--	--	--	5.5	2.4	1.1	--	--	--	--	

Note: A single-wheel assembly with a 56x16, 32-ply tire inflated to 250 psi was used for trafficking lanes 23A and 23B. The test loads were 50 and 75 kips for lanes 23A and 23B, respectively.

* Break types are defined and illustrated in Part I.

TABLE 2

SUMMARY OF CBR, DENSITY, AND WATER CONTENT DATA, TEST SECTION 10

Test Item*	Type of Surface	No. of Traffic Coverages	Depth (in.)	CBR	Water Content (%)	Dry Density (lb/cu ft)
			Lane 23A			
1	Modified T11 aluminum landing mat	0	0	2.7	29.6	89.9
			6	3.2	30.3	88.6
			12	3.1	30.2	89.7
			18	3.9	27.6	92.4
		32	0	2.8	30.9	89.5
			6	3.1	29.5	91.5
			12	2.8	30.5	90.2
			18	3.8	26.8	93.3
2	M8 steel landing mat	0	0	3.8	28.6	90.8
			6	3.5	28.2	91.7
			12	3.3	28.3	91.4
			18	3.6	30.1	89.4
		2	0	3.7	30.0	89.3
			6	4.5	28.8	91.9
			12	4.0	28.6	92.4
			18	4.4	30.4	89.7
			Lane 23B			
1	Modified T11 aluminum landing mat	0	0	2.7	29.6	89.9
			6	3.2	30.3	88.6
			12	3.1	30.2	89.7
			18	3.9	27.6	92.4
		4	0	3.3	30.3	89.4
			6	4.5	28.6	92.8
			12	4.1	28.6	90.9
			18	3.9	27.1	92.9
2	M8 steel landing mat	0	0	3.8	28.6	90.8
			6	3.5	28.2	91.7
			12	3.3	28.3	91.4
			18	3.6	30.1	89.4
		2 passes	0	3.4	29.5	90.9
			6	3.5	29.4	91.5
			12	5.8	28.9	91.5
			18	5.4	29.1	92.6

Note: For coverage-failure information, see remarks column in table 1.
* Subgrade material was heavy clay (buckshot; classified as CH) in all items.

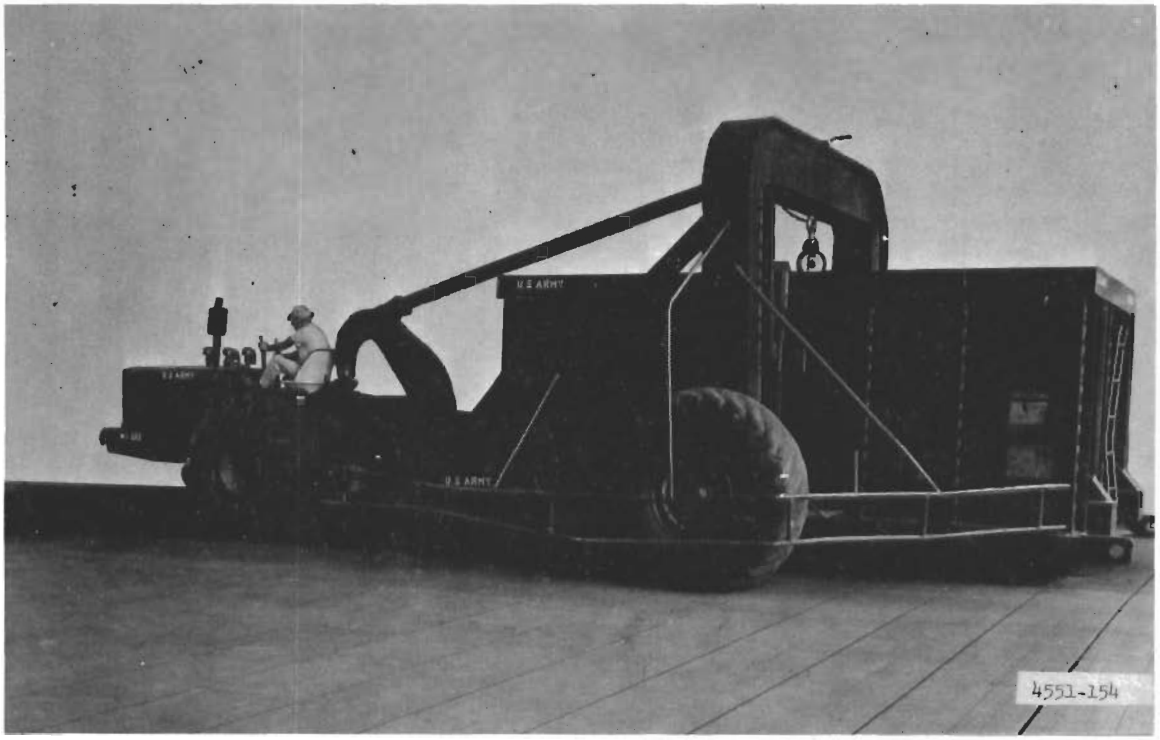


Figure 2. Test load vehicle

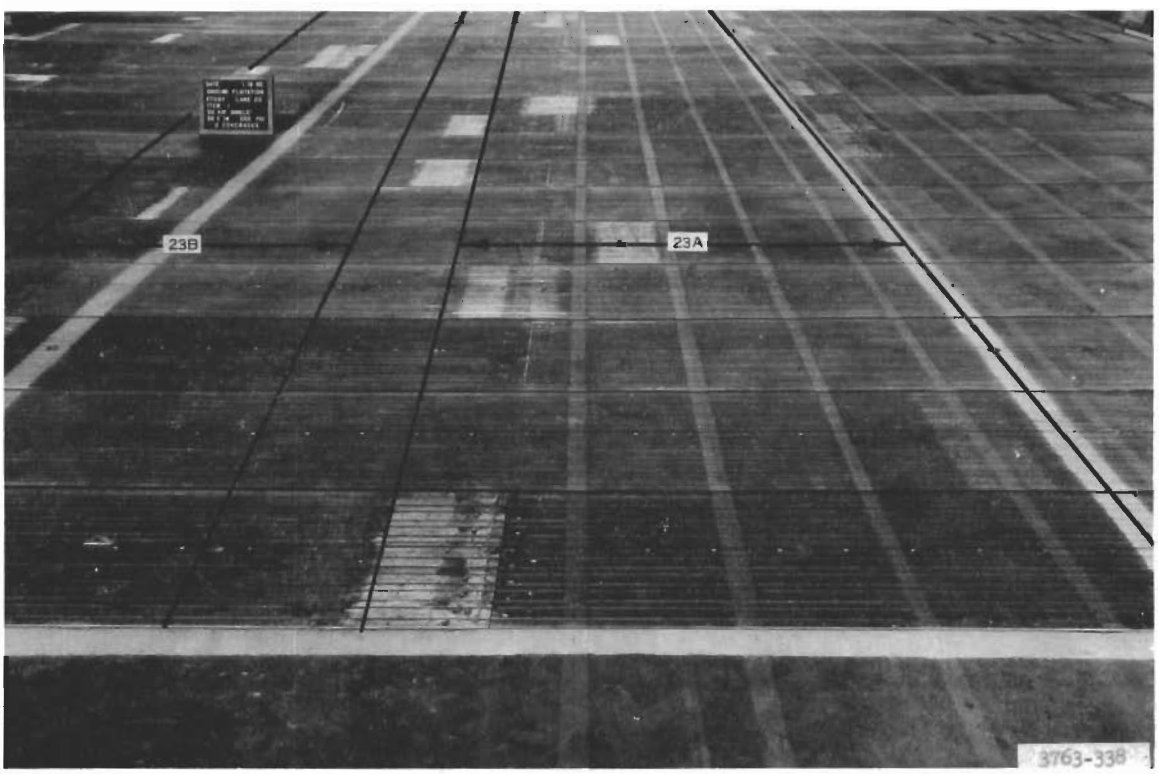


Figure 3. Lanes 23A and 23B, item 1, prior to traffic

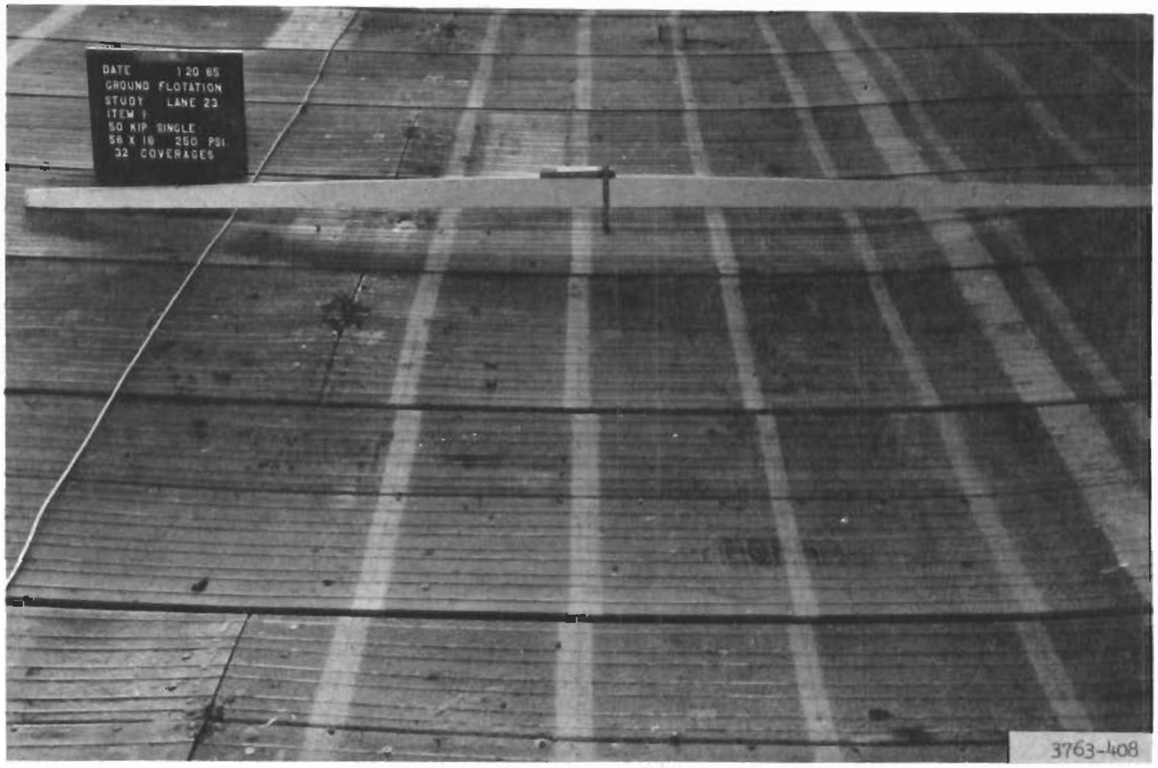


Figure 4. Lane 23A, item 1. Transverse straightedge shows roughness at 32 coverages (failure)

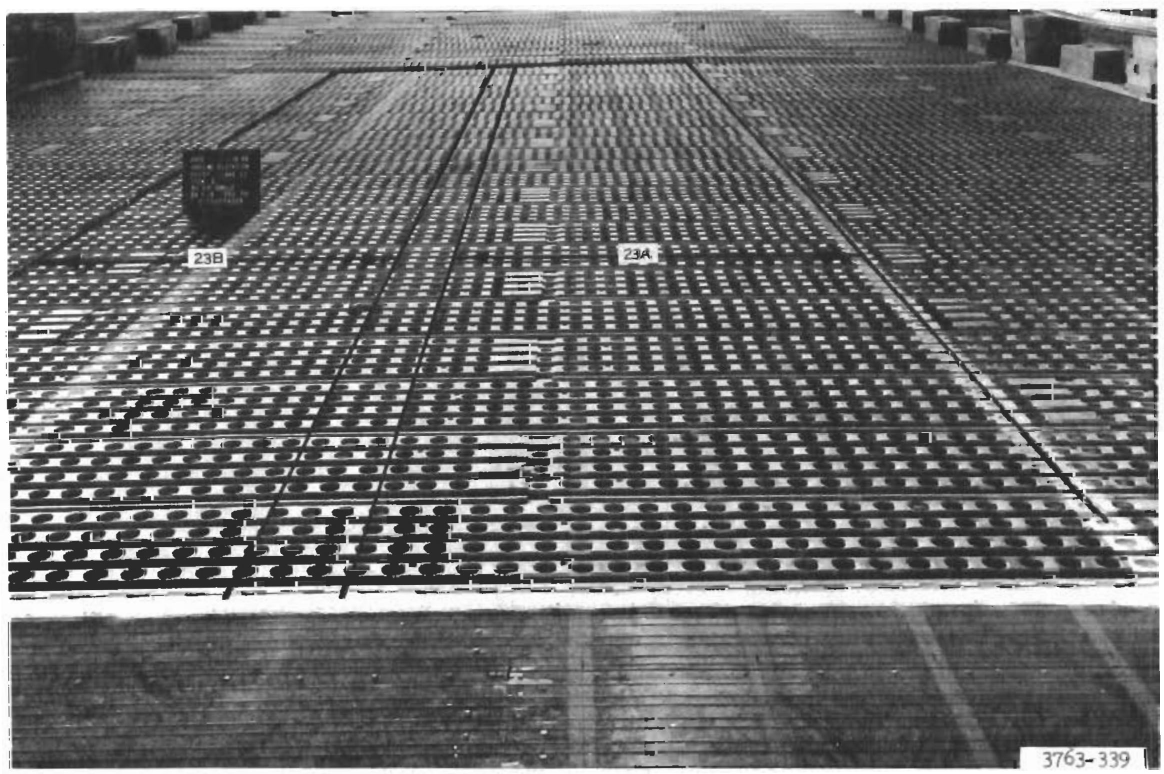


Figure 5. Lanes 23A and 23B, item 2, prior to traffic

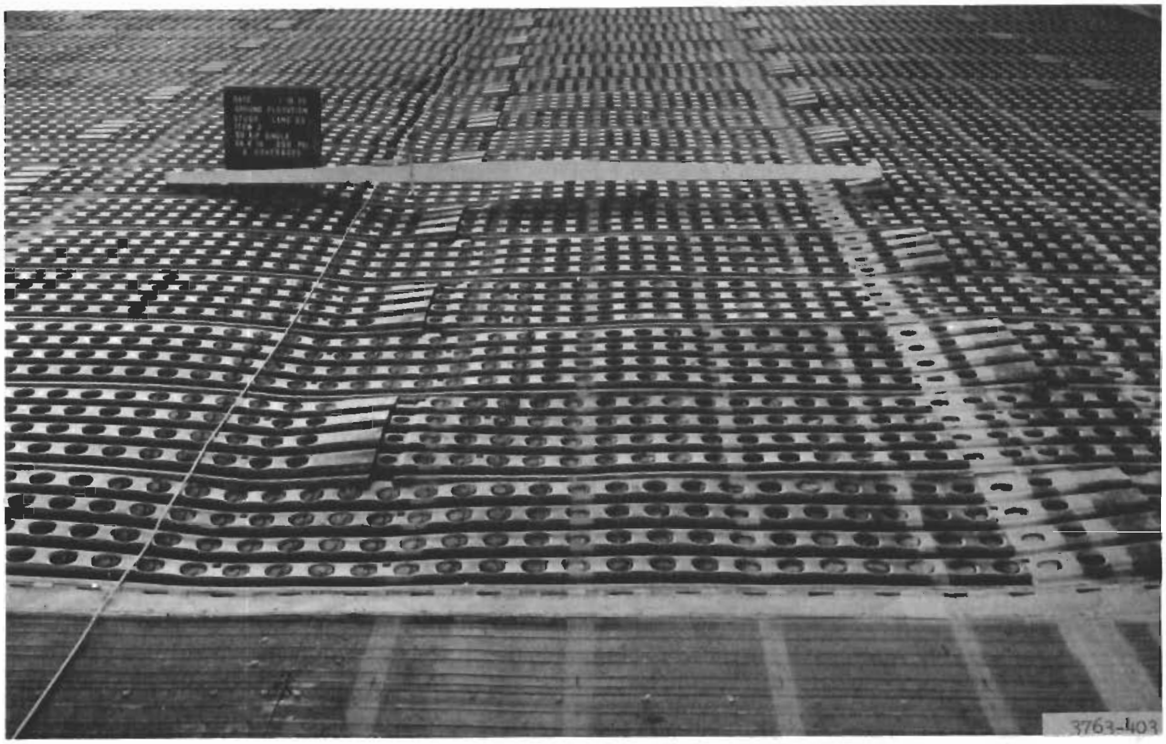


Figure 6. Lane 23A, item 2. Transverse straightedge shows roughness at 2 coverages (failure)

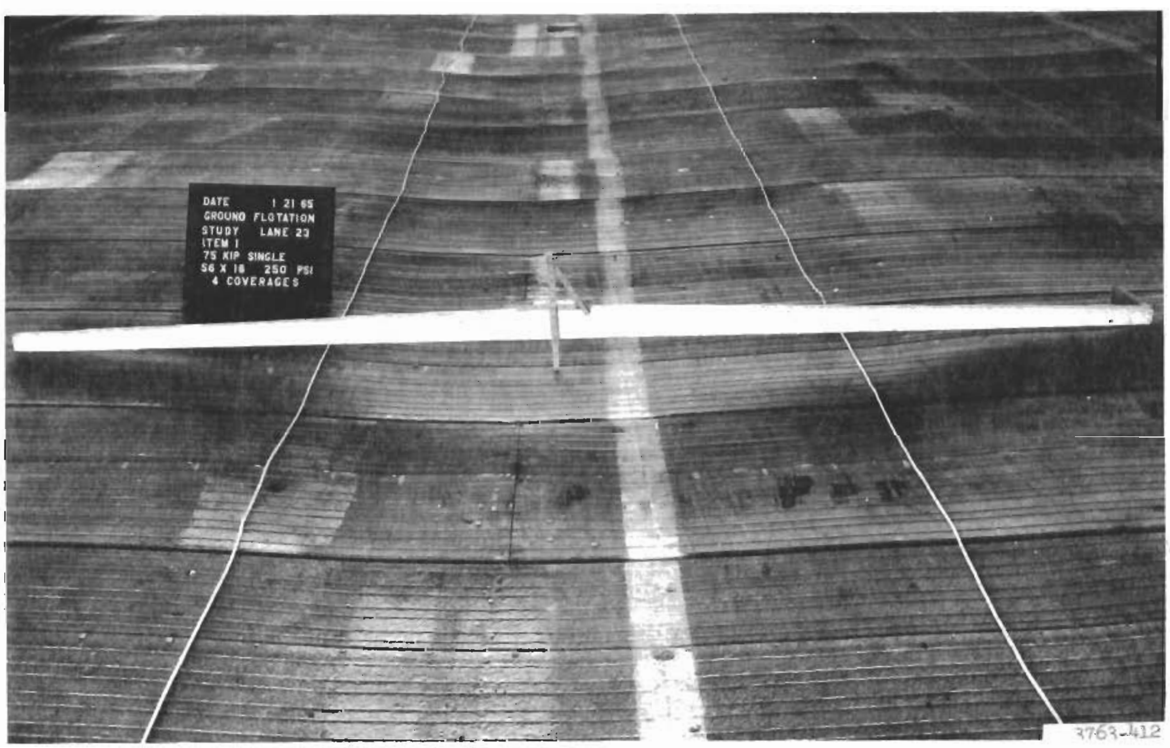


Figure 7. Lane 23B, item 1. Transverse straightedge shows roughness at 4 coverages (failure)

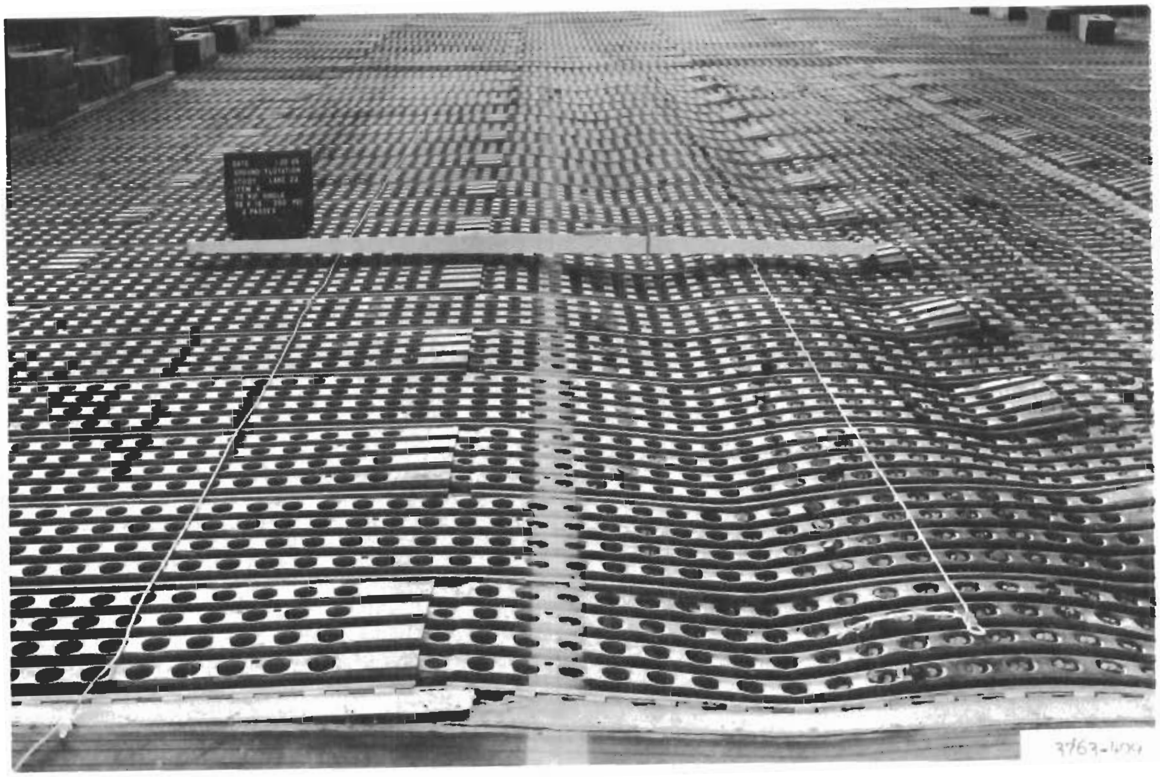
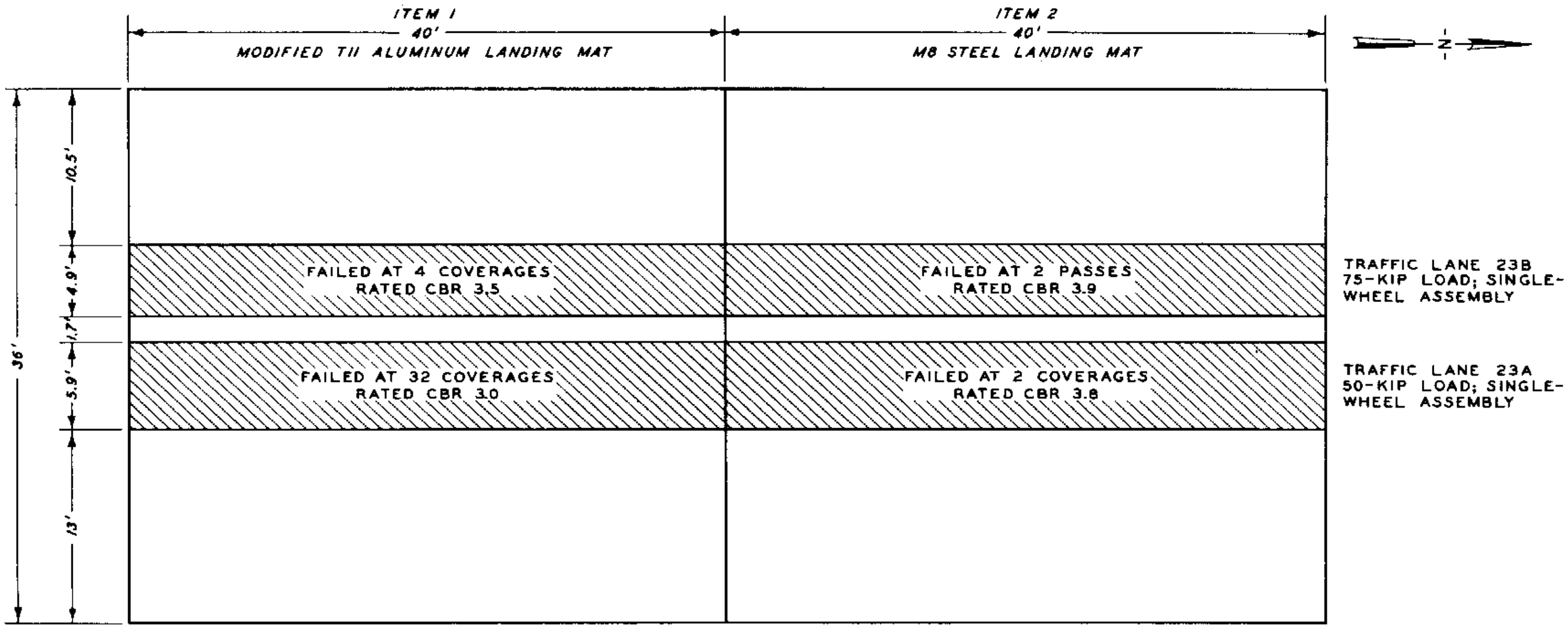


Figure 8. Lane 23B, item 2. Transverse straightedge shows roughness at 2 passes (failure)



LAYOUT OF TEST SECTION 10
AND SUMMARY OF TEST RESULTS

56 X 16, 32-PLY TIRES

250-PSI INFLATION PRESSURE

Figure 9

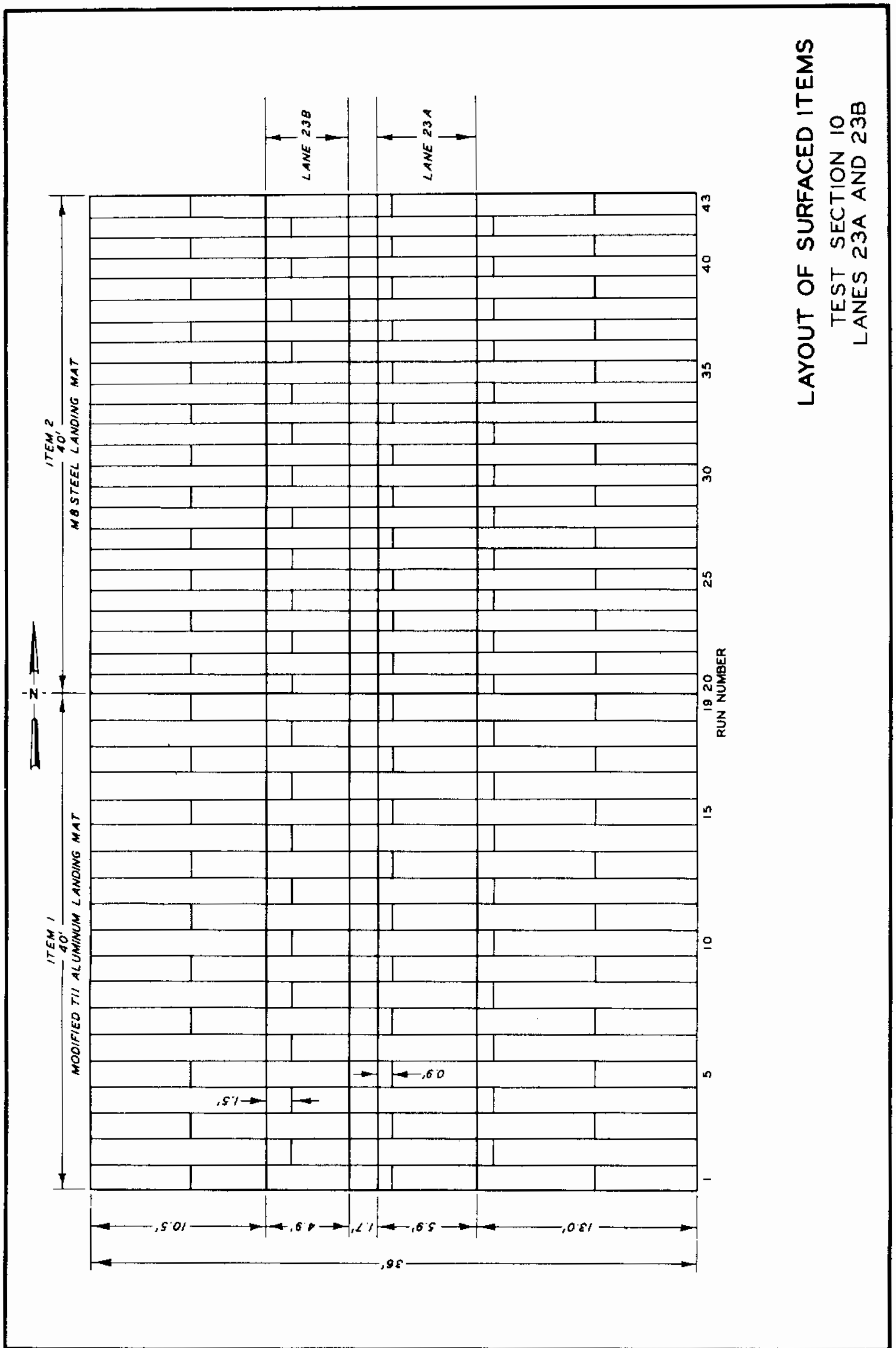
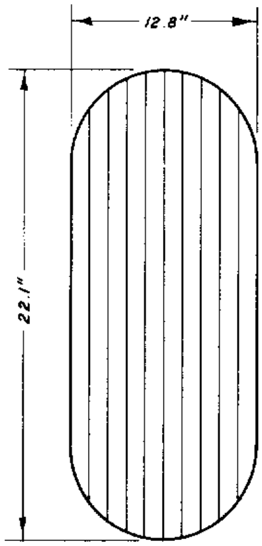
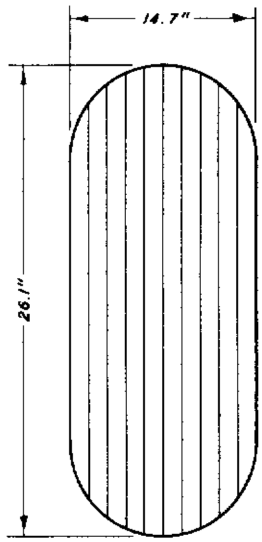

LAYOUT OF SURFACED ITEMS
TEST SECTION 10
LANES 23A AND 23B
LANE 23B
LANE 23A
ITEM 2
40'
M8 STEEL LANDING MAT
ITEM 1
40'
MODIFIED T11 ALUMINUM LANDING MAT
N
RUN NUMBER
1
5
10
15
19 20
25
30
35
40
43
1.5'
0.9'
10.5'
4.9'
1.7'
5.9'
13.0'
36'

Figure 10



CONTACT AREA, SQ IN.	228
CONTACT PRESSURE, PSI	219
INFLATION PRESSURE, PSI	250
DEFLECTION, %	25
GROSS ASSEMBLY LOAD, LB	50,000

LANE 23A



CONTACT AREA, SQ IN.	324
CONTACT PRESSURE, PSI	232
INFLATION PRESSURE, PSI	250
DEFLECTION, %	39
GROSS ASSEMBLY LOAD, LB	75,000

LANE 23B

TIRE-PRINT DIMENSIONS AND TIRE CHARACTERISTICS
56 X 16, 32-PLY TIRES
TEST SECTION 10
LANES 23A AND 23B

Figure 11

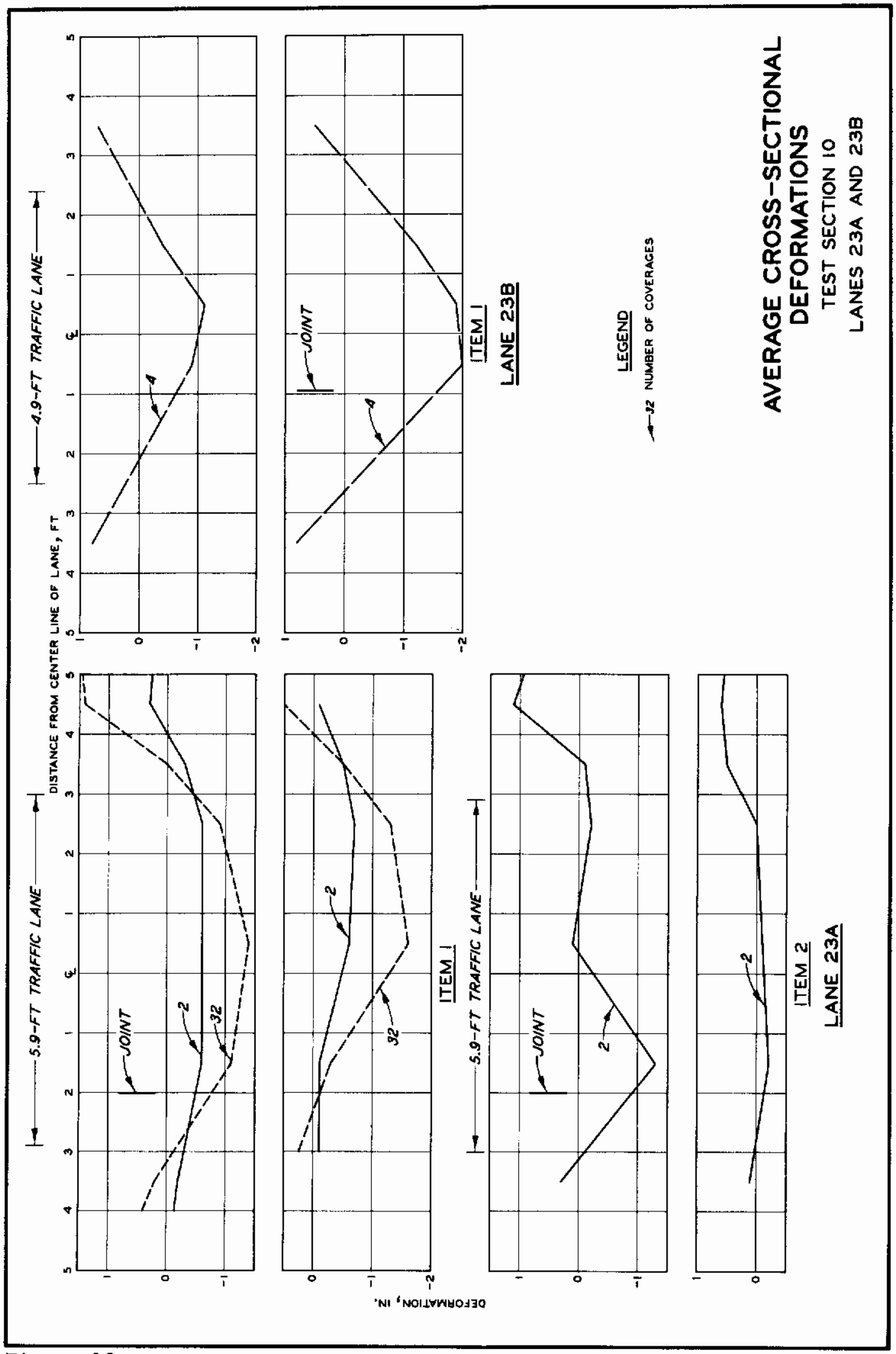
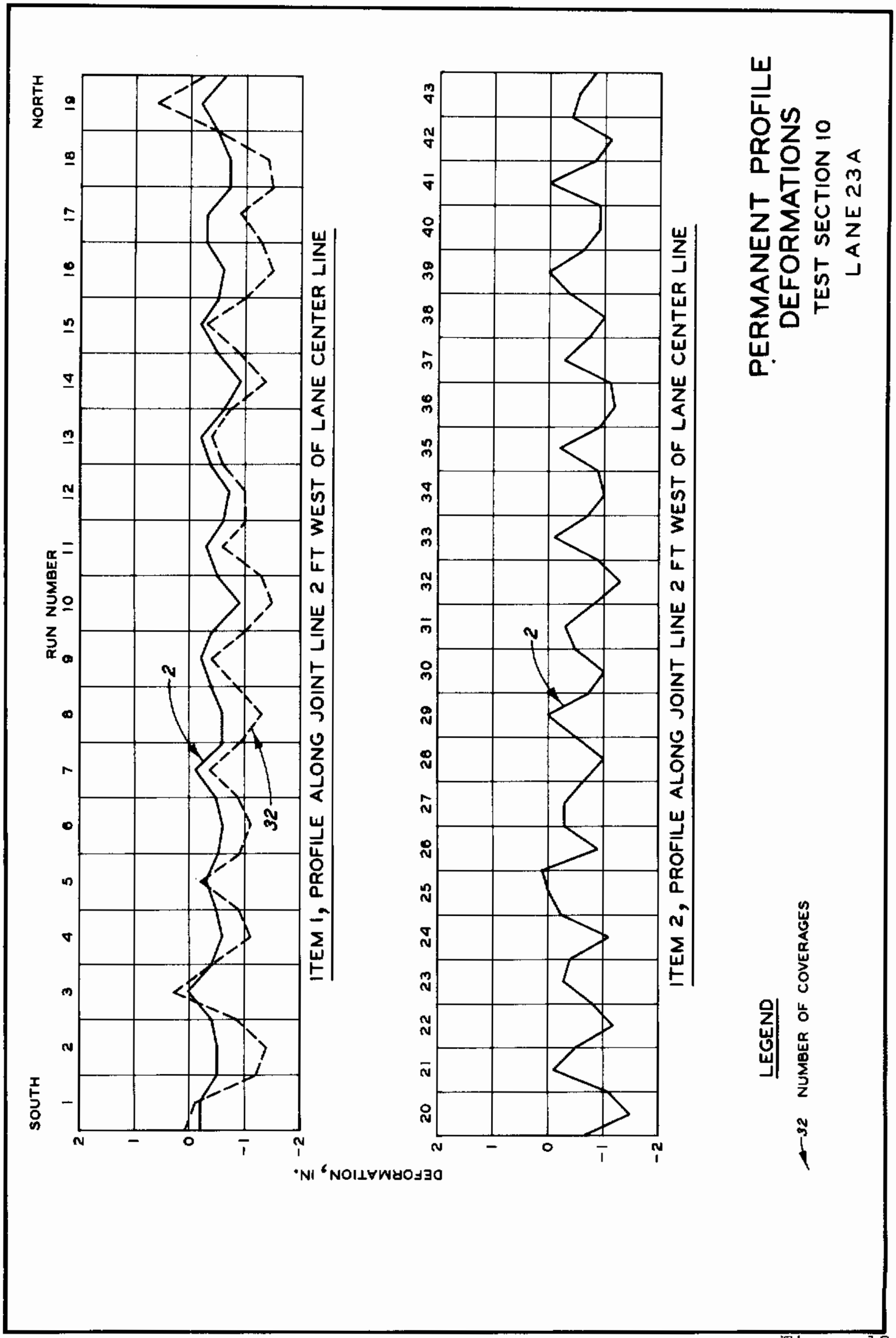

AVERAGE CROSS-SECTIONAL DEFORMATIONS
TEST SECTION 10
LANES 23A AND 23B
LEGEND
32 NUMBER OF COVERAGES
ITEM 1
LANE 23B
ITEM 1
ITEM 2
LANE 23A
4.9-FT TRAFFIC LANE
5.9-FT TRAFFIC LANE
5.9-FT TRAFFIC LANE
JOINT
DISTANCE FROM CENTER LINE OF LANE, FT
DEFORMATION, IN.

Figure 12



PERMANENT PROFILE DEFORMATIONS
TEST SECTION 10
LANE 23 A
ITEM 1, PROFILE ALONG JOINT LINE 2 FT WEST OF LANE CENTER LINE
ITEM 2, PROFILE ALONG JOINT LINE 2 FT WEST OF LANE CENTER LINE
RUN NUMBER
SOUTH
NORTH
DEFORMATION, IN.
LEGEND
32 NUMBER OF COVERAGES

Figure 13

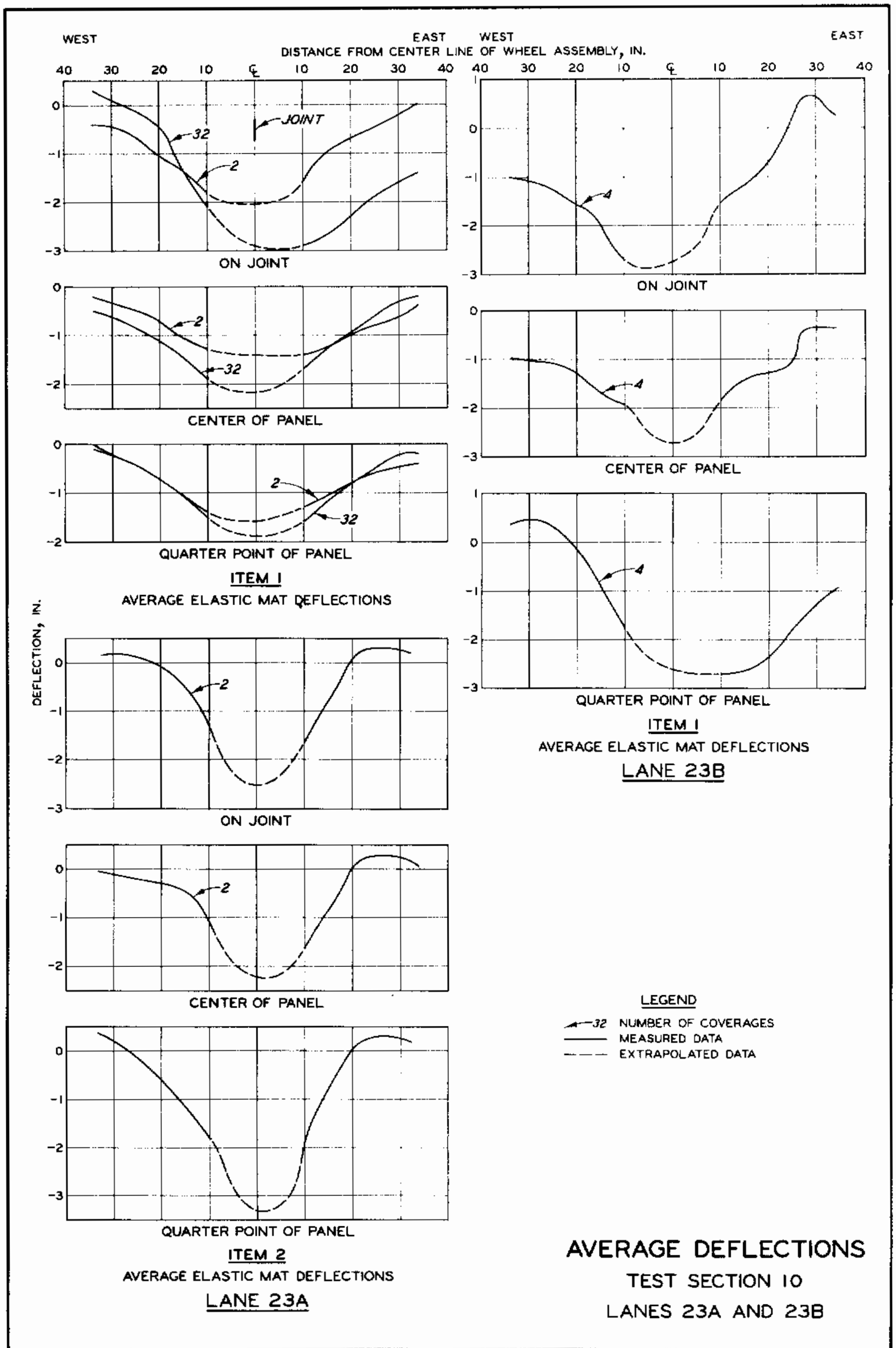

WEST
EAST
WEST
EAST
DISTANCE FROM CENTER LINE OF WHEEL ASSEMBLY, IN.
40 30 20 10 ℄ 10 20 30 40
DEFLECTION, IN.
JOINT
32
2
4
ON JOINT
CENTER OF PANEL
QUARTER POINT OF PANEL
ITEM 1
AVERAGE ELASTIC MAT DEFLECTIONS
ITEM 2
AVERAGE ELASTIC MAT DEFLECTIONS
LANE 23A
LANE 23B
LEGEND
32 NUMBER OF COVERAGES
MEASURED DATA
EXTRAPOLATED DATA
AVERAGE DEFLECTIONS
TEST SECTION 10
LANES 23A AND 23B

Figure 14

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
U. S. Army Engineer Waterways Experiment Station

2a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b. GROUP

3. REPORT TITLE
Aircraft Ground-Flotation Investigation
Part XI Data Report on Test Section 10

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Final Technical Report

5. AUTHOR(S) *(Last name, first name, initial)*
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Air Force Flight Dynamics Laboratory
Research and Technology Division
AF Systems Command, WPAFB, Ohio

13. ABSTRACT

This data report describes the results of work undertaken as part of an overall program to develop ground-flotation criteria for the C-5A aircraft.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Aircraft Ground Flotation						
Rolling Resistance						
Rear Area Airfields						
Support Area Airfields						
Forward Area Airfields						
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