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PART XV

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AIRCRAFT GROUND-FLOTATION INVESTIGATION

PART XV — DATA REPORT ON TEST SECTION 14A

J. WATKINS and G. HAMMITT II

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

TECHNICAL REPORT AFFDL-TR-66-43, PART XV

SEPTEMBER 1966

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200 - December 1966 - C0192-14-262

AIRCRAFT GROUND-FLOTATION INVESTIGATION

PART XV — DATA REPORT ON TEST SECTION 14A

J. WATKINS and G. HAMMITT II

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, H. H. Ulery, Jr., J. E. Watkins, G. M. Hammitt II, and W. J. Hill, Jr. This report was prepared by Messrs. Watkins and Hammitt.

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.

KENNERLY H. DIGGES
Chief, Mechanical Branch
Vehicle Equipment Division
AF Flight Dynamics Laboratory

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; both lanes were unsurfaced. Traffic was applied to both lanes using a 25,000-lb load on a single-wheel assembly, and an inflation pressure of 250 psi. The two tires originally selected for these tests were a 30x11.5, 24-ply aircraft tire and a 20x20, 22-ply aircraft tire. However, because of the extreme overinflation of the 20x20 tire, tire failure occurred after 1 pass of the load vehicle, and the tests were completed using a 56x16, 32-ply aircraft tire.

This report presents the data collected on soil strengths, and surface deformations and deflections. The traffic-coverage level at which failure occurred on each test item is also given.

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ILLUSTRATIONS AND TABLES

SUMMARY

Tests on Section 14A are one phase of a comprehensive research program to develop ground-flotation criteria for heavy cargo-type aircraft. Section 14A was laid out to accommodate two test lanes, lanes 32 and 32A, each of which was divided into two items having different subgrade CBR values. Both lanes were unsurfaced. Traffic was applied to both lanes using a 25,000-lb load on a single-wheel assembly, and an inflation pressure of 250 psi. The two tires originally selected for these tests were a 30x11.5, 24-ply aircraft tire and a 20x20, 22-ply aircraft tire. However, because of the extreme overinflation of the 20x20 tire, tire failure occurred after one pass of the load vehicle, and the tests were completed using a 56x16, 32-ply aircraft tire. Figure 14 gives pertinent tire-print dimensions and tire characteristics.

The lanes were trafficked to failure in accordance with the 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 size tires. Basic performance data are summarized in the following paragraphs.

Lane 32

Item 2

The item was considered failed due to rutting at 1 pass of the load wheel. The rated CBR of the item was 10.0.

Item 3

The item was considered failed due to rutting at 6 coverages of the test load. The rated CBR of the item was 14.0.

Lane 32A

Item 2

The item was considered failed due to roughness at 10 coverages. The rated CBR of the item was 10.0.

Item 3

The item was considered failed due to roughness at 60 coverages. The rated CBR of the item was 14.0.

AIRCRAFT GROUND-FLOTATION INVESTIGATION

PART XV DATA REPORT ON TEST SECTION 14A

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 410-A, MIPR No. AS-4-177, to develop ground-flotation criteria for the C-5A, a heavy cargo-type aircraft. Specifically, the tests reporte herein are part of a series of tests to determine the degree of interac ion of the wheels of multiple-wheel landing-gear assemblies on landing mat and unsurfaced soils under various conditions of loading.

Prosecution of this investigation consisted of constructing two similar traffic lanes and subjecting them to traffic of a single-wheel, 25,000-lb load with different tire sizes.

This report presents a description of the test section and gives results of traffic. Equipment used, types of data and method of recording them, and general test criteria are explained and illustrated in Part I of this report.

SECTION II: DESCRIPTION OF TEST SECTION AND LOAD VEHICLES

Description of Test Section

The test section (figure 13) was constructed within a roofed area in order to allow control of the subgrade CBR (California Bearing Ratio) in the test items. The test section was located on the same site as Test Section 14 and the surface of previously used items 2 and 3 of Section 14 was simply smoothed out for tests on this section. Item 1 of Section 14 was not reuseable. The fill material consisted of a heavy clay soil (buckshot; classified as CH according to the Unified Soil Classification System, MIL-STD-619). The fill material 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. The subgrade strengths used were those existing after smoothing out of Test Section 14. No attempt was made to construct a subgrade with a given CBR value. Both items 2 and 3 were unsurfaced.

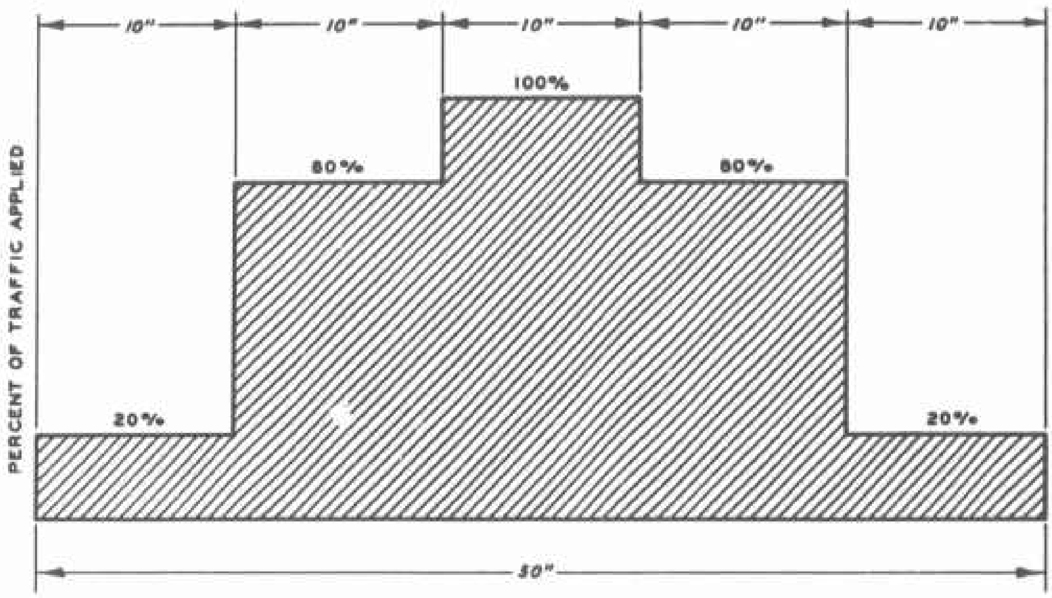
Load Vehicles

The load vehicles used for trafficking test lanes in Section 14A are shown in figures 2 and 3. Load-cart construction, details of linkage between the load compartment and prime mover, and methods of applying load are explained in Part I. For trafficking lanes 32 and 32A, a single-wheel assembly was used with a 25,000-lb load and an inflation pressure of 250 psi. A 30x11.5, 24-ply tire and a 56x16, 32-ply tire were used on lanes 32 and 32A, respectively. Tire-print data and pertinent tire characteristics are given in figure 14.

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

Application of Traffic

Traffic was applied to the test lanes in a nonuniform pattern with intensity of traffic being varied within each lane to produce three zones of approximately 100, 80, and 20 percent traffic coverage. Traffic was distributed within a traffic lane to simulate as nearly as possible the bell-shaped traffic distribution curve which results from the wander of aircraft from the lane center line. The coverage levels referred to in the tables and text herein are the total number of coverages applied to the 100 percent coverage zone. The corresponding number of coverages applied to the outer traffic zones is proportional to the percentage factor for the respective zones, as shown in figure 1.



LANES 32 AND 32A

Figure 1. Traffic distribution pattern

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 and rut depth measurements were made using a 10-ft straightedge at various traffic-coverage levels on all items.

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 wheels, and on a pin and cap device directly beneath a load wheel provided deflection data. Both total (for a single loading) and elastic (recoverable) deflections were measured.

SECTION IV: BEHAVIOR OF ITEMS UNDER TRAFFIC AND TEST RESULTS

Lane 32

Behavior of items under traffic

Item 2. Figure 4 shows item 2 prior to failure. The item was considered failed due to rutting after 1 pass of the load vehicle (figure 5). The rated CBR was 10.0.

Item 3. Figure 6 shows item 3 prior to failure. The item was considered failed due to rutting at 6 coverages (figure 7). The rated CBR was 14.0.

Test results

Traffic test results are summarized in table 1. Soil test data are shown in table 2.

Item 2. Item 2 was considered failed due to rutting after 1 pass. The following information was obtained from traffic tests on item 2.

a. Roughness. The maximum and average rut depths in item 2 at failure were 5.75 and 4.78 in., respectively.

b. Deformation. Figures 15 and 16 show cross-section and profile plots, respectively, for 1 pass of the test load. The maximum permanent deformation at failure measured 3.6 in.

c. Deflection. Only pin and cap deflections were measured in these tests. At failure the maximum total deflection was 3.6 in. The elastic soil deflection at failure was 0.6 in.

Item 3. Item 3 was considered failed due to roughness at 6 coverages. The following information was obtained from traffic tests on item 3.

a. Roughness. The maximum and average rut depths in item 3 at failure were 5.50 and 4.12 in., respectively.

b. Deformation. Figures 15 and 16 show cross-section and profile plots, respectively, for 1 pass and 6 coverages of the test load. The maximum permanent soil deformation at failure was 2.2 in.

c. Deflection. Only pin and cap deflections were measured in these tests. At failure the maximum total deflection was 1.4 in. Elastic deflection at failure measured 0.4 in.

Lane 32A

Behavior of items under traffic

Item 2. Figure 8 shows item 2 prior to traffic. The item was considered failed due to roughness at 10 coverages (figure 9). The rated CBR was 10.0.

Item 3. Figure 8 shows item 3 prior to traffic. The item was considered failed at 60 coverages (figure 10). The rated CBR for the item was 14.0.

Test results

Traffic results are summarized in table 1. Soil test data are given in table 2.

Item 2. Item 2 was considered failed due to roughness at 10 coverages. The following information was obtained from traffic tests on item 2.

a. Roughness. The average transverse and diagonal differential deformations at failure were 3.75 and 3.82 in., respectively. The maximum and average rut depths at failure measured 2.38 and 2.00 in., respectively.

b. Deformation. Figures 15 and 16 show cross-section and profile plots, respectively, for 1 pass and 10 coverages of the test load. The maximum permanent soil deformation at failure was 2.3 in.

c. Deflection. Only pin and cap deflections were measured in these tests. At failure the maximum total deflection was 0.70 in. Elastic deflection at failure was 0.50 in.

Item 3. Item 3 was considered failed due to roughness at 60 coverages. The following information was obtained from traffic tests on item 3.

a. Roughness. The average transverse and diagonal differential deformations at failure were 3.87 and 4.31 in., respectively. The maximum and average rut depths were 2.88 and 2.25 in., respectively.

b. Deformation. Figures 15 and 16 show cross-section and profile plots, respectively, for several traffic levels. The maximum permanent soil deformation at failure was 4.3 in.

c. Deflections. Only pin and cap deflections were measured in these tests. At failure the maximum total deflection was 0.70 in. The elastic soil deflection at failure was 0.50 in.

Comparison of Ruts

Figures 11 and 12 show rut depths resulting from different size tires. The three tires involved were a 20x20, 22-ply aircraft tire, a 30x11.5, 24-ply aircraft tire, and a 56x16, 32-ply aircraft tire.

SECTION V: PRINCIPAL FINDINGS

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

Load, Wheel Assembly, and Tire Pressure	Test Item*	Rated Subgrade CBR	Coverages at Failure
	Lane 32		
25,000-lb load; single-wheel assembly; 30x11.5, 24-ply tires inflated to 250 psi	2	10.0	1 pass
	3	14.0	6
	Lane 32A		
25,000-lb load; single-wheel assembly; 56x16, 32-ply tires inflated to 250 psi	2	10.0	10
	3	14.0	60

* All items were unsurfaced.

Table 1

SUMMARY OF TRAFFIC DATA, TEST SECTION 14A

Test Item	Coverages	Rated CBR	Differential Deformation (in.) Longitudinal Max	Longitudinal Avg	Transverse Max	Transverse Avg	Diagonal Max	Diagonal Avg	Rutting (in.) Max	Rutting Avg	Total and Elastic Deflection (in.) Total	Elastic	Remarks
							Lane 32						
2	1 Pass	10.0	--	--	--	--	--	--	5.75	4.78	3.60	0.60	Failed at 1 pass
3	1 Pass	14.0	--	--	--	--	--	--	1.63	1.09	--	--	Failed at 6 coverages
	6		--	--	--	--	--	--	5.50	4.12	1.40	0.40	
							Lane 32A						
2	1 Pass	10.0	--	--	--	--	--	--	1.38	1.16	--	--	Failed at 10 coverages
	10		0.50	0.31	4.13	3.75	4.25	3.82	2.38	2.00	0.70	0.50	
3	1 Pass	14.0	--	--	--	--	--	--	0.63	0.50	--	--	Failed at 60 coverages
	10		0.50	0.25	1.50	1.28	1.63	1.35	1.13	0.94	0.70	0.50	
	60		0.60	0.40	4.88	3.87	5.25	4.31	2.88	2.25	0.70	0.50	

Note: For lane 32, a single-wheel assembly with a 30x11.5, 24-ply tire inflated to 250 psi was used for trafficking. For lane 32A, a single-wheel assembly with a 56x16, 32-ply tire inflated to 250 psi was used for trafficking. A 25-kip load was used on both assemblies.

TABLE 2

SUMMARY OF CBR, DENSITY, AND WATER CONTENT DATA, TEST SECTION 14A, LANES 32 AND 32A*

Test Item**	Coverages	Depth (in.)	CBR	Water Content (%)	Dry Density (lb/cu ft)	Remarks
2	0	0	0	26.0	97.1	
		6	10	25.6	96.2	
		12	10	27.9	93.9	
2	0	0	9	26.6	96.7	
		6	10	25.5	96.8	
		12	11	26.2	94.7	
2	1 Pass	0	9	26.2	96.9	
		6	9	23.1	95.8	
		12	9	23.9	94.7	
3	0	0	15	23.5	100.5	
		6	16	23.1	100.1	
		12	12	23.9	96.6	
3	6	0	15	23.6	102.5	Data taken inside traffic lane
		6	15	23.4	99.6	
		12	14	23.8	100.0	
3	6	0	15	23.4	98.8	Data taken outside traffic lane
		6	14	24.6	96.8	
		12	15	23.6	98.9	

Note: Subgrade material was a heavy clay (buckshot; classified as CH) in all items.

* Test lanes 32 and 32A as constructed were extra narrow and close together. Therefore, the data obtained for lane 32 is considered applicable to lane 32A. No failure data were obtained for lane 32A.

** All items were unsurfaced.

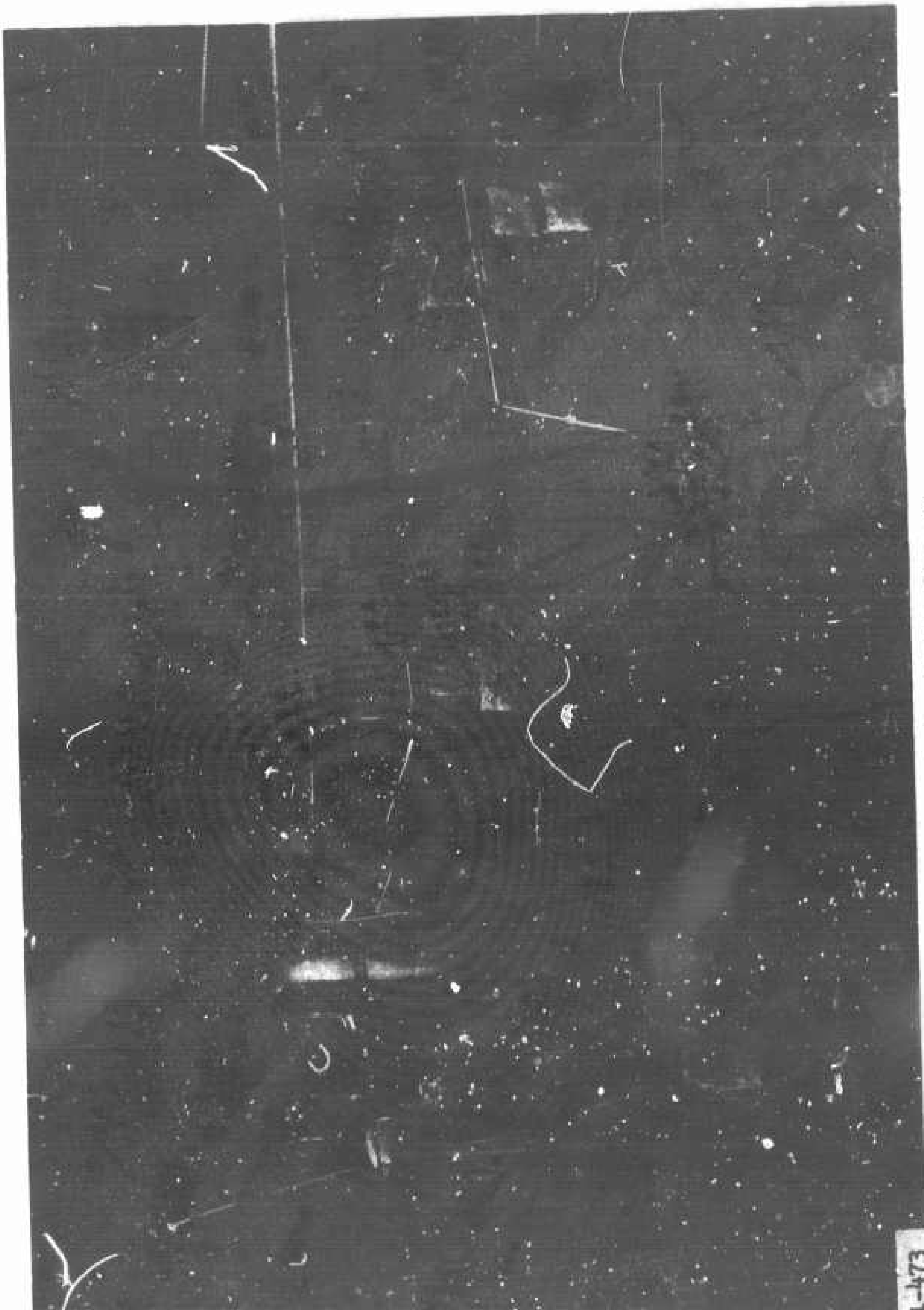


Figure 2. Test load vehicle, lane 32

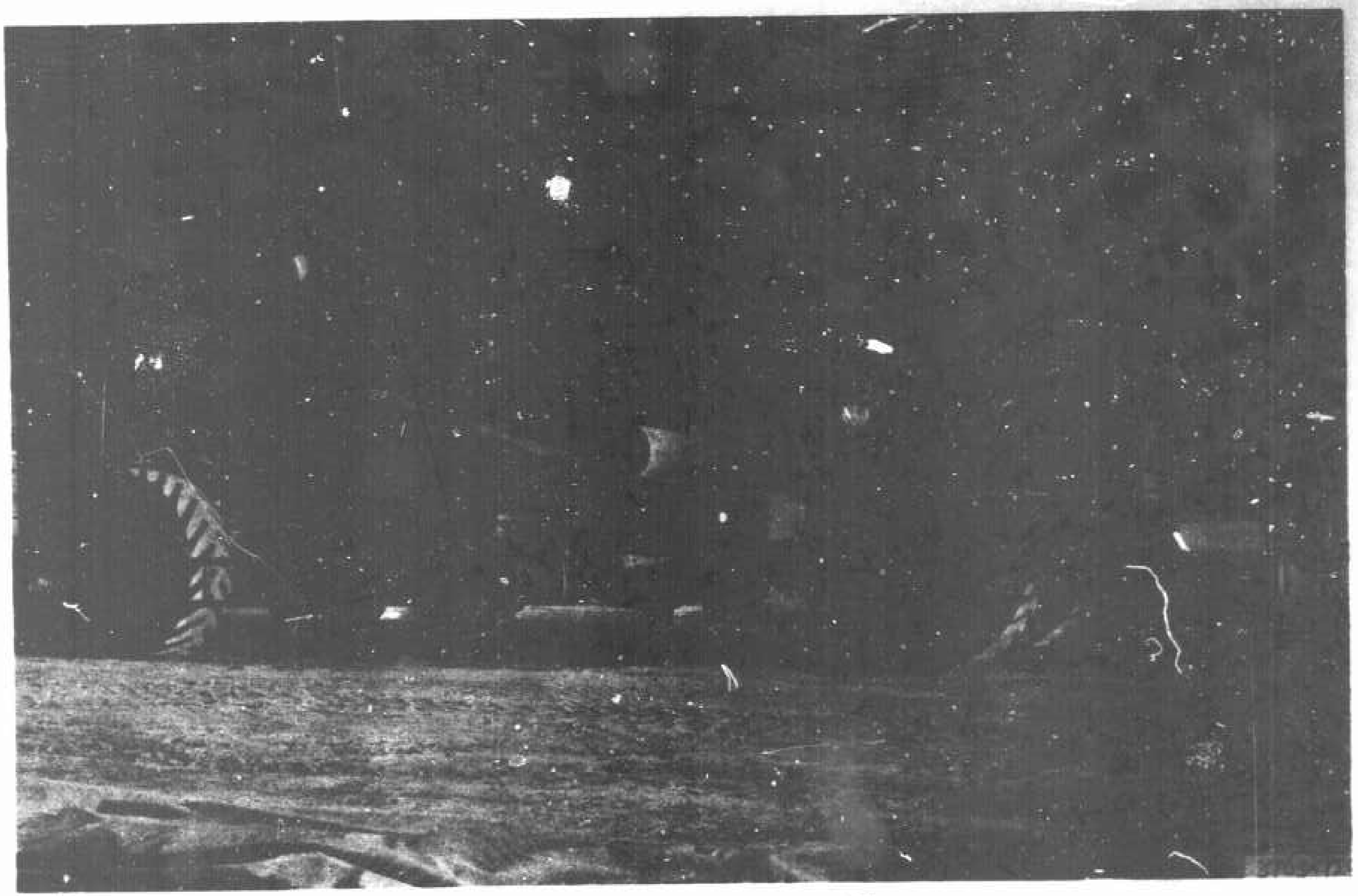


Figure 3. Test load vehicle, lane 32A

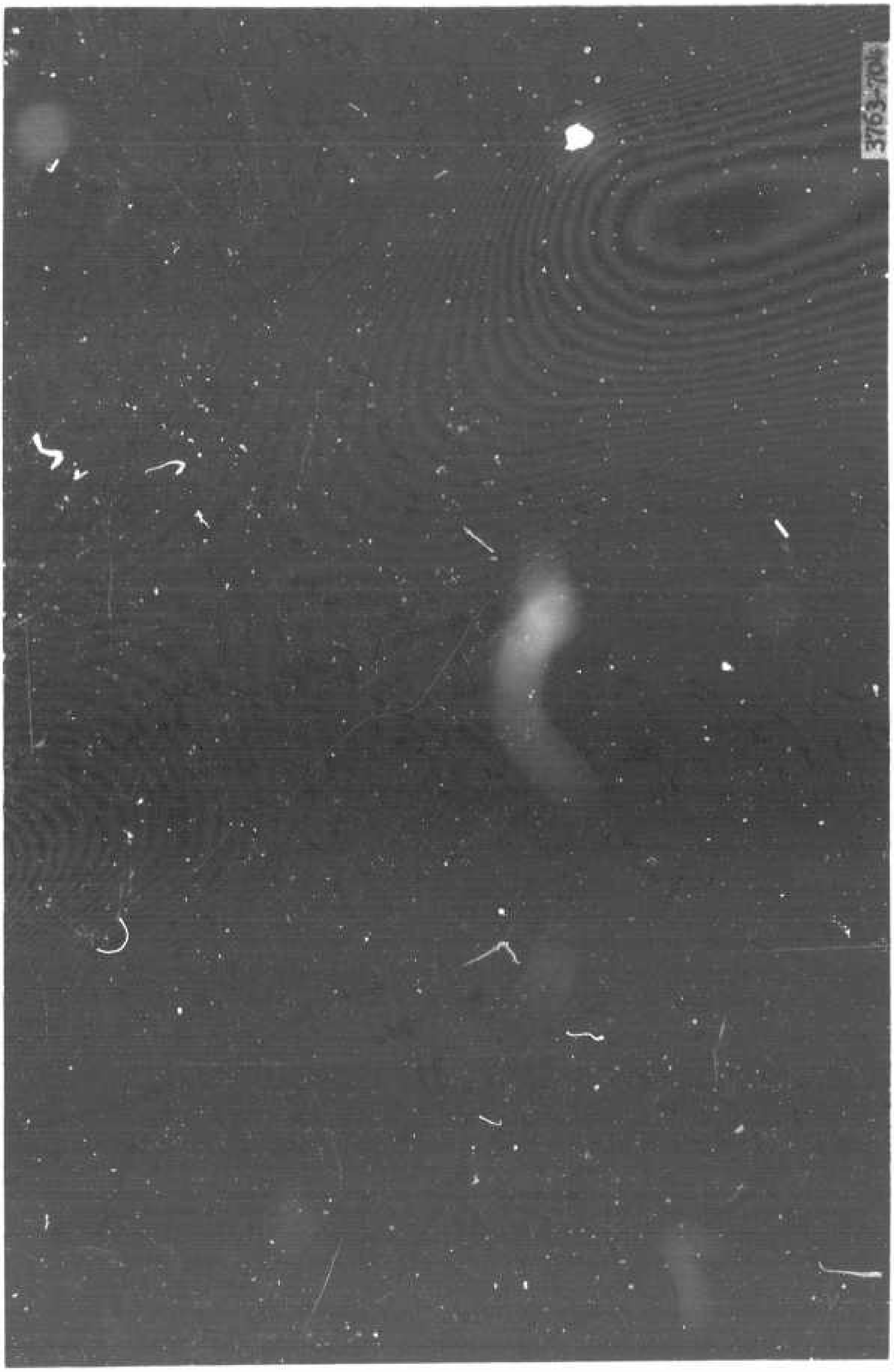


Figure 4. Lane 32, items 2 and 3, prior to traffic

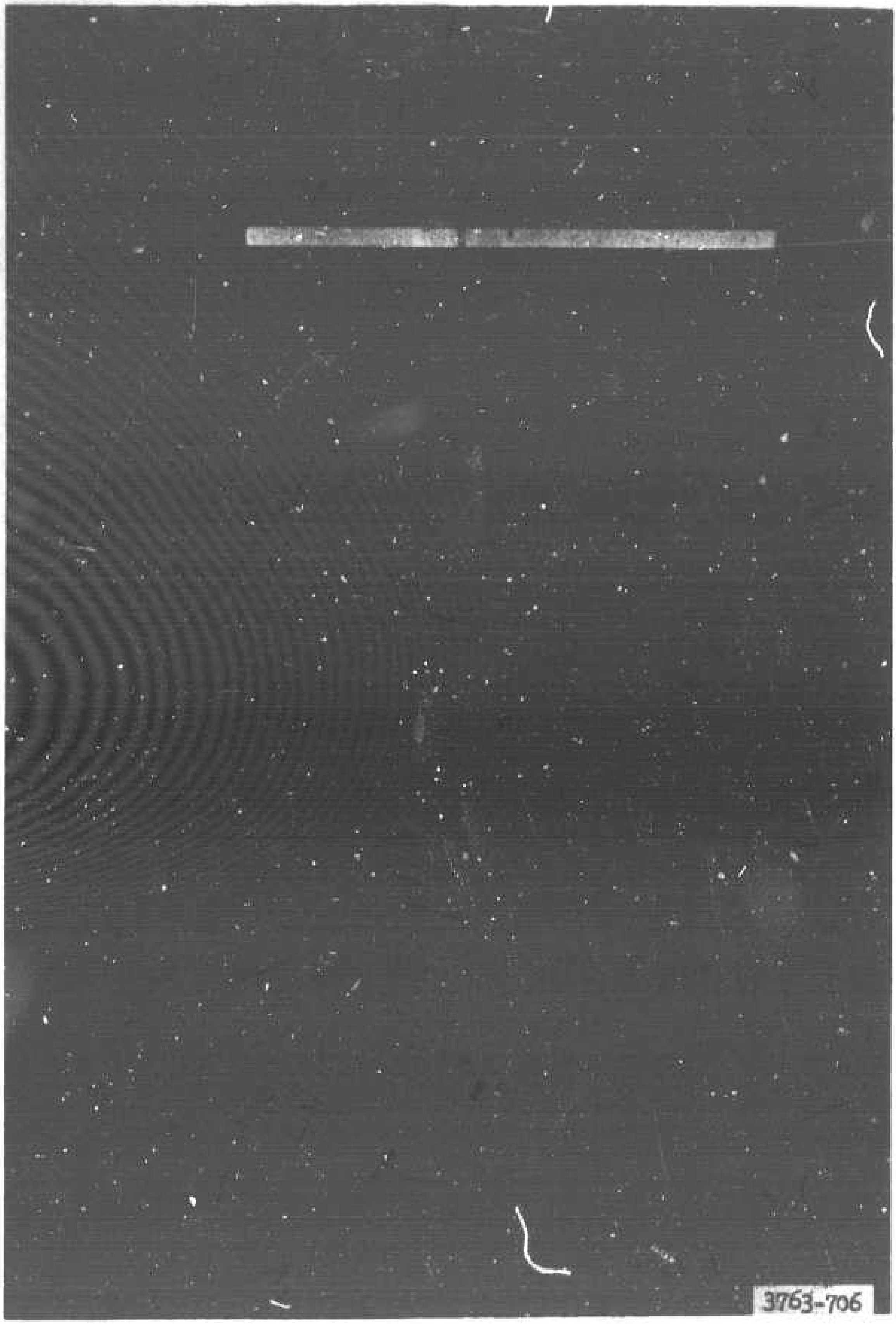


Figure 5. Lane 32, item 2, after 1 pass (failure)

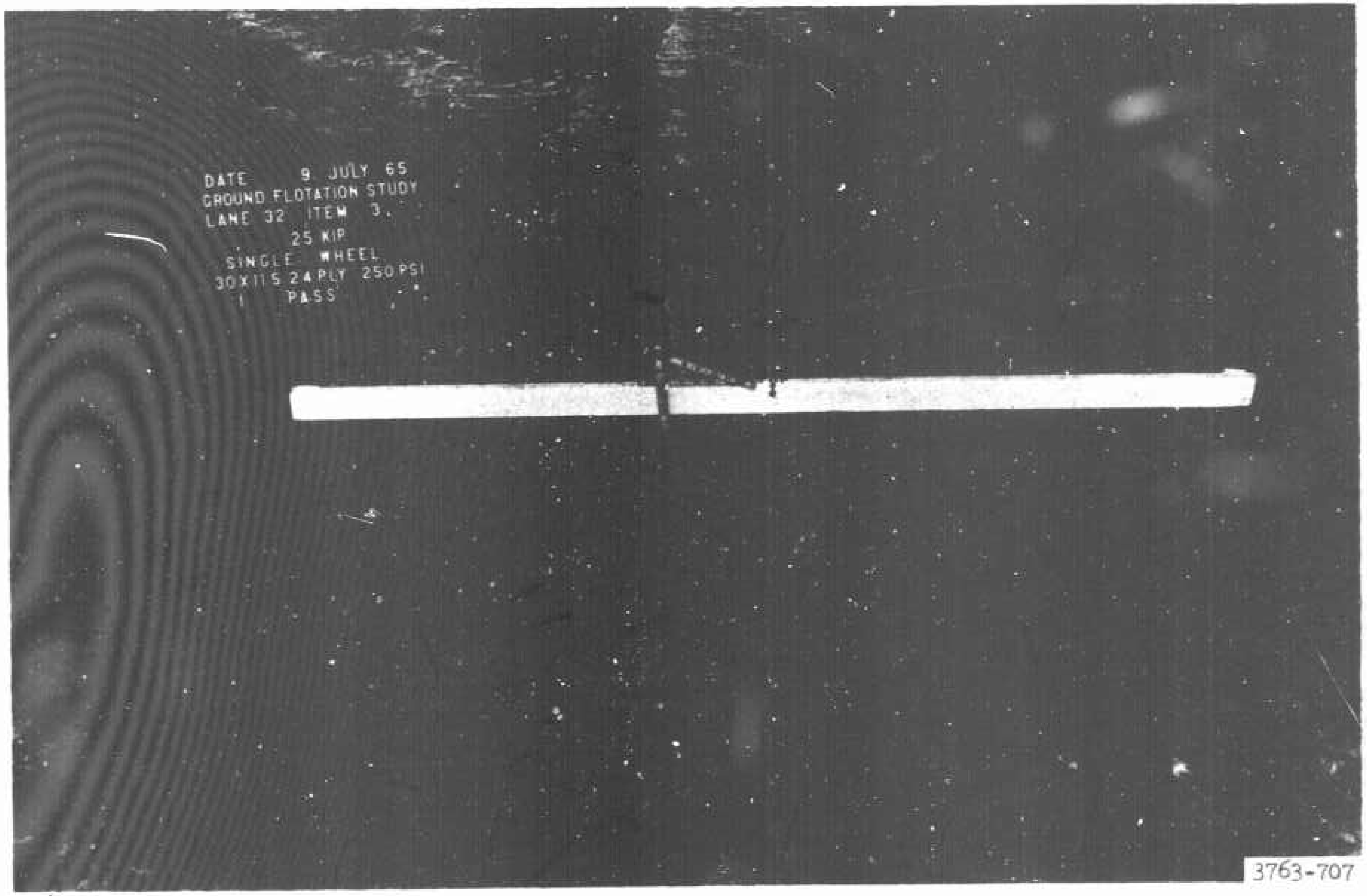


Figure 6. Lane 32, item 3, after 1 pass

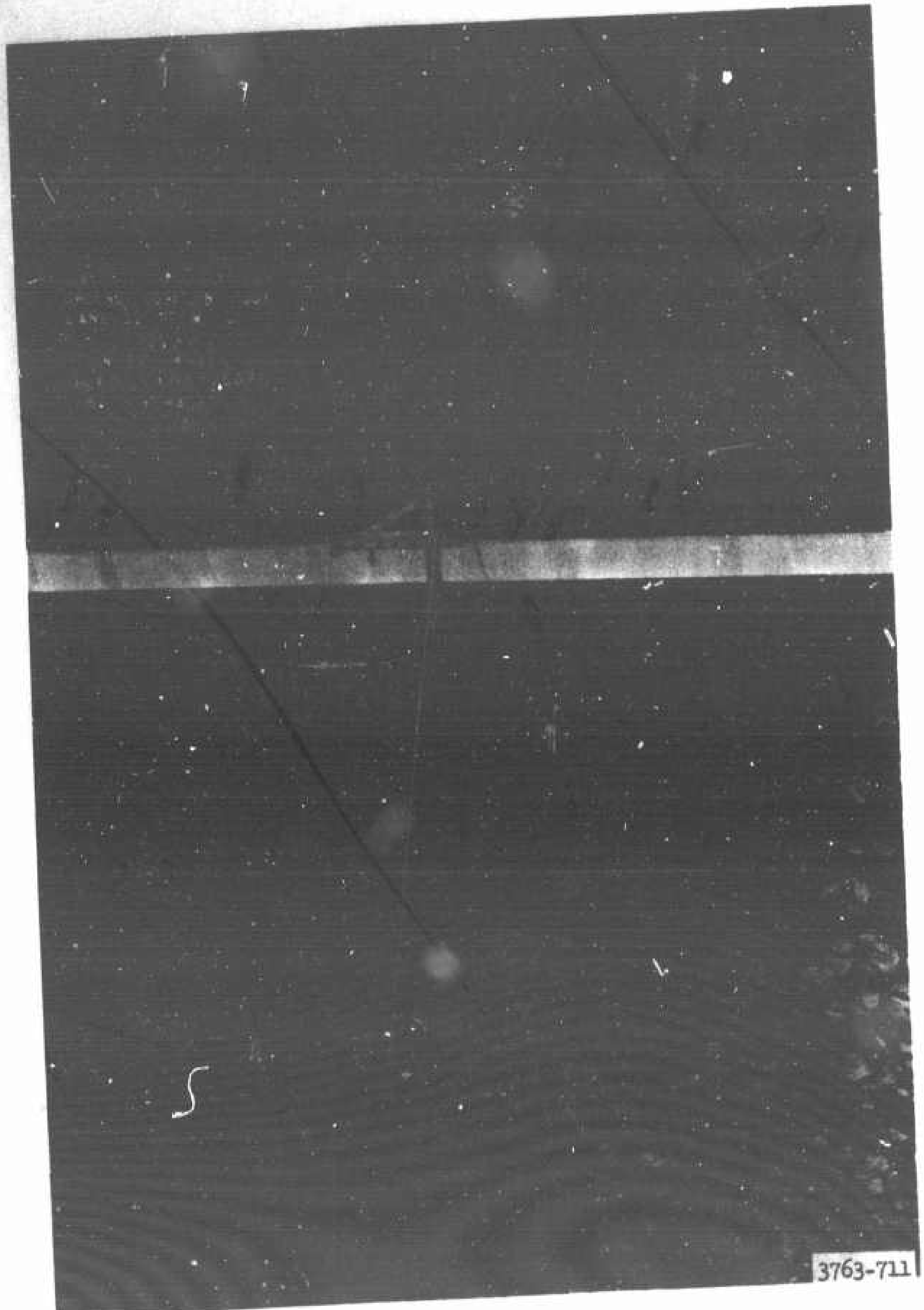


Figure 7. Lane 32, item 3, after 6 coverages (failure)

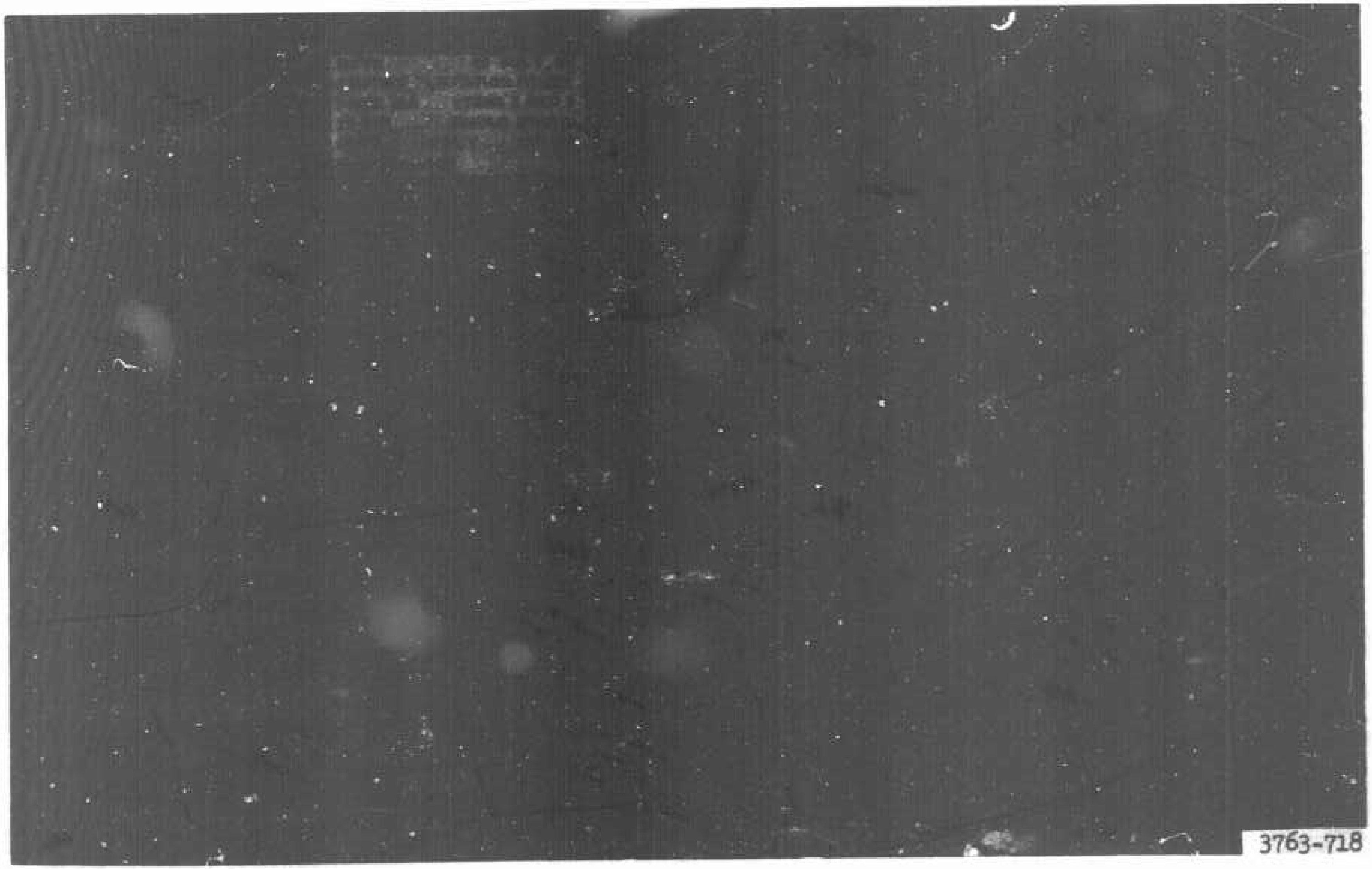


Figure 8. Lane 32A, items 2 and 3, prior to traffic

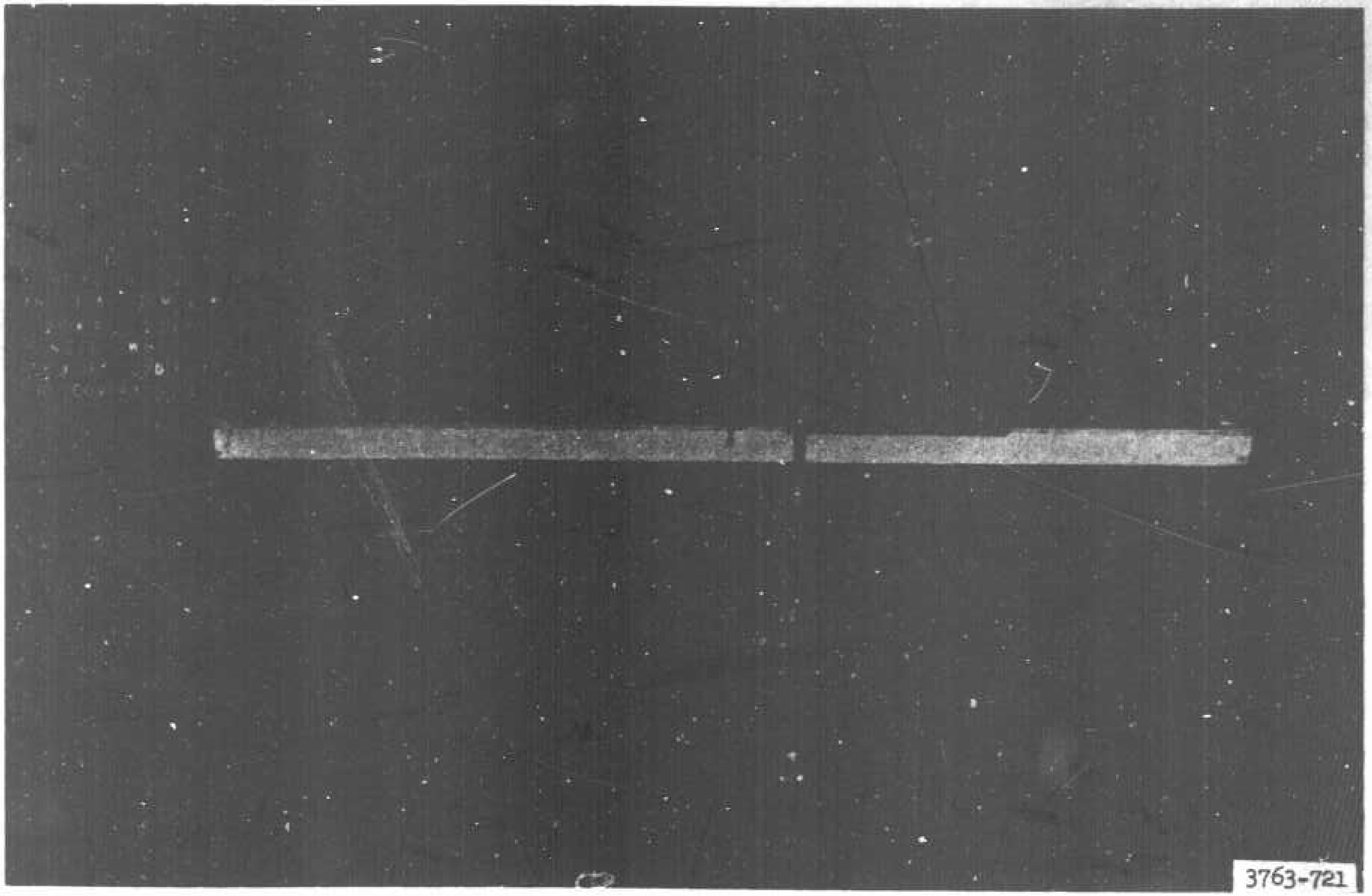


Figure 9. Lane 32A, item 2, after 10 coverages (failure)

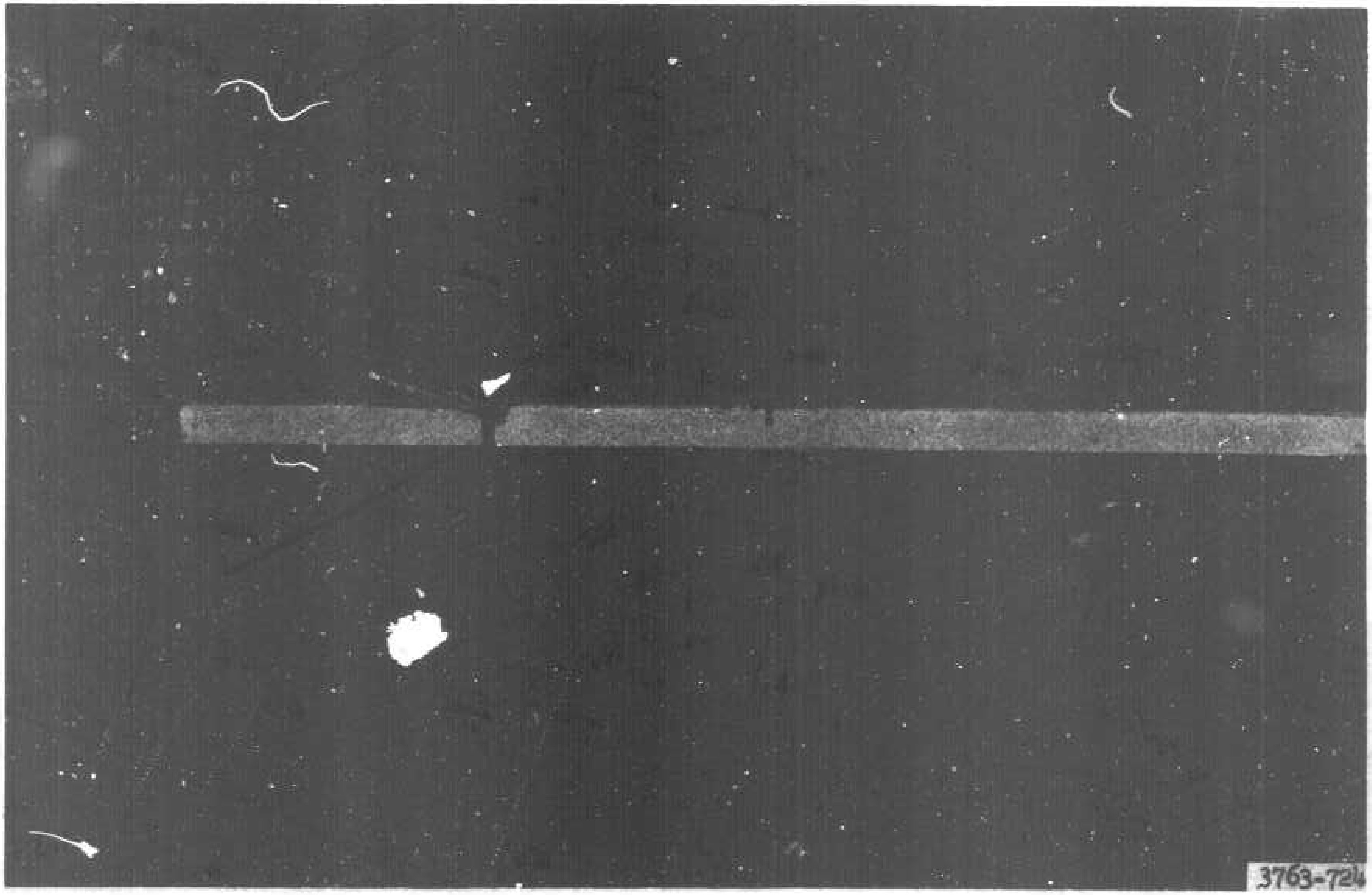


Figure 10. Lane 32A, item 3, after 60 coverages (failure)

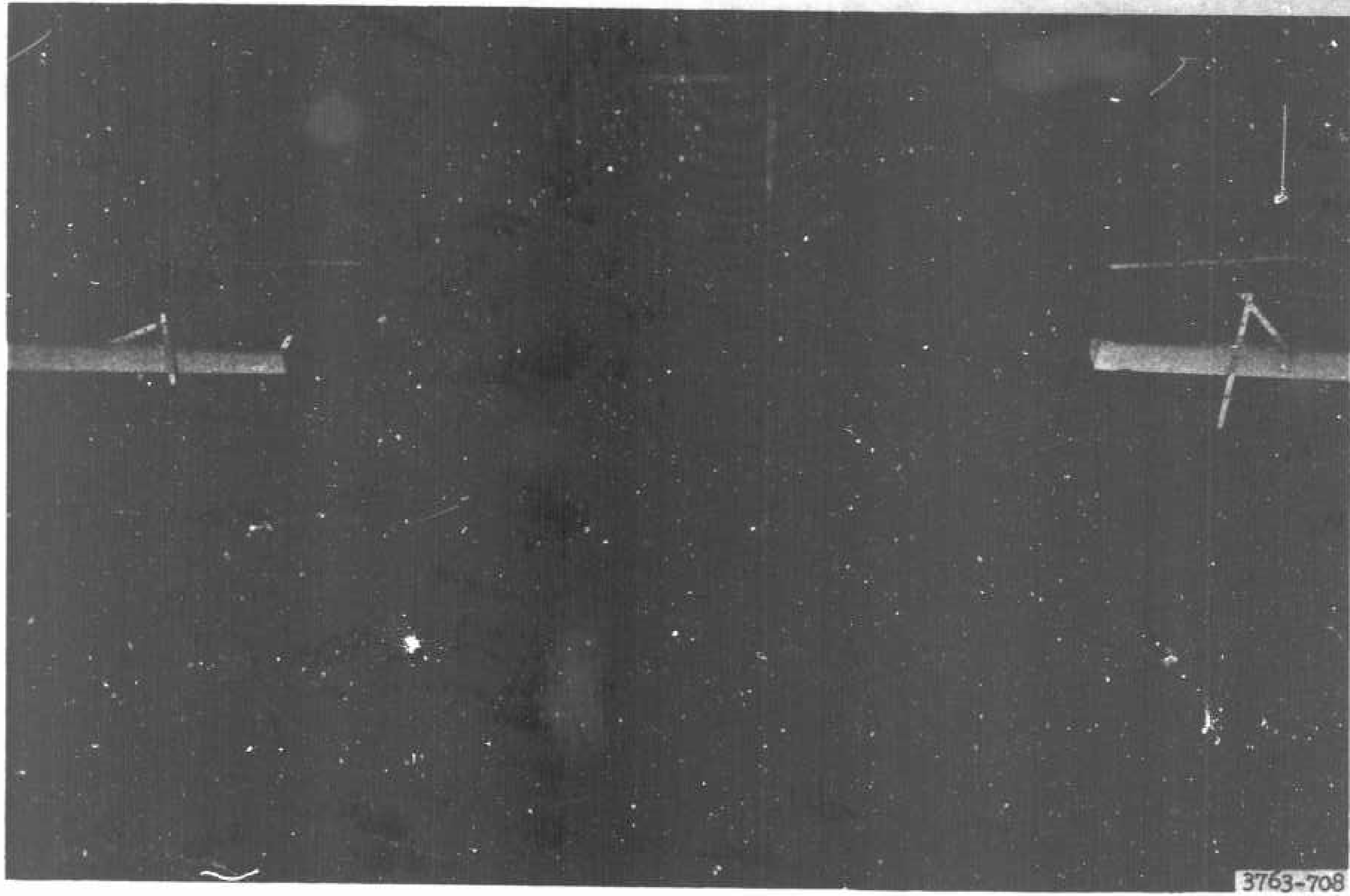


Figure 11. Rut depths resulting from different size tires
(20x20, 22-ply tire and 30x11.5, 24-ply tire)

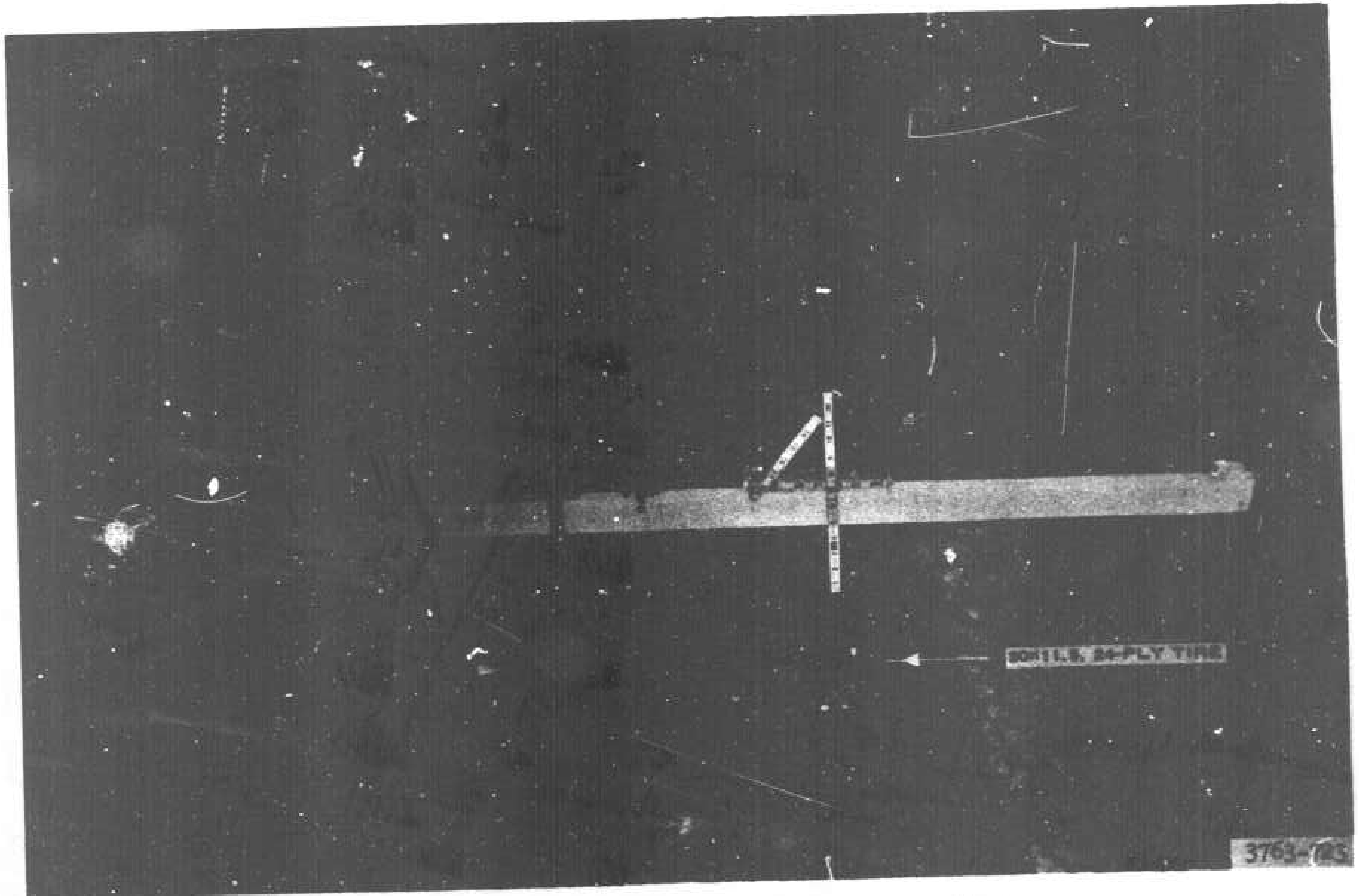


Figure 12. Rut depths resulting from different size tires (56x16, 32-ply tire and 30x11.5, 24-ply tire)

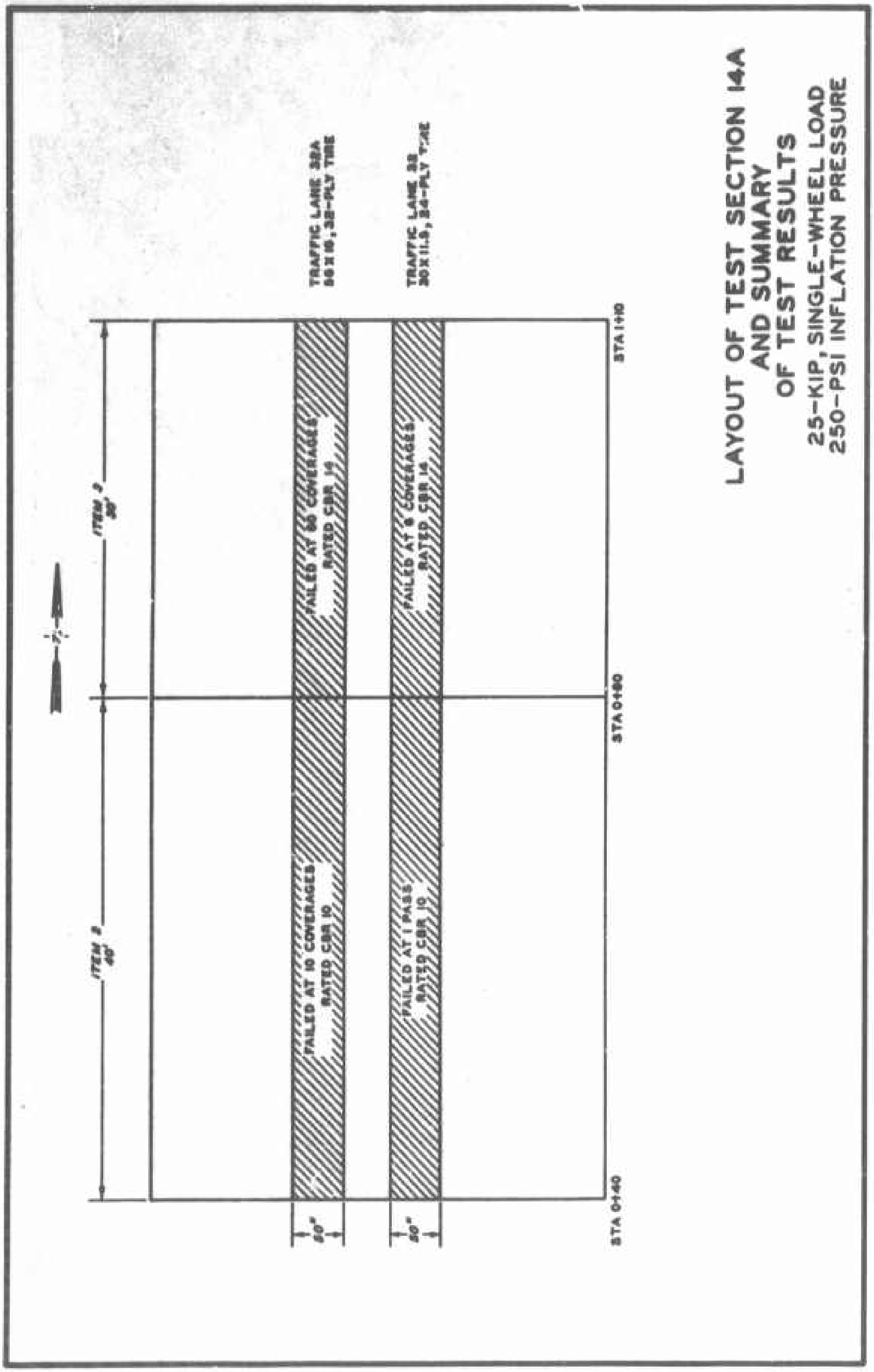
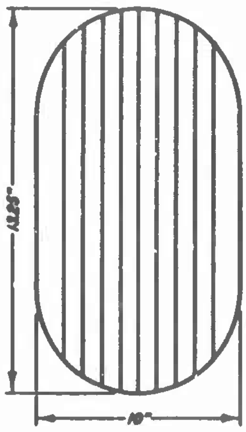
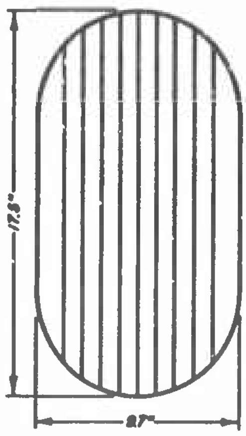

ITEM 2
40'
ITEM 3
FAILED AT 10 COVERAGES
RATED CBR 10
RATED CBR 14
TRAFFIC LANE 32A
32-PLY TIRE
FAILED AT 1 PASS
RATED CBR 10
RATED CBR 14
TRAFFIC LANE 32
24-PLY
STA 0+40
STA 0+80
STA 1+10
LAYOUT OF TEST SECTION 14A
AND SUMMARY
OF TEST RESULTS
25-KIP, SINGLE-WHEEL LOAD
250-PSI INFLATION PRESSURE

Figure 13



TIRE SIZE	30 X 11.5
NO. OF PLYS	24
CONTACT AREA, SQ IN.	110
CONTACT PRESSURE, PSI	228
INFLATION PRESSURE, PSI	[illegible]
DEFLECTION, %	37

LANE 32



TIRE SIZE	56 X 16
NO. OF PLYS	32
CONTACT AREA, SQ IN.	141
CONTACT PRESSURE, PSI	177
INFLATION PRESSURE, PSI	250
DEFLECTION, %	16

LANE 32A

TIRE-PRINT DIMENSIONS AND TIRE CHARACTERISTICS

TEST SECTION 14A
LANES 32 AND 32A

Figure 14

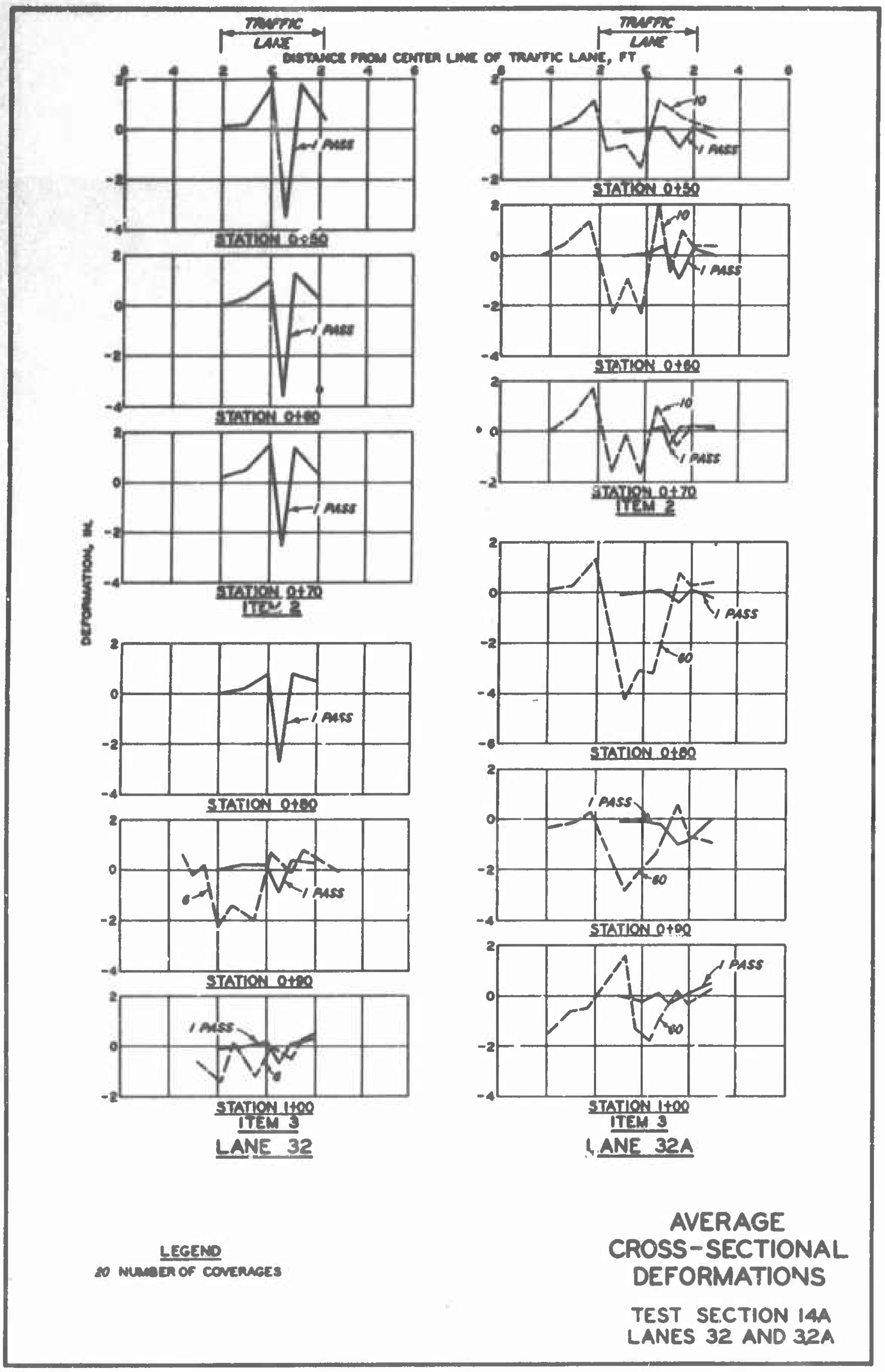

TRAFFIC LANE
DISTANCE FROM CENTER LINE OF TRAFFIC LANE, FT
DEFORMATION, IN.
STATION 0+50
STATION 0+60
STATION 0+70
ITEM 2
STATION 0+80
STATION 0+90
STATION 1+00
ITEM 3
LANE 32
LANE 32A
1 PASS
10
60
LEGEND
20 NUMBER OF COVERAGES
AVERAGE CROSS-SECTIONAL DEFORMATIONS
TEST SECTION 14A
LANES 32 AND 32A

Figure 15

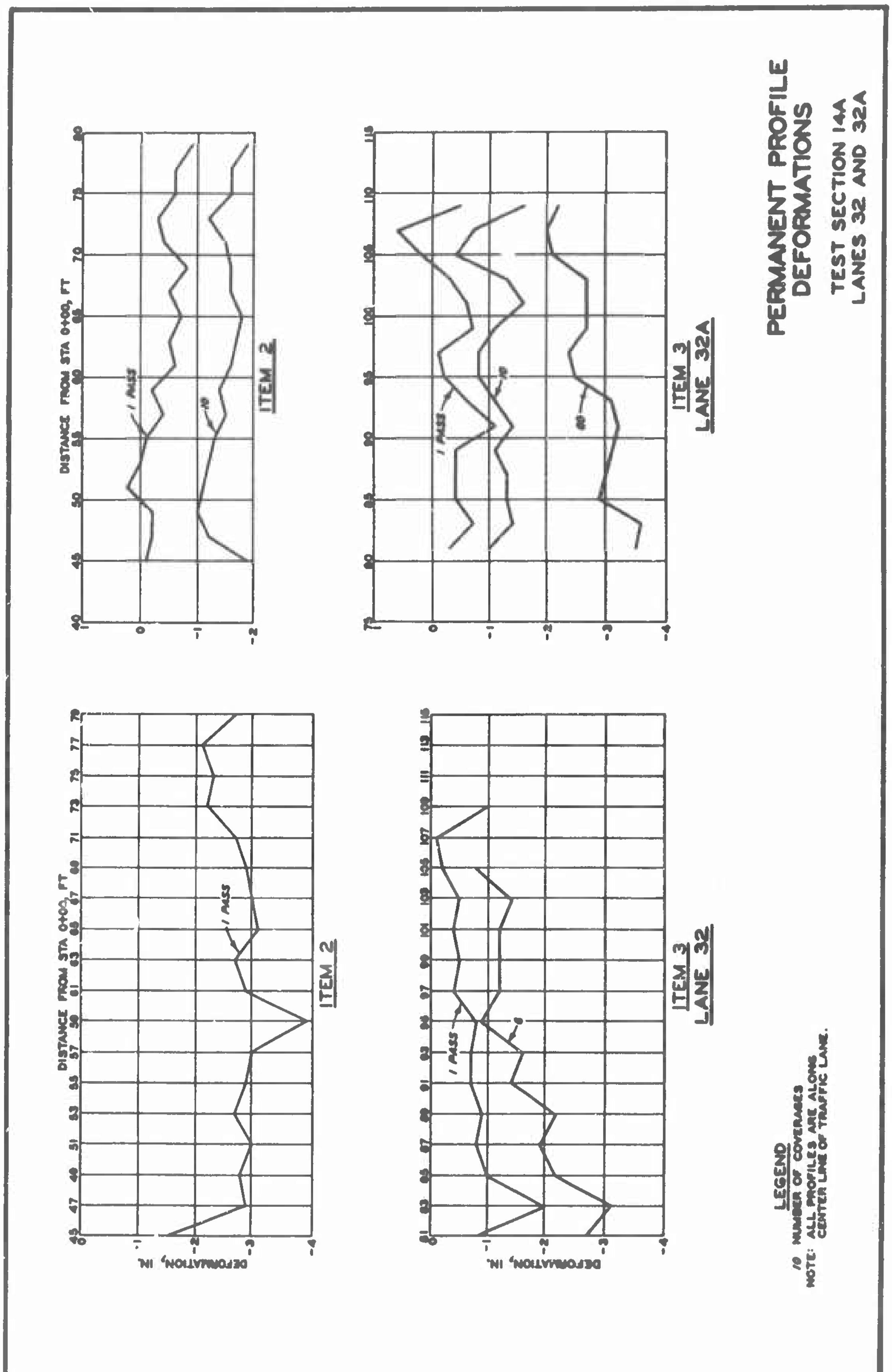

PERMANENT PROFILE DEFORMATIONS
TEST SECTION 14A
LANES 32 AND 32A
DISTANCE FROM STA 0+00, FT
DEFORMATION, IN.
1 PASS
10
ITEM 2
ITEM 3
LANE 32
6
ITEM 3
LANE 32A
60
LEGEND
10 NUMBER OF COVERAGES
NOTE: ALL PROFILES ARE ALONG CENTER LINE OF TRAFFIC LANE.

Figure 16

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Part XV Data Report on Test Section 14A

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	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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UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

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

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