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EVALUATION OF KAISER MX19-B AND MX19-C ALUMINUM HONEYCOMB LANDING MAT

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Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

March 1973

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EVALUATION OF KAISER MX19-B AND MX19-C ALUMINUM HONEYCOMB LANDING MAT

by

G. L. Carr, D. A. Ellison

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13. ABSTRACT

This report describes an investigation conducted to evaluate the MX19 aluminum honeycomb-core landing mat with modified male and female hinge-type connectors. The MX19 mat, designed and fabricated by Kaiser Aluminum and Chemical Sales, Inc., Oakland, Calif., was a sandwich-type structure composed of an aluminum honeycomb core bonded by an adhesive to top and bottom aluminum sheets. The extruded aluminum edge connectors were welded to the sheets and bonded with adhesive to the core. The panels were joined along two edges by a hinge-type male/female connection. The adjacent edges were joined by an overlap/underlap connection secured by a locking bar. In previous engineer design tests of MX19 mat, although results indicated that the mat exceeded by 175 percent the Qualitative Materiel Requirement (QMR) service life of 200 coverages, a fairly consistent failure mode was established along the female connector. Field performances in Vietnam indicated that a longer service life would be required than that specified by the QMR and that sustained by the MX19 mat. Since the QMR was soon to be revised to require a service life of 1000 coverages, the manufacturer's design efforts were directed toward extending the service life of the MX19 mat. Subsequently, modifications were made in both the male and the female connectors. The MX19 mat with modifications in both connectors was designated MX19-B, and the mat with modifications in only the female connector was designated MX19-C. This investigation consisted of traffic and skid tests to obtain information on the effectiveness of the modified connectors in extending the service life of the mats and on the skid-resistance and tire-wear characteristics of the mat surfaces, respectively. The traffic tests were conducted on a test section with rated CBR's of 4.3 and 4.2 for the MX19-B and MX19-C, respectively, using a 25,000-lb single-wheel load with a tire-inflation pressure of 250 psi. Results of the investigation indicated that the MX19-B would sustain 750 coverages and the MX19-C, in excess of 2050 coverages on a 4.0-CBR subgrade. Thus, the service life of the MX19-C mat should exceed by 10 times that of the QMR (200 coverages) and by approximately 4 times that of the MX19 mat (550 coverages). The coefficients of friction of the mat surfaces during dry and wet conditions were 0.32 and 0.22, respectively. These coefficients of friction were lower than those determined for the MX19 mat in a previous investigation and did not meet the QMR performance specification of a 0.40 to 0.80 range for coefficients of friction on both dry and wet surfaces. Premature failure of some of the panels, resulting from breaks along the sheet-to-male-connector welds, indicated that the location of trepanning should be shifted from the center of connectors and that the shape of the notch formed during the procedure should be altered to permit complete refilling of the hole with weld.

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Honeycomb landing mats						
Kaiser landing mats						
MX19 landing mat						

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FOREWORD

The investigation reported herein was conducted as part of Research and Development Project No. 1T062103A046, "Trafficability and Mobility Research," Task 05, "Mobility Engineering Support," under the sponsorship of the Research and Development Directorate, U. S. Army Materiel Command (AMC). The U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., was directed by Headquarters, AMC, Washington, D. C., to procure approximately 5,000,000 sq ft of MX19 mat for use in Southeast Asia. The WES Director, as Contracting Officer, granted authorization for accelerated traffic tests on a quantity taken from the production line.

The engineer design tests pertinent to this investigation were performed at the WES during January-April 1967 under the general supervision of Messrs. W. J. Turnbull, Chief (retired), and J. P. Sale, Chief, Soils and Pavements Laboratory. Personnel of the Expedient Surfaces Branch who were actively engaged in the planning, testing, analyzing, and reporting phases of this investigation under the supervision of Messrs. W. L. McInnis and H. L. Green were Messrs. G. L. Carr, D. W. White, Jr., and D. A. Ellison. The General Engineering Support Branch was responsible for constructing and trafficking the test section and for performing the necessary soils tests under the supervision of Messrs. R. G. Ahlvin and C. D. Burns. This report was prepared by Messrs. Carr and Ellison.

COL John R. Oswalt, Jr., CE, COL Levi A. Brown, CE, and COL Ernest D. Peixotto, CE, were Directors of the WES during the conduct of this investigation and the preparation and publication of this report. Messrs. J. B. Tiffany and F. R. Brown were Technical Directors.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
square inches	6.4516	square centimeters
square feet	0.092903	square meters
cubic feet	0.0283168	cubic meters
pounds (mass)	0.45359237	kilograms
kips	453.59237	kilograms
pounds (force) per square inch	0.6894757	newtons per square centimeter
pounds (mass) per square foot	4.88243	kilograms per square meter
pounds (mass) per cubic foot	16.0185	kilograms per cubic meter
miles per hour	1.609344	kilometers per hour

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SUMMARY

This report describes an investigation conducted to evaluate the MX19 aluminum honeycomb-core landing mat with modified male and female hinge-type connectors. The MX19 mat, designed and fabricated by Kaiser Aluminum and Chemical Sales, Inc., Oakland, Calif., was a sandwich-type structure composed of an aluminum honeycomb core bonded by an adhesive to top and bottom aluminum sheets. The extruded aluminum edge connectors were welded to the sheets and bonded with adhesive to the core. The panels were joined along two edges by a hinge-type male/female connection. The adjacent edges were joined by an overlap/underlap connection secured by a locking bar.

In previous engineer design tests of MX19 mat, although results indicated that the mat exceeded by 175 percent the Qualitative Materiel Requirement (QMR) service life of 200 coverages, a fairly consistent failure mode was established along the female connector. Field performances in Vietnam indicated that a longer service life would be required than that specified by the QMR and that sustained by the MX19 mat. Since the QMR was soon to be revised to require a service life of 1000 coverages, the manufacturer's design efforts were directed toward extending the service life of the MX19 mat. Subsequently, modifications were made in both the male and the female connectors. The MX19 mat with modifications in both connectors was designated MX19-B, and the mat with modifications in only the female connector was designated MX19-C.

This investigation consisted of traffic and skid tests to obtain information on the effectiveness of the modified connectors in extending the service life of the mats and on the skid-resistance and tire-wear characteristics of the mat surfaces, respectively. The traffic tests were conducted on a test section with rated CBR's of 4.3 and 4.2 for the MX19-B and MX19-C, respectively, using a 25,000-lb single-wheel load with a tire-inflation pressure of 250 psi. Results of the investigation indicated that the MX19-B would sustain 750 coverages and the MX19-C, in excess of 2050 coverages on a 4.0-CBR subgrade. Thus, the service life of the MX19-C mat should exceed by 10 times that of the QMR (200 coverages) and by approximately 4 times that of the MX19 mat (550 coverages). The coefficients of friction of the mat surfaces during dry and wet conditions were 0.32 and 0.22, respectively. These coefficients of friction were lower than those determined for the MX19 mat in a previous investigation and did not meet the QMR performance specification of a

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Premature failure of some of the panels, resulting from breaks along the sheet-to-male-connector welds, indicated that the location of treganning should be shifted from the center of connectors and that the shape of the notch formed during the procedure should be altered to permit complete refilling of the hole with weld.

EVALUATION OF KAISER MX19-B AND MX19-C ALUMINUM HONEYCOMB LANDING MAT

PART I: INTRODUCTION

Background

1. The investigation reported herein comprised an engineer design test (EDT) in the U. S. Army Materiel Command's (AMC) continuous program for the development of satisfactory landing mats for use as expedient surfacing materials for forward-area airfields. The U. S. Army Engineer Waterways Experiment Station (WES) is responsible for the development of metallic and plastic mats.

2. The development of the extruded T8 magnesium mat and the similarly designed extruded T11 aluminum mat represented a tremendous advancement in landing mats. Through the extrusion process, metal can now be placed where it will do the most good, resulting in a stronger mat of reduced weight. An investigation conducted at the WES[1] indicated that the T11 mat was superior to previously tested mats and prompted limited field tests of the modified T11 aluminum mat by the Air Force at England AFB, Alexandria, La., from December 1963 to July 1964. Results of these tests, reported in references 2 and 3, prompted the Air Force to formulate "Performance Requirements for Landing Mat," which was sent to AMC as an inclosure to a letter, subject: "Development of Landing Mat," dated 8 October 1964. These requirements closely paralleled criteria that AMC had previously furnished the WES for guidance in the mat program. AMC's requirements were revised and sent to WES as an inclosure to a letter, subject: "Requirements for Expedient Surfacings for Construction of Forward-Area Airfields," dated 5 February 1965. From the AMC and Air Force requirements, a Qualitative Materiel Requirement (QMR) for Prefabricated Airfield Surfacing was developed and was approved on 14 April 1966.

3. In 1965, during the evolution of the QMR, accelerated EDT's were initiated in an effort to design and develop a landing mat that

would be compatible with present-day operational concepts of the armed services. Results of these tests, reported in references 4 and 5, indicated that an engineer design/service test was needed to validate results of the design test which had indicated that the prototype MX19 mat would sustain 550 coverages of the F-4C aircraft loading on a 4.0-CBR subgrade.

4. A production contract was awarded on the basis of results obtained in the EDT described in reference 4. The production contract was awarded to obtain mats for service tests; and, during production, the quantity of mats to be produced was increased from 5,000,000 to a total of 9,000,000 sq ft.* EDT's of the first production mats[6] indicated that a service life of 200 to 210 coverages of the F-4C aircraft on a 4.0-CBR subgrade would be obtained and established a consistent failure mode along the female connector. This coverage level represented a reduction of 36 percent from the level sustained by the prototype MX19 mat, and efforts were directed towards modifying the design to increase the service life of the production mat. Past experience indicated that production mat performance would fall short of prototype mat performance by 30 to 50 percent; however, the contractor and WES were confident that, with proper design modifications and adequate quality control, production mats could be fabricated with a service life equal or nearly equal to prototype mat. Reports from Southeast Asia indicated that matted airfields were being upgraded to perform for longer periods of time (three to five years), and consequently the mat would be required to sustain from three to eight times as many coverages as specified by the 1966 QMR. Advance information was that the QMR would be revised to require a service life of 1000 coverages.**

5. Studies of the failure mode and concentrated laboratory retesting of mats in the failure area resulted in recommendation of modifications to the mat connectors.[7,8] (A complete history of Kaiser mat

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* A table of factors for converting British units of measurement to metric units is presented on page ix.

** This increased service life requirement was effected in the revised QMR, approved 2 April 1968.

development and a listing of mat nomenclature are presented in reference 9.) The investigation reported herein was performed on MX19 landing mats modified to eliminate the failure mode pattern and to extend the service life of the mat to meet the requirements discussed above.

Objectives and Scope of Investigation

Objectives

6. The general objective of this investigation was to evaluate the performance of the MX19-B and MX19-C landing mats. Specific objectives were to determine the following:

a. The service life of the mats when placed on a 4.0-CBR subgrade and trafficked with a 25,000-lb load on a test wheel having a tire inflated to 250 psi to produce a contact area of 111 sq in.

b. The skid-resistance and tire-wear characteristics of the mat surfaces.

c. The average placing rate of the mats.

Scope

7. This report describes traffic and skid tests conducted to evaluate the MX19-B and MX19-C mats. Data for the evaluation were obtained by the following:

a. Traffic tests were conducted on a test section to study subgrade behavior and to observe the performance of the mat under a rolling wheel load.

b. Skid tests were conducted to determine the force required to skid a loaded cart over the mat and the coefficients of friction.

c. Placement times were recorded to compute the average placing rate.

Definitions of Pertinent Terms

8. For information and clarity, definitions of certain terms used in this report are given below:

Subgrade. An area of soil processed under controlled conditions to provide a desired bearing capacity and upon which the landing mat is placed.

Test section. A subgrade surfaced with landing mat.

Traffic lane. That portion of the test section that is subjected to the moving wheel load of the load cart.

Load cart. A specially constructed item of equipment used in WES engineering tests for simulating aircraft taxiing and braking operations.

Test wheel. The wheel on the load cart that supports the main load.

Coverage. One application of the test wheel of the load cart over every point in the traffic lane.

Static deflection. Temporary longitudinal bending of landing mat panels under the static load from the test wheel.

Longitudinal dishing. Permanent deformation of a panel parallel to the direction of traffic.

Transverse dishing. Permanent deformation of a panel perpendicular to the direction of traffic.

CBR (California Bearing Ratio). A measure of the bearing capacity of the soil based upon its shearing resistance. The CBR value is calculated by dividing the unit load required to force a piston into the soil by the unit load required to force the same piston the same depth into a standard sample of crushed stone and multiplying by 100.

Trepanning. An operation performed on the weld at the edge midpoint of the panel connectors using a conical-shaped cutter that rotates about the axis of the height of the cone. The drilling point is placed on the weld bead and a conical notch (hole) is drilled through the weld bead. The weld area is etched and checked for weld penetration. The conical notch is then rewelded to blend with adjacent welds.

PART II: DESCRIPTION OF MAT

Fabrication Features

9. The MX19 landing mat (fig. 1) was a sandwich-type structure with a honeycomb core of aluminum foil bonded to 0.063-in.-thick top and bottom rolled-aluminum sheets by a fiber-film epoxy adhesive. The edge connectors were welded to the top and bottom sheets and were bonded with a potting compound to the core. The core of 0.0007-in.-thick 5056-H19 aluminum alloy foil, tempered to an H39* condition, was formed into 1/8-in. hexagonal cells. All surface pieces of the panel were formed from 6061 aluminum alloy artificially aged to a T6* condition. The panels were joined along two edges by a hinge-type male/female connection. The adjacent edges were joined by an overlap/underlap connection secured by a locking bar. The locking bar was formed from 6061 aluminum alloy artificially aged to a T6 condition. The dimensions and weight of the bar were 48-1/2 by 5/8 by 3/16 in. and 0.55 lb, respectively. The panels were coated with an antiskid material that appeared somewhat

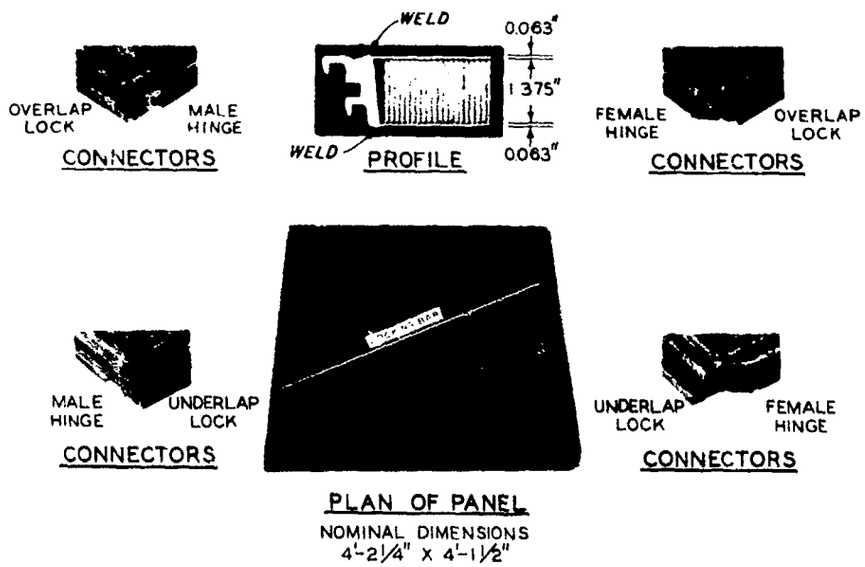

Fig. 1. Kaiser MX19 mat panel

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* H and T denote temper conditions to produce various strengths.

streaked. The grit of the antiskid material appeared to be rounded. These conditions were probably the result of the curtain coating method of antiskid application.

10. Since previous EDT's of MX19 mat had established a fairly consistent failure mode along the female connector,[1,2] modifications of the male and female connectors, directed towards extending the service life of the mat, were incorporated in the design (see fig. 2). The MX19-B had the following modifications:

a. The female connector was strengthened by increasing the thickness of the vertical member to reduce flexure and deflection.

b. A wedge of metal was removed from between the lip and flange of the male connector (fig. 2) to relieve the concentrated stresses between the male and female connectors at the load transfer point.

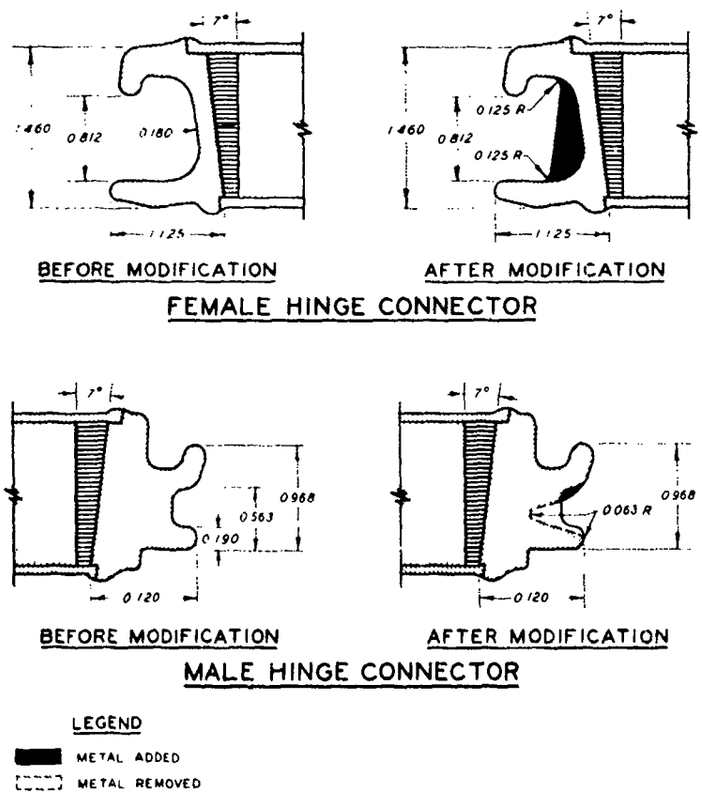

Fig. 2. Modification of MX19 male and female connectors

The MX19-C panels had the modified female connector described in a above and the standard male connector. All other features of the mats were the same as those of previously tested MX19 mat.

Physical Dimensions

11. The mats were shipped in bundles (fig. 3) averaging 25 panels each for the MX19-B and 22 panels each for the MX19-C. Individual

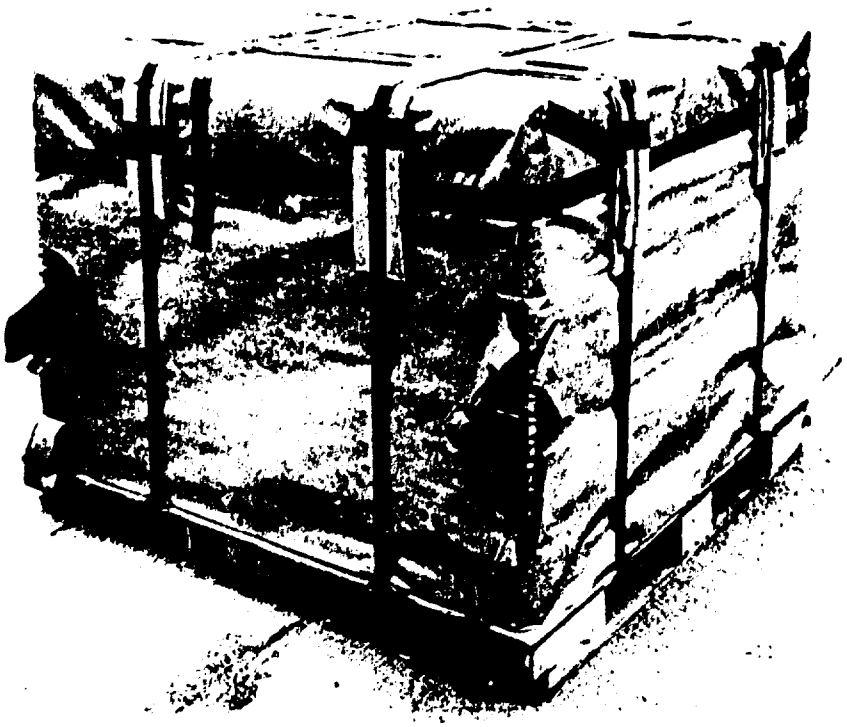

Fig. 3. Bundle of modified MX19 mat

panels (without locking bars) and bundles were weighed and measured, and average weights and dimensions were as follows:

Panels

Type	Length, in. Over-all	Length, in. Placing	Width, in. Over-all	Width, in. Placing	Depth in.	Placing Area per Panel sq ft	Weight lb	Weight per sq ft of Placing Area, lb
MX19-B	50.14	49.97	49.50	48.10	1.5	16.7	69.0	4.13
MX19-C	50.12	49.97	49.50	48.10	1.5	16.7	69.0	4.13

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Bundles							
Type	Length ft	Width ft	Depth ft	Volume cu ft	Weight lb	No. Panels	Total Placing Area, sq ft
MX19-B	4.18	4.12	3.35	57.69	1840	25	417.5
MX19-C	4.17	4.11	3.50	59.99	1625	22	367.4

PART III: TEST SECTION, EQUIPMENT, AND PROCEDURES

Test Section

12. The test area was located under a hangar-type structure to provide both protection from the elements and the conditions necessary for accurately controlled, comparative traffic tests. The test section (plate 1) was 82 ft long and 24 ft wide, with a 10-ft-wide traffic lane in the longitudinal center. The subgrade of the test section was excavated to a depth of 24 in. and backfilled with five 5-in.-thick compacted lifts of a heavy clay (CH) having an average liquid limit of 58 and an average plasticity index of 33 (plate 2).

13. The subgrade was graded to provide a smooth surface with no transverse grade. An approach area was provided at each end of the section for maneuvering of the load cart in the application of traffic. The mat was seated in the subgrade by eight coverages of a seven-wheel, 25-kip Bros roller with tires inflated to 65 psi. Lead weights were used at the sides of the test section to anchor the panels.

14. The test section was divided into two items (see plate 1): item 1, surfaced with MX19-C mat; and item 2, surfaced with MX19-B mat.

Mat Placement

15. The panels were placed in a brickwork pattern, with the male/female connectors parallel to the direction of traffic, by an experienced crew under the direction of a foreman. The panels were stacked in open bundles and were maneuvered by a forklift to minimize the distance that panels had to be hand-carried. The operator's time was not recorded for placing rate computations. Assembly of the panels was accomplished by interlocking the female connector of a panel with the male connectors previously in position (fig. 4), and dropping the panel into position. The overlap/underlap connectors were then nested and secured by a locking bar.

16. The seven-man crew placed both items on the flat subgrade at an average rate of 573 sq ft per man-hour.

Fig. 4. Interlocking female connector with male connectors during assembly of MX19 panels

Traffic Test Equipment

17. The traffic tests were performed with a load cart (fig. 5), powered by the front half of a 4-wheel-drive truck, loaded to 25,000 lb on the test wheel. An outrigger wheel (load considered insignificant)

Fig. 5. Load cart with test wheel loaded to 25,000 lb and tire inflated to 250 psi to produce contact area of 111 sq in. and average contact pressure of 225 psi

prevented overturning. The test wheel had a 30.00x11.5, 24-ply tire inflated to 250 psi to produce a contact area of 111 sq in. and an average contact pressure of 225 psi.

Application of Traffic

18. Traffic was applied to simulate the traffic distribution pattern that would be encountered in aircraft takeoffs and landings. This pattern approaches a normal distribution curve.[10,11] Traffic was started at one side of the traffic lane; the load cart was driven forward and then backward in the same path for the length of the test section. The path of the load cart was shifted laterally 10 in. (the width of a tire print) on each forward trip; thus, two coverages of the traffic lane were completed when the load cart had maneuvered from one side of the traffic lane to the other. The interior 100 in. of the traffic lane were trafficked for six additional coverages. The longitudinal center 60 in. of the traffic lane received two additional coverages for a total of ten coverages. The net result was that the center 60 in. of the traffic lane received 100 percent of the traffic, the 20-in.-wide strips on each side of the center 60 in. received 80 percent, and the 10-in.-wide edge strips received 20 percent (plate 3). This pattern of traffic application was repeated until mat failure occurred.

Skid Test Equipment

19. Skid tests were performed on dry and wet surfaces with a two-wheel, pneumatic-tired load cart. The two wheels of the cart were loaded with 10,000 lb each, and the new 26.00x6.6 tires were inflated to 200 psi to produce a contact area of 53 sq in. and an average contact pressure of 190 psi. The front half of a 4-wheel-drive truck was used for steering, and a Tournadozer was used to pull the load cart. A 50,000-lb-capacity dynamometer was used to measure the force required to skid the cart. An electric strip chart recorded the force required to skid and the distance of the skid.

Application of Skids

20. The load cart was positioned along one side of the traffic lane with the wheels locked. The cart was skidded over the mat at a uniform speed for a given distance to determine the skid-resistance and tire-wear characteristics of the surfaces.

PART IV: CRITERIA FOR MAT FAILURE AND TYPES OF DATA TAKEN

Failure Criteria

21. The following guidelines were used to determine failure of the mat:

a. Excessive mat breakage.

(1) Weld failure: when the weld failure appreciably affected the performance of the mat or became a tire hazard.

(2) Core failure: when the core failure appreciably affected the performance of the mat or caused undue roughness.

(3) End-joint failure.

(4) Breaks.

(a) A panel was considered failed when a break was considered to be a tire hazard.

(b) An item was considered failed when breaks exceeding 6 in. in length occurred in 50 percent of the panels or when breaks extending 40 percent of the length of a panel occurred in 20 percent of the panels.

b. Static deflection. Usually not to exceed 1 in. maximum (accompanied by indication of structural failure).

c. Roughness.

(1) Deflection not to exceed 1 in. at side joint, measured from a 4-ft-long straightedge.

(2) Dishing not to exceed 0.6 in.

(3) Instability of the load cart as determined by observations and experienced judgment when the load cart was traveling at a uniform rate of speed (approximately 2 to 4 mph).

22. Since it was assumed that a certain amount of maintenance will be performed in the field during usage of the mat, it was considered feasible to replace 10 percent of the panels receiving 100 percent of the traffic with new panels. When an additional panel required replacement, or was considered to be a tire hazard, the item was considered failed.

Types of Data Recorded

Skid tests

23. Electric strip chart recordings of the force required to pull the load cart and of the length of the skid were made on individual oscillograms. Comparative tire wear was estimated by observations supplemented by photographs. Observations and photographs of the antiskid coatings on the mat were made before and after the skid tests.

Traffic tests

24. Subgrade densities, water contents, and in-place CBR's were measured before, during, and after traffic (see table 1). The locations of the test pits are shown in plate 1. A minimum of three recordings per level were made at the surface and at depths of 6 and 12 in. for each category. Static deflection was measured at the center of a panel, the joint of two panels, and the joint of three panels (see plates 4 and 5). Level readings (transverse and longitudinal) were taken before, during, and after traffic (see plates 6 and 7, respectively). Observations of the mat, subgrade behavior, and other relevant factors were recorded throughout the periods of traffic and were supplemented by photographs. Table 2 presents a summary of static deflection measurements and mat failures.

PART V: TEST RESULTS AND ANALYSIS

Test Results

Skid tests

25. Since the antiskid material and the method of application for the two items were identical, skid tests were performed on only one item. The antiskid coating adhered to the mat surfaces adequately during the tests. An average force of 6500 lb was required to skid the load cart with locked wheels a distance of 18 ft on a dry surface (photo 1). On a wet surface, an average force of 4500 lb was required to skid the cart a distance of 16 ft. A summary of the skid test results is presented in the following tabulation:

Condition of surface	Length of Skid, ft	Wheel load lb	Average Force, lb	Coefficient of Friction
Dry	18	20,000	6500	0.32
Wet	16	20,000	4500	0.22

Tire wear on the wet surface was negligible, and only slight wear resulted from skidding on the dry surface (photo 2).

Traffic tests

26. Item 1, MX19-C. Prior to traffic, the surface of item 1 (modified female connectors) was generally smooth (photo 3), and the average CBR of the subgrade was 3.4. After 500 coverages, no mat breaks were observed, and the mat was in excellent condition. At 900 coverages, tests of the subgrade indicated that the strength of the upper 12 in. had increased to a CBR of 5.0. Therefore, all panels were removed from the test section, and the subgrade was reprocessed. The strength of the reprocessed subgrade in item 1 averaged 4.1 CBR. Panels were replaced in their original positions, and traffic was resumed.

27. After 1560 coverages,* panel 39 had developed a

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* All coverage levels are cumulative totals of the coverages applied to the mat.

1-1/2-in.-wide depression, beginning at the center of the panel and extending diagonally for approximately 17 in. toward the female connector. The panel was considered failed and was removed from the test section for analysis. A section was cut from the panel, and the core was split (i.e., cut on a plane parallel with the top and bottom panel surfaces) for inspection. Separation of the core material of panel 39 is shown in photo 4. The failed panel was replaced with a new panel. Traffic was continued to 2400 coverages with no additional failures or breaks, and the general condition of the item remained good. Soil tests at the joint of panels 14, 15, and 18 revealed that the strength of the subgrade at the surface had increased to 5.4 CBR. The mat was removed, and the upper 16 in. of the subgrade were reprocessed. The strength of the reprocessed subgrade averaged 3.2 CBR. Each panel was replaced in its original position, and traffic was continued.

28. After 2480 coverages, a small crack had developed in panel 11 at the midpoint of the male connector (photo 5). The break originated at the point of trepanning and extended for approximately 3-1/2 in. toward the mat center. Traffic was continued until 2756 coverages had been completed. At that point, the break in panel 11 had progressed toward the center of the panel for 14-3/4 in., and a second break had occurred along the male connector (photo 6). Panel 11 was considered failed and was removed from the test section. Further examination of the panel revealed a 36-in.-long bottom-sheet break along the male connector (photo 7).

29. After 2756 coverages, the subgrade strength averaged 5.2 CBR (table 1), and the maximum permanent deformation was 0.6 in. The general appearance of the item was good (see photo 8). Although the item was not considered failed (see paragraph 21), traffic was discontinued for the following reasons:

a. The MX19-C mat had already performed satisfactorily for more than two and one-half times as many actual coverages as the MX19-B mat (see paragraph 33), for more than seven times as many as the prototype MX19 mat, and for more than two times as many as the 1000 coverages stipulated by the QMR.

b. Determining the failure point of the item was not considered worth the additional time and money required to reprocess the subgrade and continue traffic.

30. The rated CBR of the subgrade of item 1 ranged from 4.1 to 4.3 (table 1). The maximum static deflection was 1.0 in., measured at the joint of three panels after 2400 coverages (table 2); and the maximum permanent deformation was 0.6 in., recorded after 2756 coverages (plate 7). These maximum measurements occurred on subgrades with an average CBR of 4.7 and 4.9, respectively.

31. Item 2, MX19-B. Prior to the application of traffic, the surface of item 2 (modified female and male connections) was generally smooth (photo 9), and the average CBR of the subgrade was 4.0. After 170 coverages, a narrow 16-1/2-in.-long depression had developed in panel 47, perpendicular to the direction of traffic (photo 10). After ten additional coverages, this depression had increased to 33 in. in length and 11 in. in width. After 190 coverages, panel 47 was considered failed (photo 11).

32. At 900 coverages, panel 66 had a 24- by 8-in. depression paralleling the direction of traffic along the female connector (photo 12). Panel 66 was considered failed and was removed from the test section and replaced with a new panel. Soil tests under panel 66 revealed that the CBR of the top 12 in. of the subgrade had increased to 6.0. Therefore, all panels were removed from the test section, and the subgrade was reprocessed. The strength of the reprocessed subgrade in item 2 averaged 3.9 CBR. Each panel was replaced in its original position, and traffic was resumed.

33. At 940 coverages, panels 43 and 67 had small cracks at the center of the male connector, similar to the crack in panel 11 after 2480 coverages (see paragraph 28 and photo 5). The cracks in panels 43 and 67 originated at the point of trepanning and extended toward the mat center. After 948 coverages, panel 67 was removed for inspection. Although the panel apparently would withstand additional traffic, failure was considered imminent; therefore, panel 67 was replaced with a new panel. However, since it had been removed from the item before actual

failure, panel 67 would be considered failed when the next failure occurred. Panel 78, which contained a narrow depression similar to that in panel 47 at 170 coverages (see photo 10), was also removed for inspection. Since no breaks were noted on the top and bottom sheets, the panel was put back into the test section for additional traffic. After 1008 coverages, however, a permanent set of 1-5/8 in. had developed along the female connector, and a weld break had developed along the overlap connector (see photo 13). Therefore, panel 78 was considered failed. Since more than 10 percent of the panels in the 100 percent coverage area had been considered failed (panels 47, 66, 67, and 78), the item was considered failed at 1008 coverages.

34. At this point, soil tests were performed under panels 70 and 78 (table 1). The general condition of item 2, other than panels 43 and 78, at 1008 coverages was good (photo 14). The maximum permanent deformation measured was 0.4 in. (plate 7), which occurred at 500 coverages, and the maximum static deflection was 0.7 in., measured at the joint of two panels at 1008 coverages (plate 5).

35. Since traffic was continued on the test section after item 2 (MX19-B mat) had failed at 1008 coverages, further observations of the performance of item 2 were possible. The break in panel 43, which had developed after 940 coverages at the point of trepanning on the male connector (see paragraph 33), lengthened as follows:

No. of Coverages	Length of Break, in.
940	1-1/2
1244	9
1275	10
1350	19
1378	23

At 1378 coverages, panel 43 had a maximum of 9/16-in. deflection and had an 8-3/4-in. break along the male connector. At 1386 coverages, the core of panel 43 collapsed, causing the load vehicle to become immobilized (photo 15). Inspection of the panel after removal from the test section indicated that the collapse resulted from a break originating at

trepanning on the male connector (photo 16). The remainder of item 2 was in good condition.

Analysis of Results

Skid tests

36. The coefficients of friction, 0.32 and 0.22 on dry and wet surfaces, respectively, were somewhat lower than those previously obtained on MX19 mat and did not meet the QMR performance specifications of a 0.40 to 0.80 range. The grit of the antiskid material appeared to be rounded, and the coating was somewhat streaked. The streaks probably resulted from a faulty method of antiskid application, and the condition of grit probably resulted from an overcoating of paint to produce a symmetrically shaped grit. However, the coating did adhere to the surface adequately during testing.

Traffic tests

37. Item 1. The first panel failure occurred in the honeycomb core near the center of panel 39 at 1560 coverages. The failed core, dissected for inspection, is shown in photo 4. The second panel failure (panel 11) was caused by the trepanning operation performed during manufacture to check weld penetration. This failure began at 2480 coverages with a small crack 3-1/2 in. long perpendicular to the male connector at the point of trepanning (see photo 5). As traffic continued to 2692 coverages, this crack developed into a 12-in.-long break. This break had also progressed for 2-1/2 in. at the weld along the male connector. At 2756 coverages, panel 11 failed abruptly when the potting sheared along the male connector (photo 6), causing the bottom skin to tear as shown in photo 7.

38. Item 2. The first panel failure occurred in the honeycomb core near the center of panel 47 at 190 coverages. This failure began as a small depression followed by a greater depression and separation of skin and core materials. Photo 17 shows the panel after being cut and dissected for an inspection of the core failure. The second panel failure (panel 66) also occurred as a depression in the core material approximately 24 in. long in a longitudinal direction and 8 in. wide in

an area along the female connector (900 coverages). Photo 18 is a closeup view of panel 66, showing details of the failure. The maximum deformation measured in this panel was 0.15 in. After 948 coverages, panel 67 revealed signs of distress with a small crack at the center of the panel beginning at the male connector and progressing transversely, identical with the failure of panel 11 described in paragraphs 28 and 37. Panel 67 was removed for analysis. Failure was considered imminent, and this panel was replaced with a new panel.

39. The third failure began after 948 coverages with a small depression in panel 78. By 1008 coverages, a severe depression had developed, along with an approximately 20-in. weld failure in the top skin along the overlap connector (photo 13). The bottom skin weld failed along the entire length of the overlap connector (photo 19).

40. An analysis of the failure of panels 11, 43, and 67 revealed that the trepanning operation and the method and location of the operation had contributed to premature failure of these panels. The trepanning operation was located at the center of the connectors and was at a point of maximum stress concentration on the male and female connectors as adjacent panels transferred the load at these points. Weld inspections at the quarter point or at any other point, except where these maximum stresses were concentrated, would probably have prevented these failures. Also, the inspection notch (hole) should have been changed to a flat-bottom hole to ensure complete refilling of the hole with weld. These two types of weld inspection holes are shown in plate 8.

Mat strength evaluation

41. The rated CBR, total single-wheel load, tire pressure, and actual number of coverages were substituted in the equation*

$$\frac{t}{0.23 \log_{10}(C) + 0.15} = \sqrt{P\left(\frac{1}{8.1\ \mathrm{CBR}} - \frac{1}{p\pi}\right)}$$

where

t = design thickness of pavement structure, in.

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* This equation is a combination of equation 2, page 2, and the equation for the slope of the curve in plate 3 from reference 12.

C = coverages

P = total single-wheel load, lb (25,000)

CBR = rated California Bearing Ratio

p = tire pressure, psi (250)

to solve for t . Once t had been determined, the required CBR of 4.0 and the t , P , and p values were substituted in the above equation to solve for the number of coverages C that the MX19-B and MX19-C mats would withstand. Since, during this investigation, the subgrade had to be reprocessed to maintain the desired range of CBR's, the equations for determining the number of coverages which the mats would withstand on a 4.0-CBR subgrade had to be solved for each instance. The following tabulation summarizes the actual number of coverages and rated CBR's for the mat tests and shows the equivalent coverages on a 4.0-CBR subgrade.

Item No.	Subgrade	Coverage Increment	Actual Coverages	Rated CBR	Equivalent Coverages on 4.0-CBR Subgrade
1	Original	0-900	900	4.2	700
	Reprocessed	901-2400	1500	4.3	1040
	Re-reprocessed	2401-2756	356	4.1	310
		Total	2756*	Total	2050
2	Original	0-900	900	4.3	660
	Reprocessed	901-1008	108	4.3	90
		Total	1008	Total	750

* Item had not failed when traffic was discontinued.

The above computations indicated that the MX19-B and MX19-C mats on a 4.0-CBR subgrade would withstand 2050 and 750 coverages of traffic, respectively, when subjected to a 25,000-lb single-wheel load with a tire-inflation pressure of 250 psi. The strength evaluation of the two mats is shown graphically in plate 9.

PART VI: CONCLUSIONS

42. Based on the data obtained in this investigation, the following conclusions are believed warranted:

a. The trepanning operation used to check weld penetration in fabrication contributed to failures that developed in some of the mats, particularly in item 2, and possibly prevented a true evaluation of the design changes in the MX19-B mat. However, the MX19-B mat did sustain 750 coverages of the F-4C loading on a 4.0-CBR subgrade, as compared with 550 coverages for the prototype MX19 mat (an increase of 37 percent).

b. The MX19-C mat sustained in excess of 2050 coverages of the F-4C loading on a 4.0-CBR subgrade, or an increase of greater than 370 percent over the prototype MX19 mat. The 2050 coverages were more than twice the anticipated increased service life requirement of 1000 coverages.

c. The modifications of the connectors of the MX19-B and MX19-C eliminated the previously established failure mode for the MX19 mat since no panels failed along the female connectors.

d. The coefficients of friction of 0.32 and 0.22 on a dry and a wet surface, respectively, for the modified mats were considerably less than the values (0.56 and 0.28) obtained on the prototype mats.

e. The placing rate of 573 sq ft per man-hour was equal to that obtained with the prototype mat.

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Table 1

Summary of CBR, Water Content, and Dry Density

Item	Total No. of Coverages	Location of Test Pit Panel No.	Depth in.	CBR	Rated CBR	Water Content %	Dry Density pcf
1	0	17	0	3.6	4.2	25.4	95.5
			6	3.3		26.0	95.4
			12	3.2		26.5	94.5
			Avg	3.4		26.0	95.1
	900	27	0	6.5		25.0	96.6
			6	4.4		25.4	95.7
			12	4.1		26.4	91.9
			Avg	5.0		25.6	94.7
	900*	13	0	3.5	4.3	26.0	95.6
			6	4.5		25.5	95.5
			12	4.3		24.6	97.1
			Avg	4.1		25.4	96.1
	1084	30	0	4.1		26.7	95.6
			6	4.1		25.7	96.0
			12	4.0		25.7	95.4
			Avg	4.1		26.0	95.7
	1560	22		[illegible]		25.4	96.6
			6	4.4		24.9	96.9
			12	3.6		25.3	95.7
			Avg	4.3		25.2	96.4
	1800	19	0	4.0		27.2	96.4
			6	4.3		25.4	97.1
			12	4.0		26.2	95.5
			Avg	4.1		26.3	96.3
	2400	14,15,18	0	5.4		25.6	98.8
			6	4.6		23.7	97.0
			12	4.2		25.2	96.3
			Avg	4.7		24.8	97.4
	2400*	18,19,22	0	3.2	4.1	25.4	95.6
			6	3.1		25.9	93.9
			12	3.3		26.1	95.3
			Avg	3.2		25.8	94.9
	2400*	35	0	3.1		25.9	95.4
			6	3.3		25.2	94.4
			12	3.1		25.7	95.7
			Avg	3.2		25.6	95.2

Item	Total No. of Coverages	Location of Test Pit Panel No.	Depth in.	CBR	Rated CBR	Water Content %	Dry Density pcf
1 (Cont'd)	2756	26	0	6.2	4.1	25.0	98.4
			6	6.0		24.6	95.9
			12	3.4		26.1	95.5
			Avg	5.2		25.2	96.6
	2756**	11	0	5.4		25.7	96.3
			6	5.3		24.8	96.6
			12	3.4		25.9	94.7
			Avg	4.7		25.5	95.9
2	0	56	0	3.9	4.3	25.4	95.1
			6	3.0		24.8	94.0
			12	5.0		25.9	98.6
			Avg	4.0		25.4	95.9
	190	47	0	3.9		25.6	97.1
			6	3.9		25.7	97.4
			12	3.0		26.4	95.3
			Avg	3.6		25.9	96.6
	900	71	0	4.8		25.9	97.4
			6	6.0		25.1	97.3
			12	3.9		26.0	94.8
			Avg	4.9		25.7	96.5
	900	63	0	5.0		25.4	97.2
			6	4.6		25.6	96.5
			12	4.7		26.2	95.2
			Avg	4.8		25.7	96.3
	900*	60	0	3.7	4.3†	24.8	97.3
			6	4.2		25.6	95.8
			12	3.9		25.9	95.0
			Avg	3.9		25.4	96.0
	1008††	70	0	5.2		25.1	96.8
			6	4.1		26.5	95.0
			12	4.7		25.7	94.7
			Avg	4.7		25.8	95.5
	1008	78	0	5.1		24.7	96.2
			6	3.5		26.1	93.9
			12	5.6		24.8	96.4
			Avg	4.7		25.2	95.5

* Subgrade reprocessed.
** Traffic discontinued.
† Data in both items used.
†† Item failed.

Table 2

Summary of Static Deflection Data and Mat Failures

Item	No. of Coverages	No. of Panels Failed	Maximum Measured Mat Deflections, in. Center Panels	Transverse Joints	Transverse and Longitudinal Joints
1	0		0.5	0.7	0.7
	50		0.4	0.6	0.7
	100		0.4	0.7	0.8
	200		0.6	0.7	0.8
	500		0.5	0.7	0.7
	900		0.5	0.6	0.7
	1008		0.6	0.7	0.7
	1560	1	--	--	--
	2400		0.6	0.8	1.0
	2756*	1	0.5	0.9	0.9
	Total	2			
2	0		0.6	0.8	0.7
	50		0.4	0.6	0.7
	100		0.4	0.7	0.7
	190	1	--	--	--
	200		0.4	0.7	0.7
	500		0.4	0.6	0.7
	900	1	0.4	0.7	0.6
	948	1**	--	--	--
	1008†	1	0.5	0.7	0.8
	Total	4			

* Item 1 still performing at 2756 coverages; traffic discontinued.

** Panel 67 was removed for analysis before failure actually occurred, and inspection revealed that failure was imminent. However, since it had been removed before actual failure, panel 67 would be considered failed when the next failure occurred (see paragraphs 22 and 33).

† Item 2 failed at 1008 coverages.

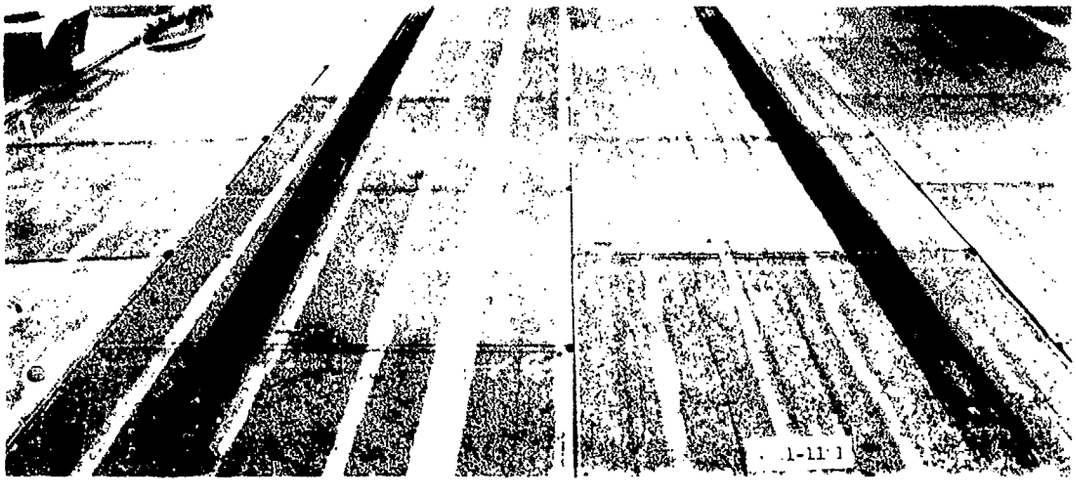

Photo 1. Skid marks on dry mat surface

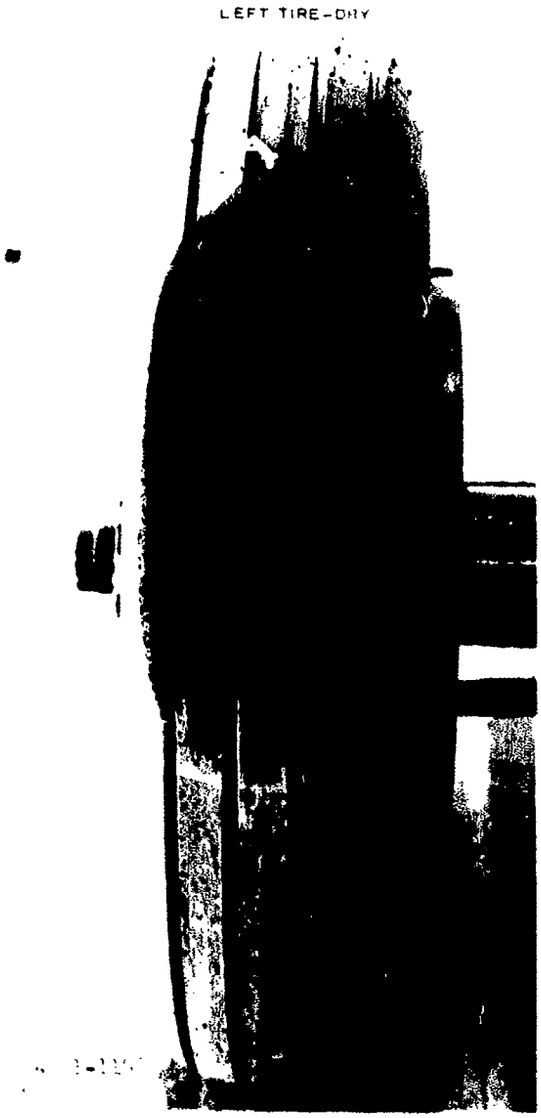

Photo 2. Tire after skid on dry mat surface

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Photo 3. Item 1 (XX19-C) prior to traffic

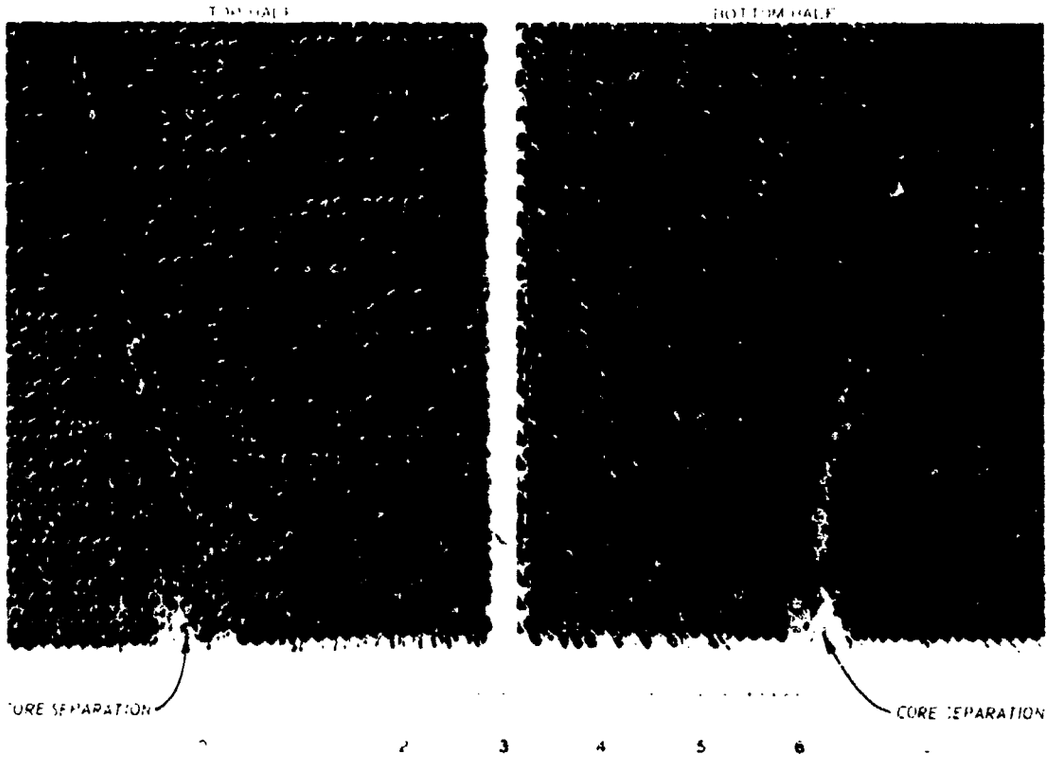

Photo 4. Separation of core material in failed panel 39 (1560 coverages)

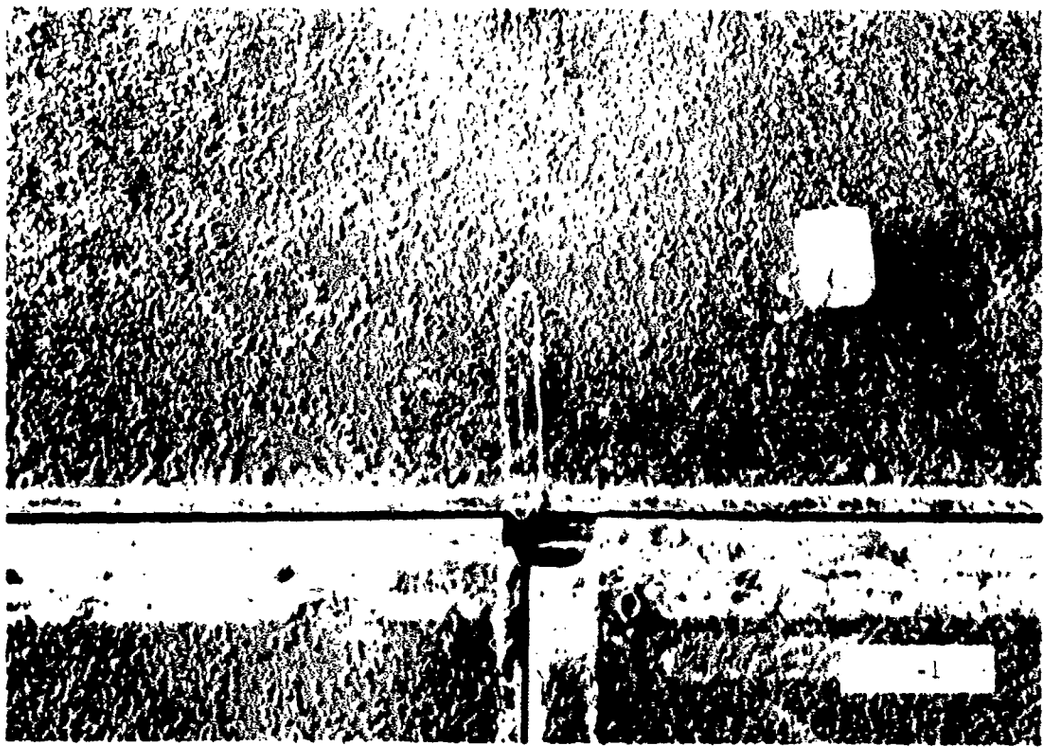

Photo 5. Break originating at location of trepanning on male connector of panel 11 (2480 coverages)

Photo [illegible]. Failure of panel J1 after [illegible] cover[illegible]

[illegible] from [illegible] skin of panel [illegible] [illegible]
[illegible] verages)

Fig. 5. Item 1 after [illegible]

Fig. 9. Rear view (Mk-9b) [illegible]

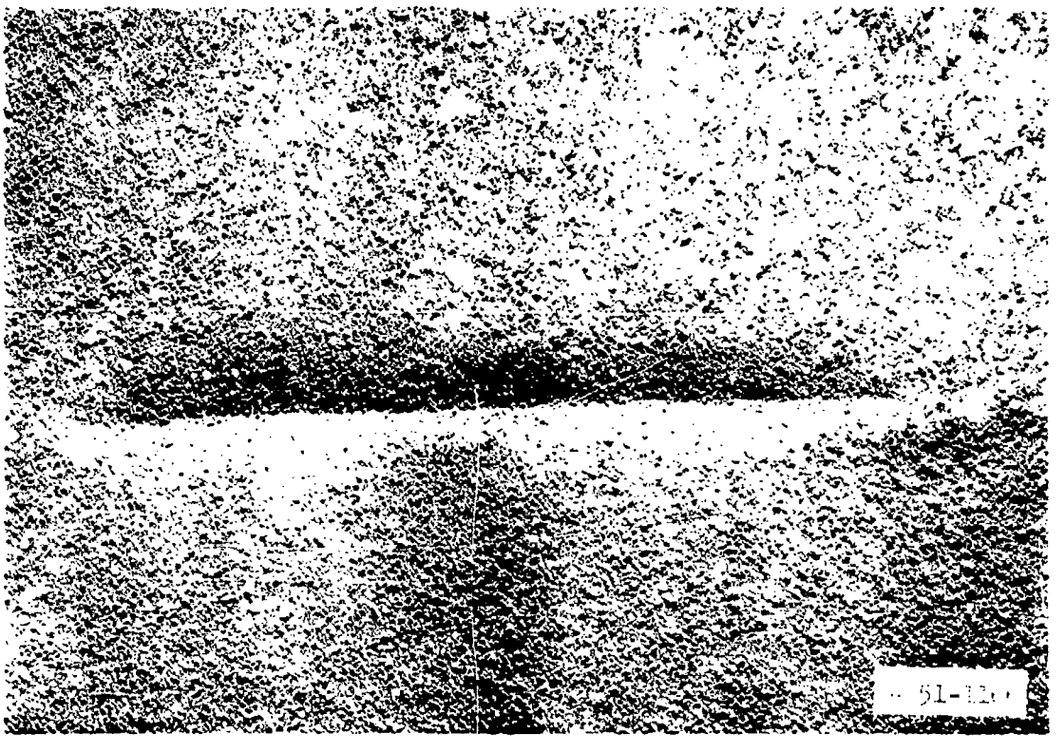

Photo 10. Depression in panel 47 at 170 coverages

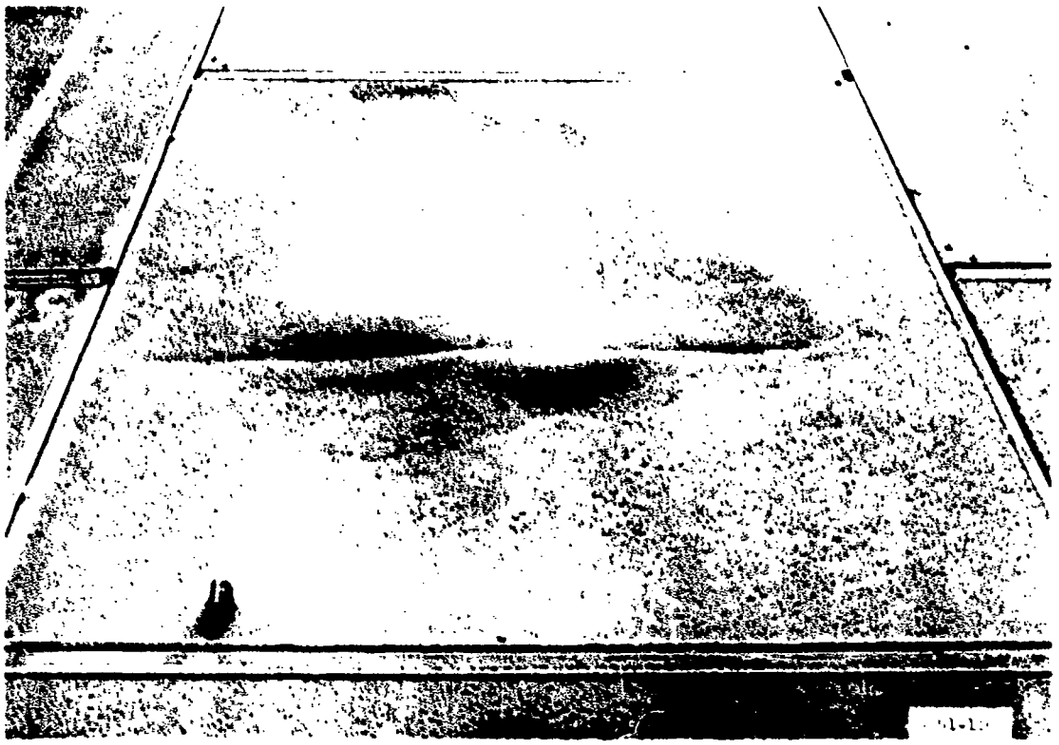

Photo 11. Failure of panel 47 after 190 coverages

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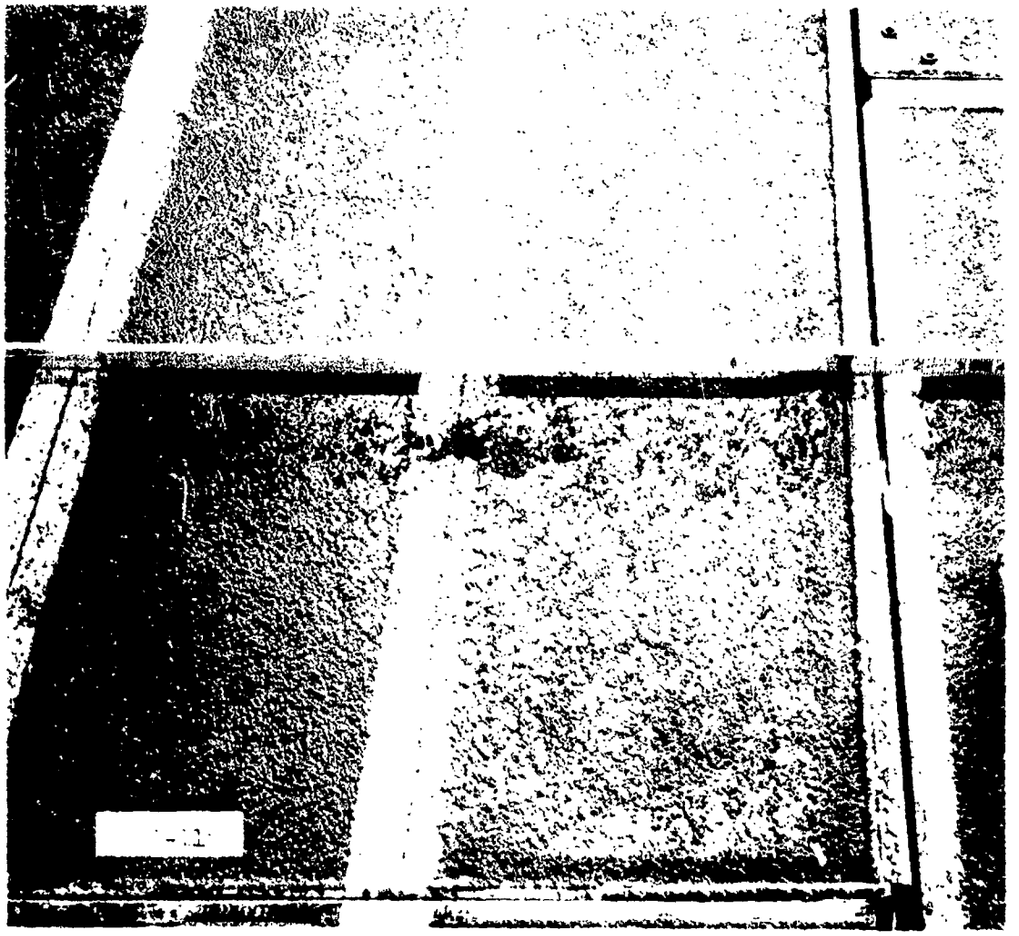

Fig. [illegible] Failure of panel 60 after [illegible] cycles

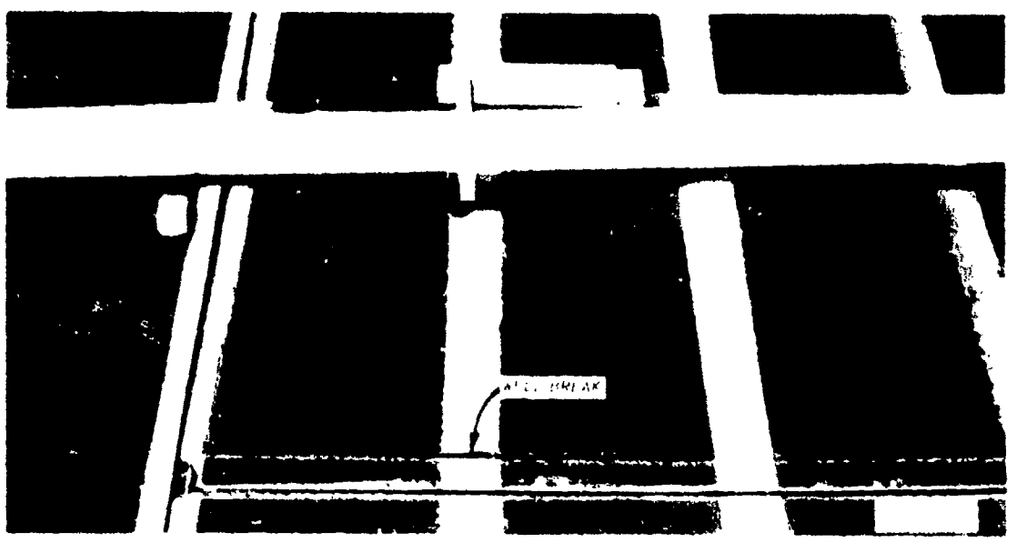

Figure [illegible] Failure of panel 78 after [illegible] cycles

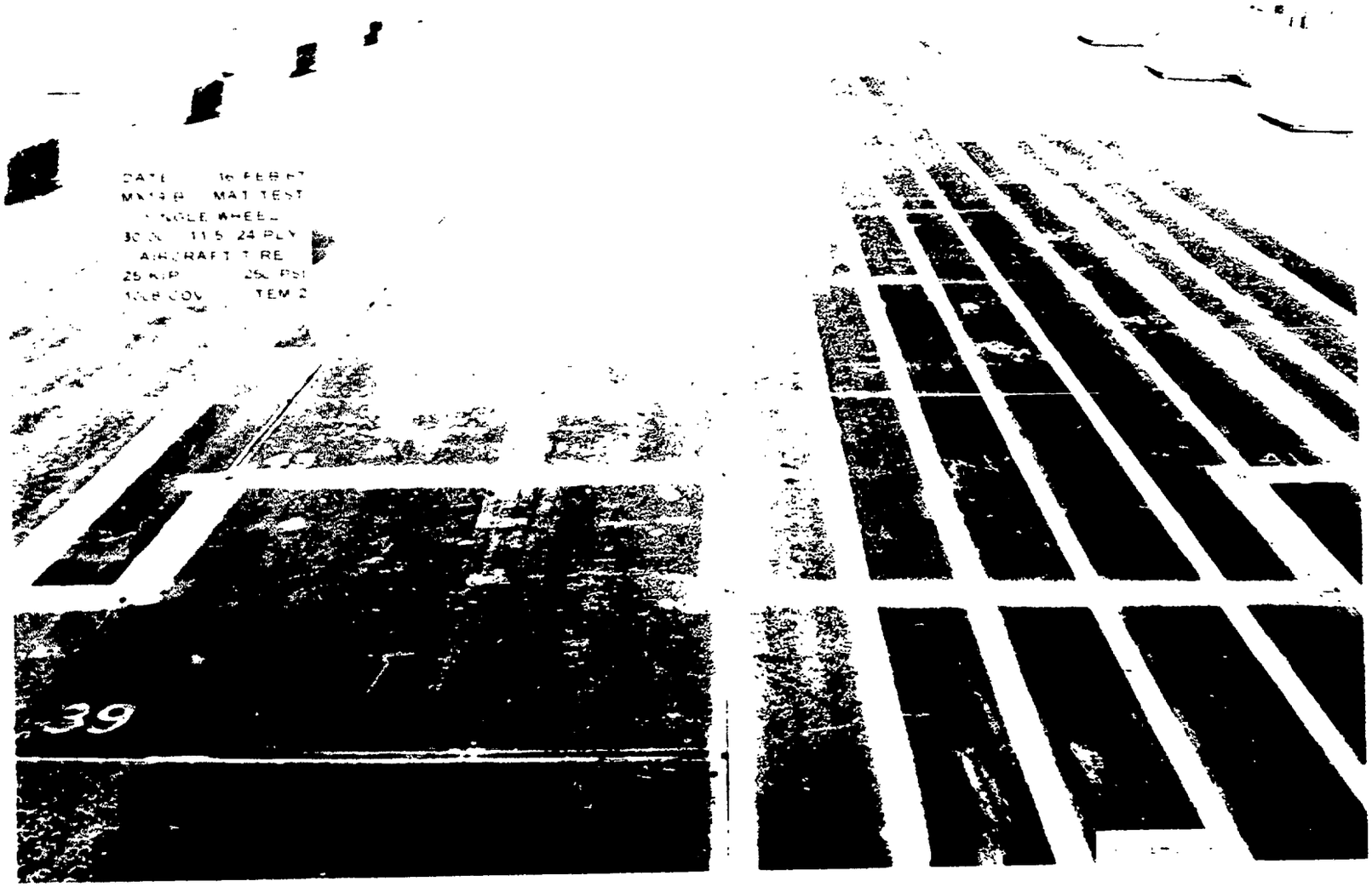

Photo 14. Item 2 after 1008 coverages

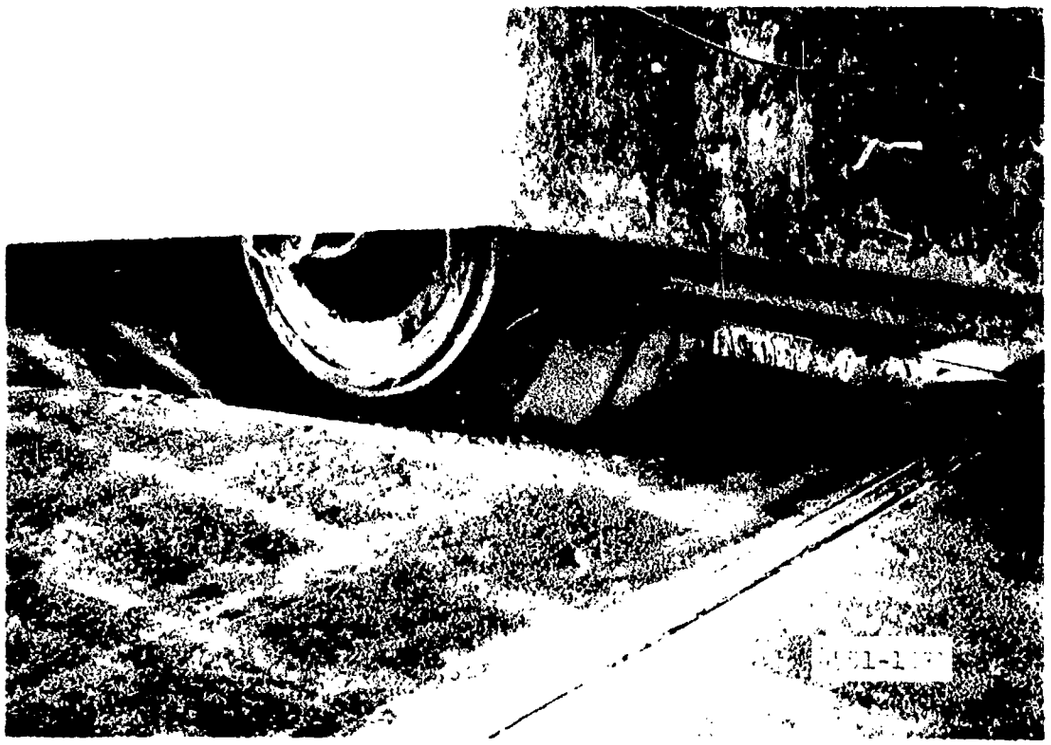

Photo 15. Collapse of panel 43 at 1386 coverages

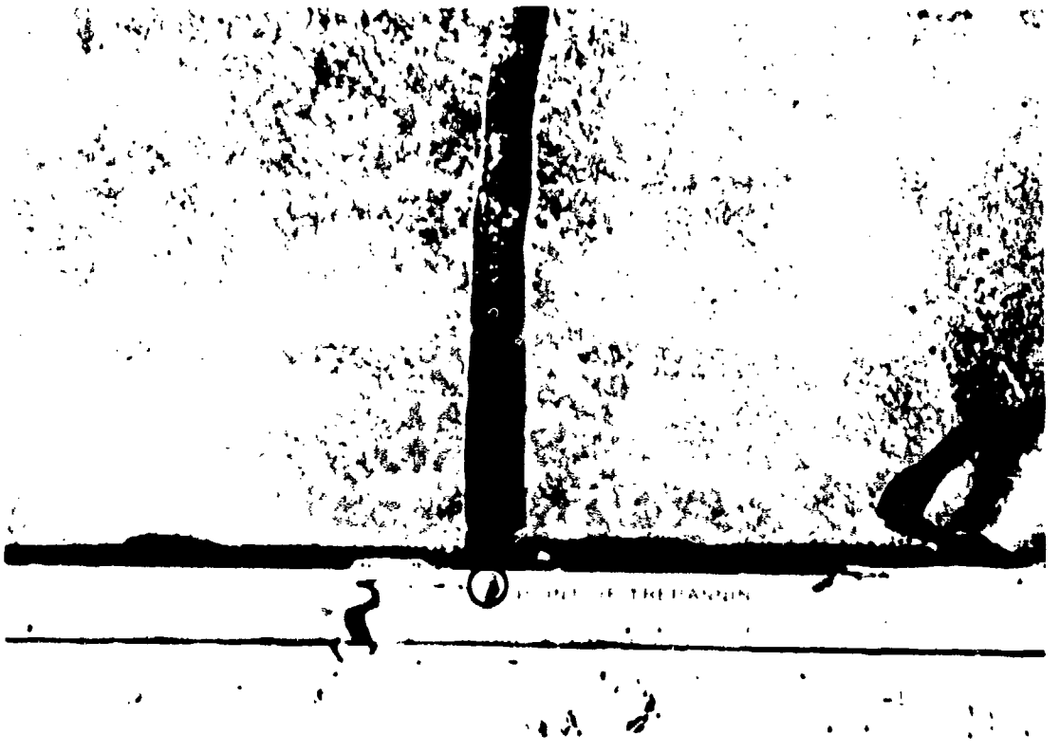

Photo 16. Break originating at point of trepanning on male connector of panel 43, resulting in collapse (1386 coverages)

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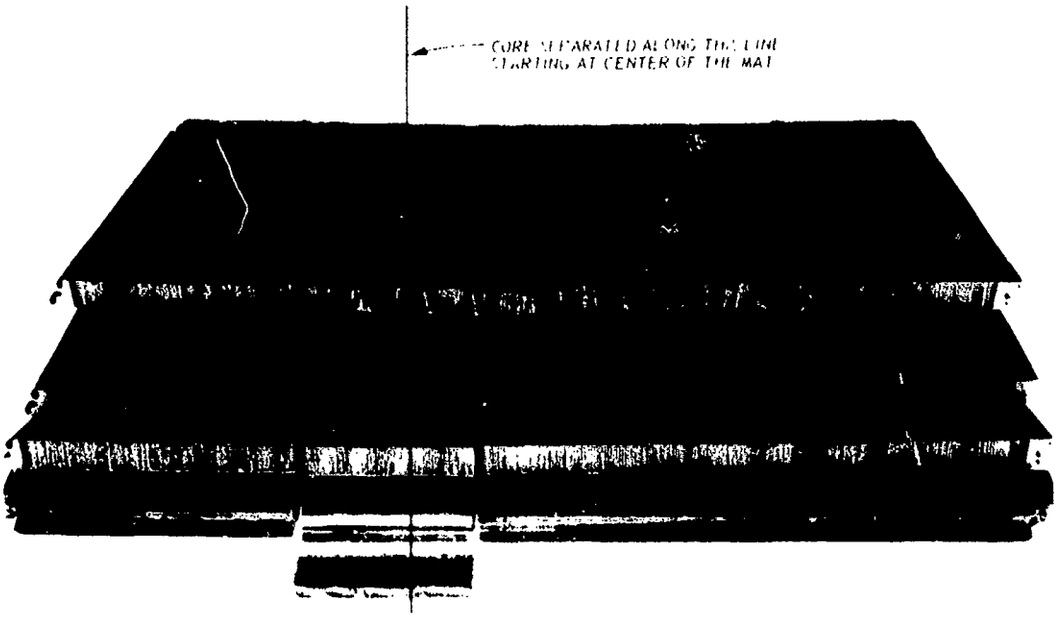


Photo 17. Panel 47, dissected, showing core failure at 190 coverages

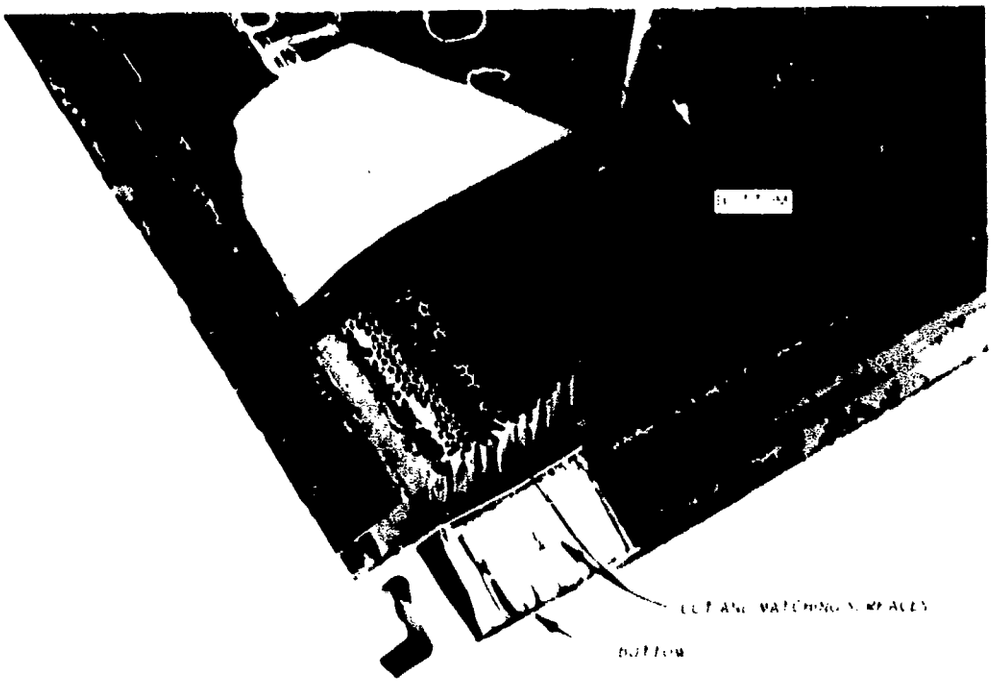


Photo 18. Panel 66, dissected, showing core failure at 900 coverages

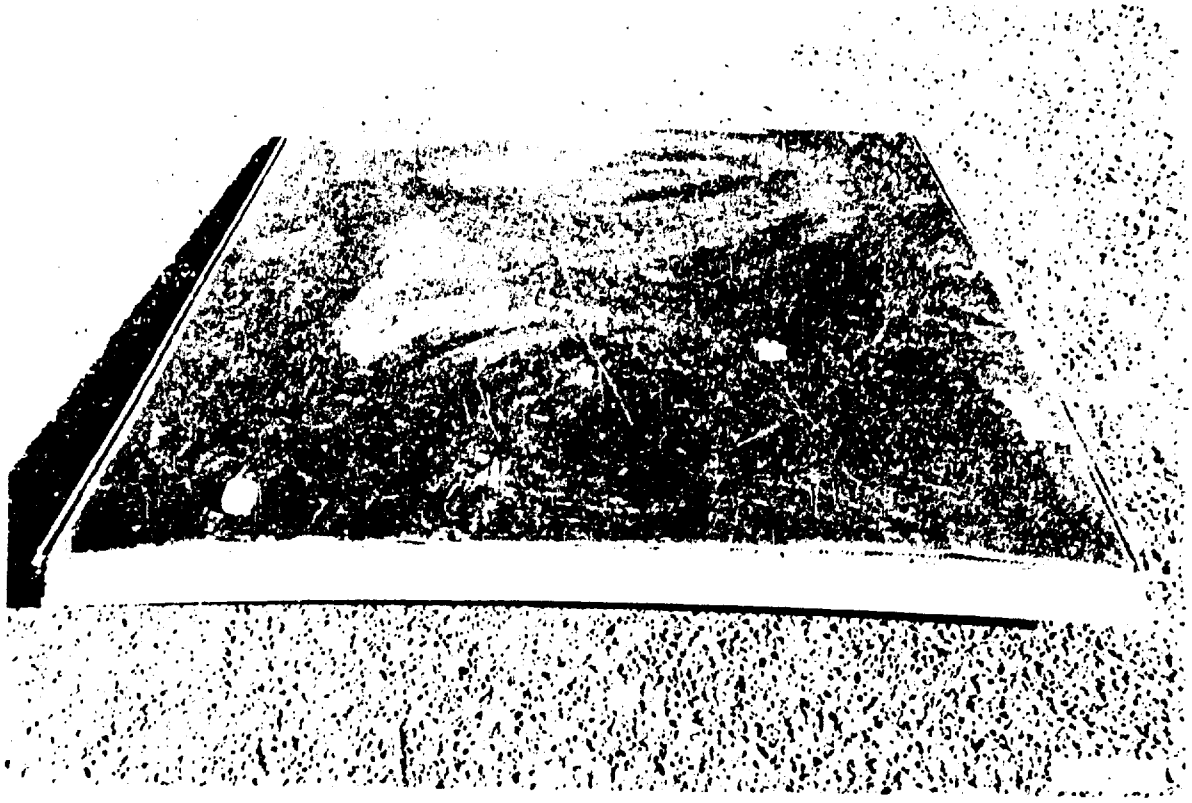
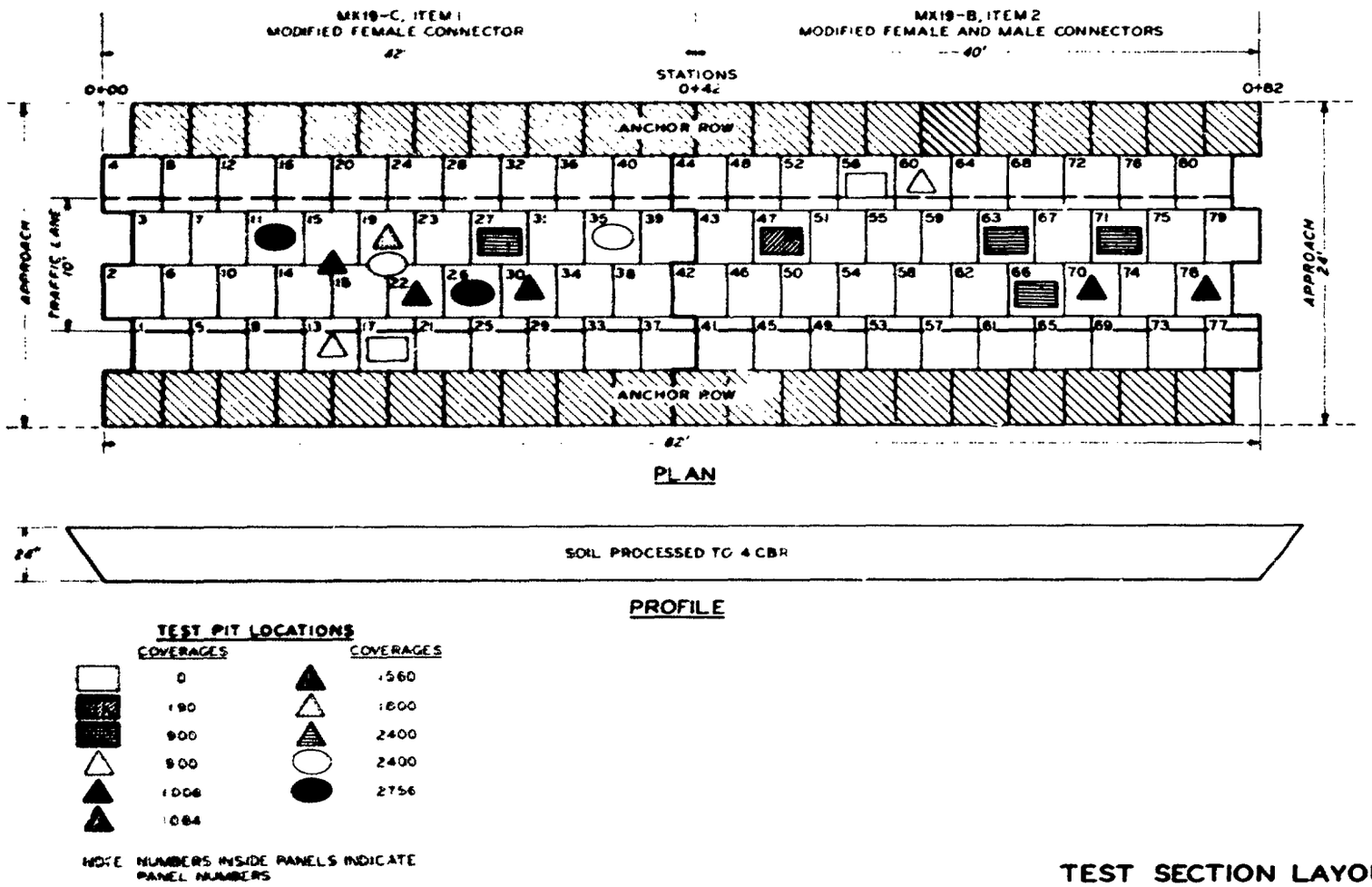
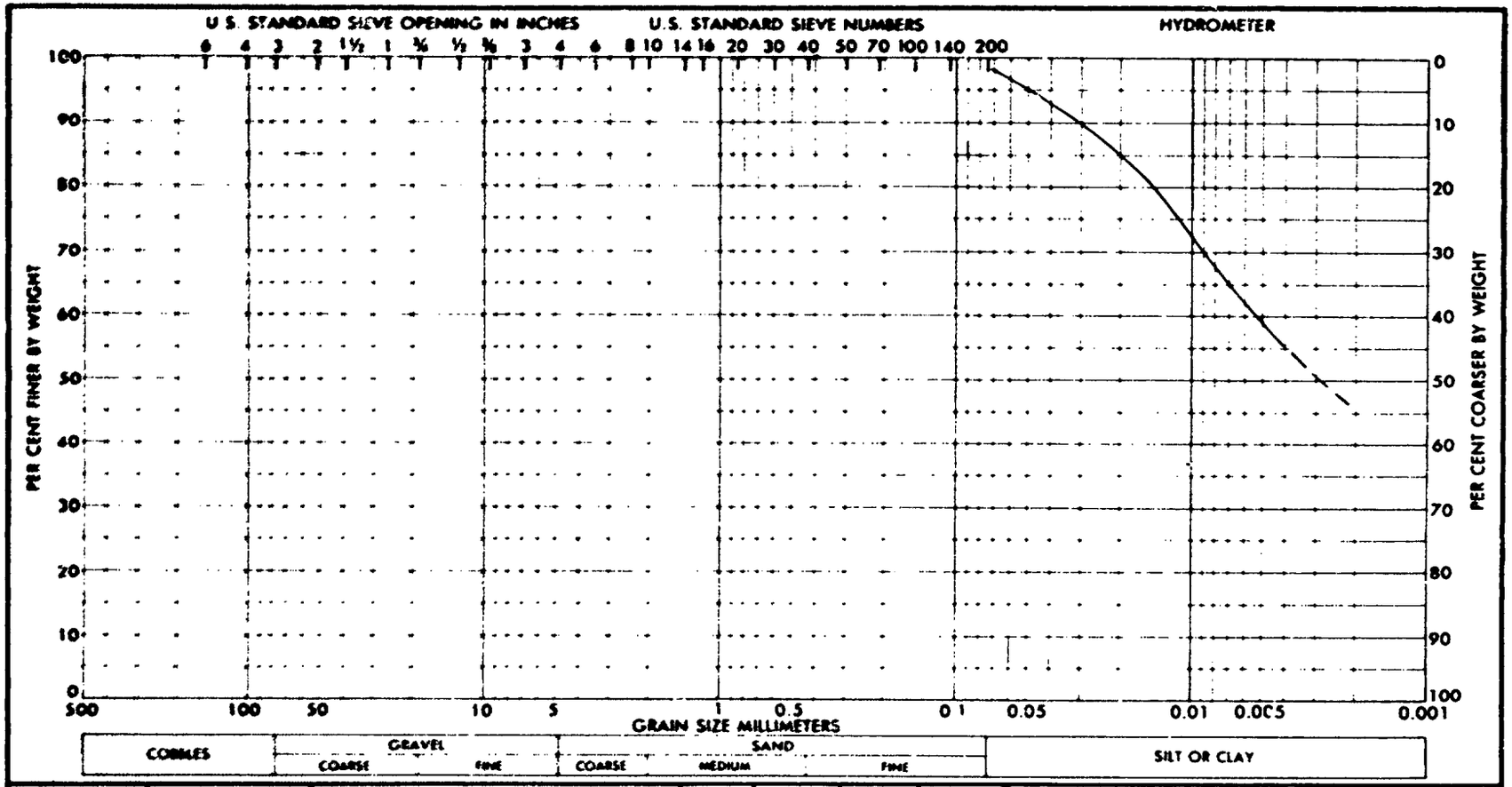


Photo 19. Panel 75 at 1096 coveragges with failure of bottom sheet-to-connector weld along overlap connector

Best Available Copy



TEST SECTION LAYOUT

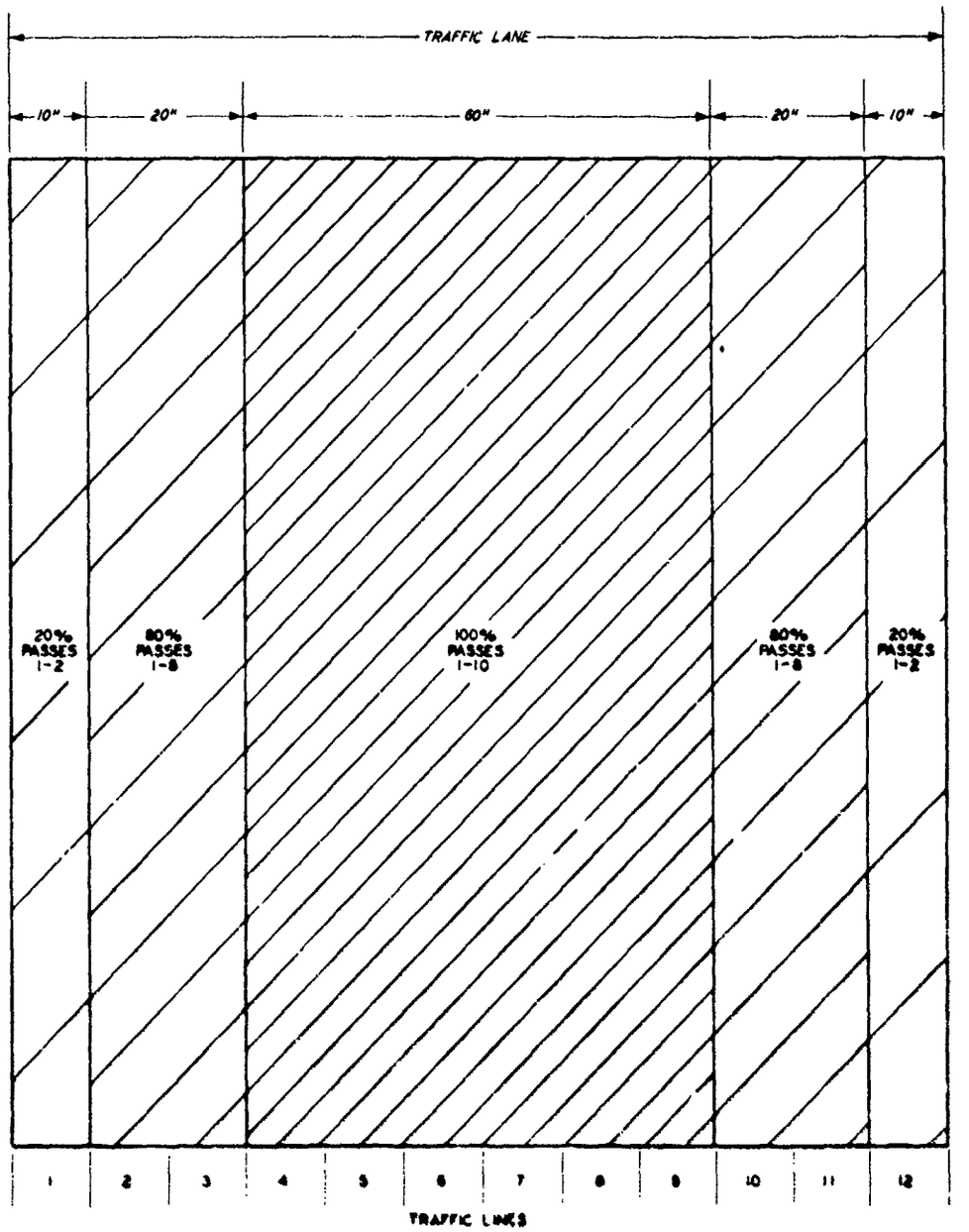


SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
		CLAY (CH)		59	25	33

CLASSIFICATION DATA

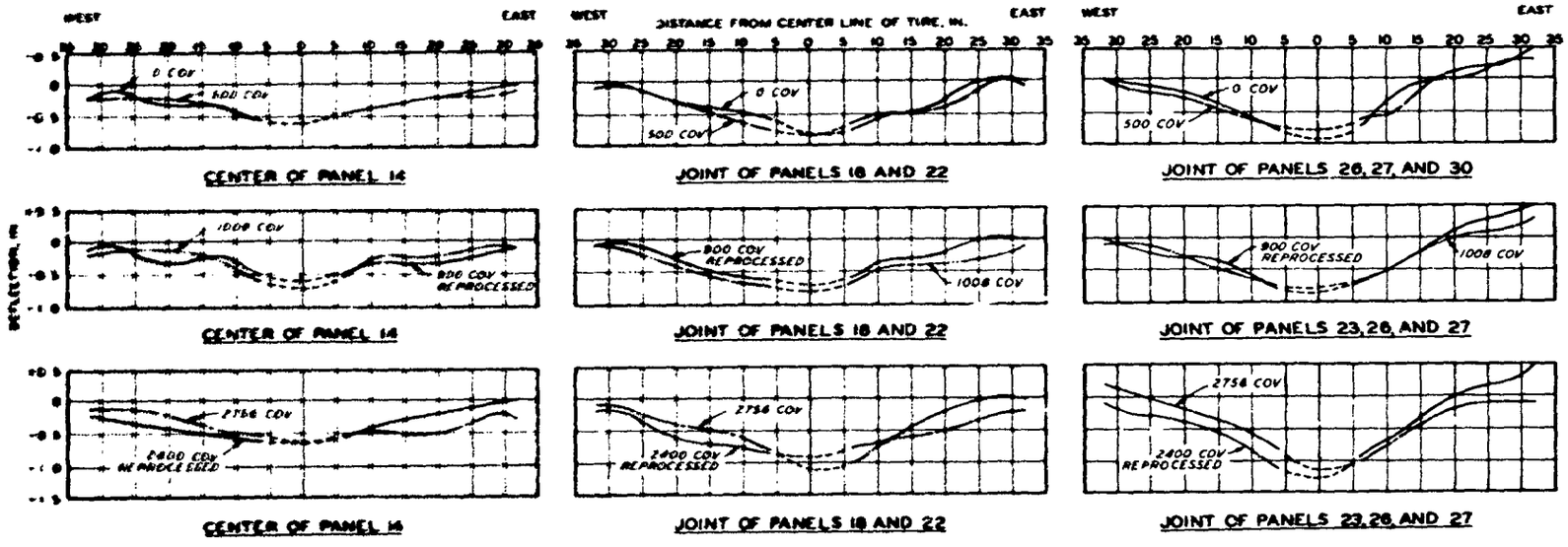
CLAY SUBGRADE

PLATE 2



NOTE EACH PASS IS EQUAL TO A
AVERAGE BY A 10-IN-WIDE
LOAD WHEEL OVER EACH
TRAFFIC LINE

TRAFFIC DISTRIBUTION
F-4C LOADING

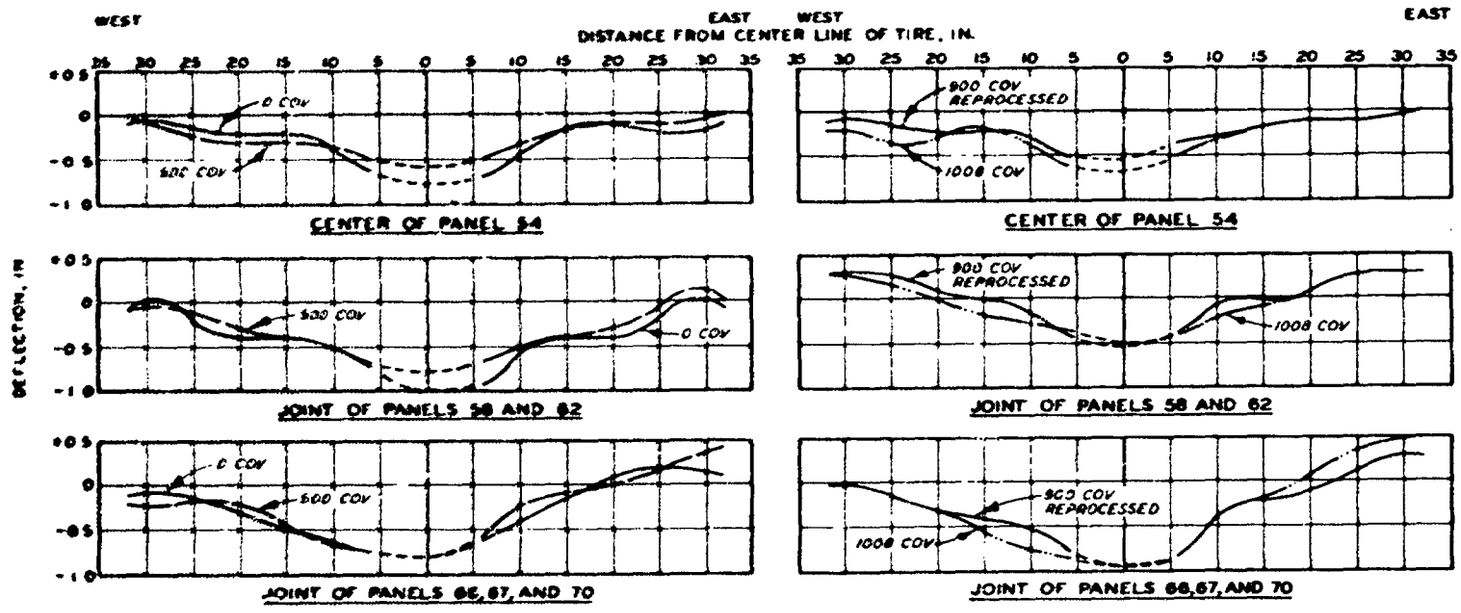


LEGEND

------- EXTRAPOLATED

STATIC DEFLECTION

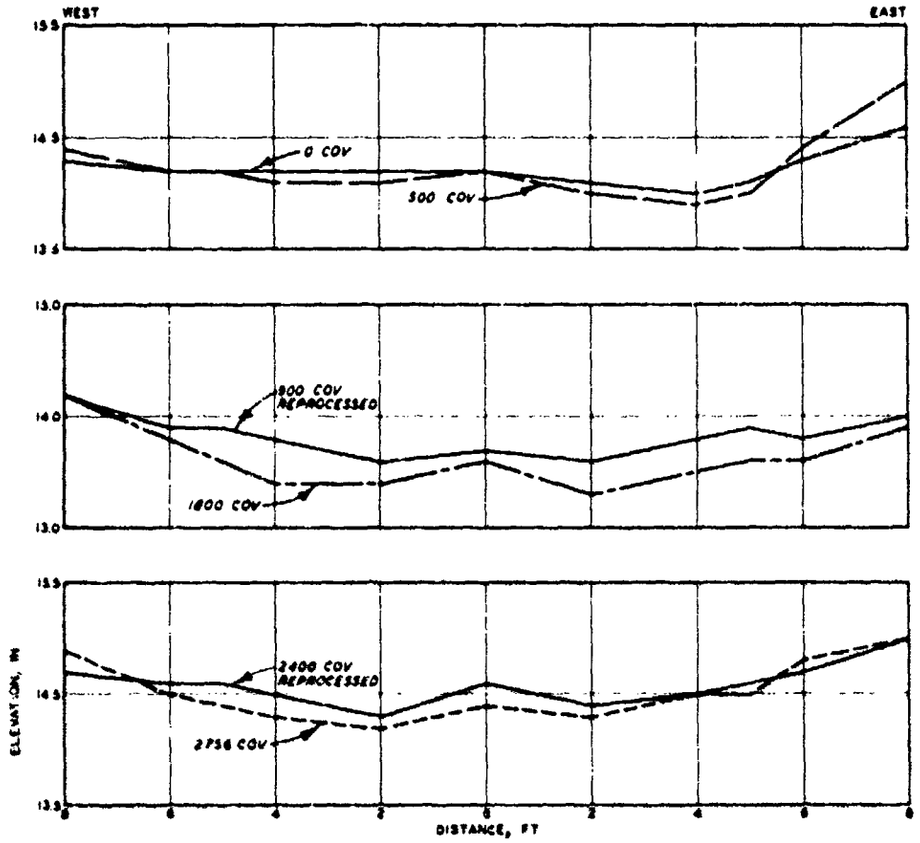
ITEM 1, MX19-C MAT



LEGEND

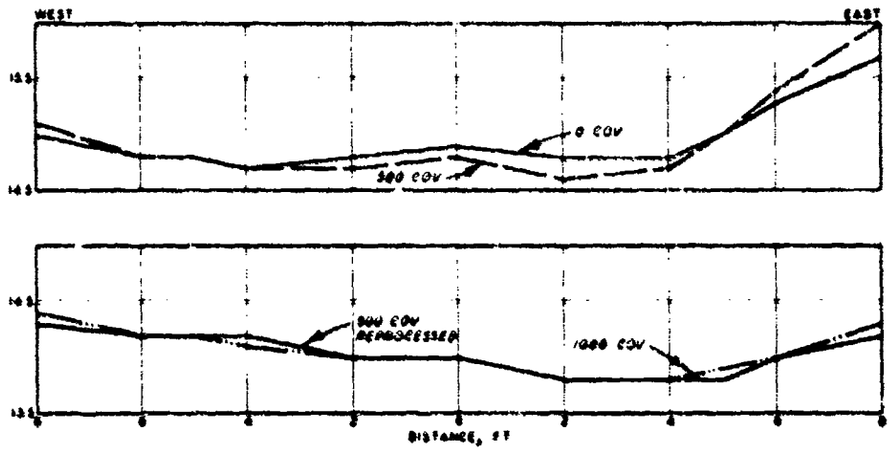
------ EXTRAPOLATED

STATIC DEFLECTION
ITEM 2, MX19-B MAT



ITEM 1, MX19-C

STA 0+32

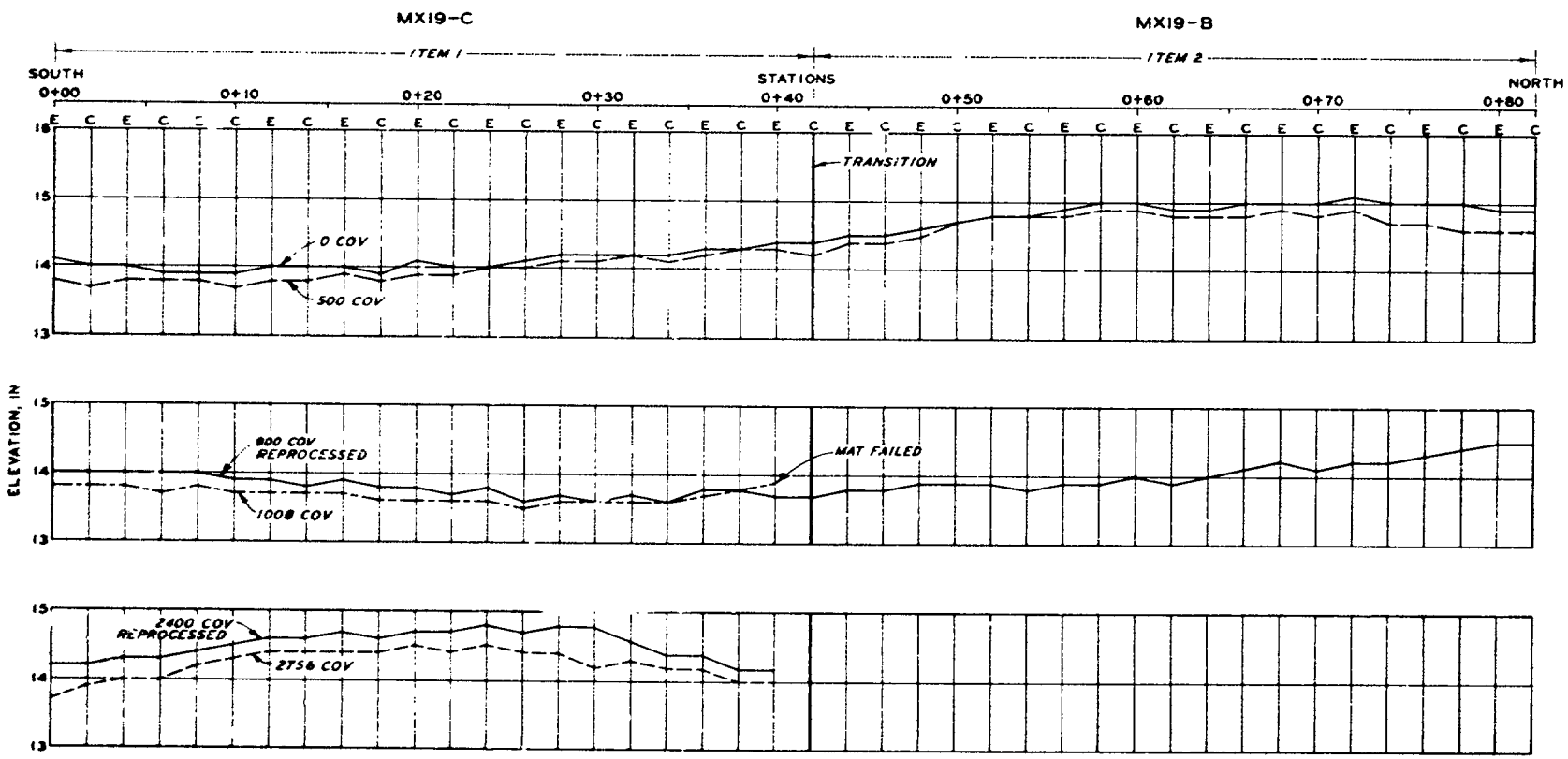


ITEM 2, MX19-B

STA 0+82

CROSS SECTIONS OF TRAFFIC LANE

PLATE 6

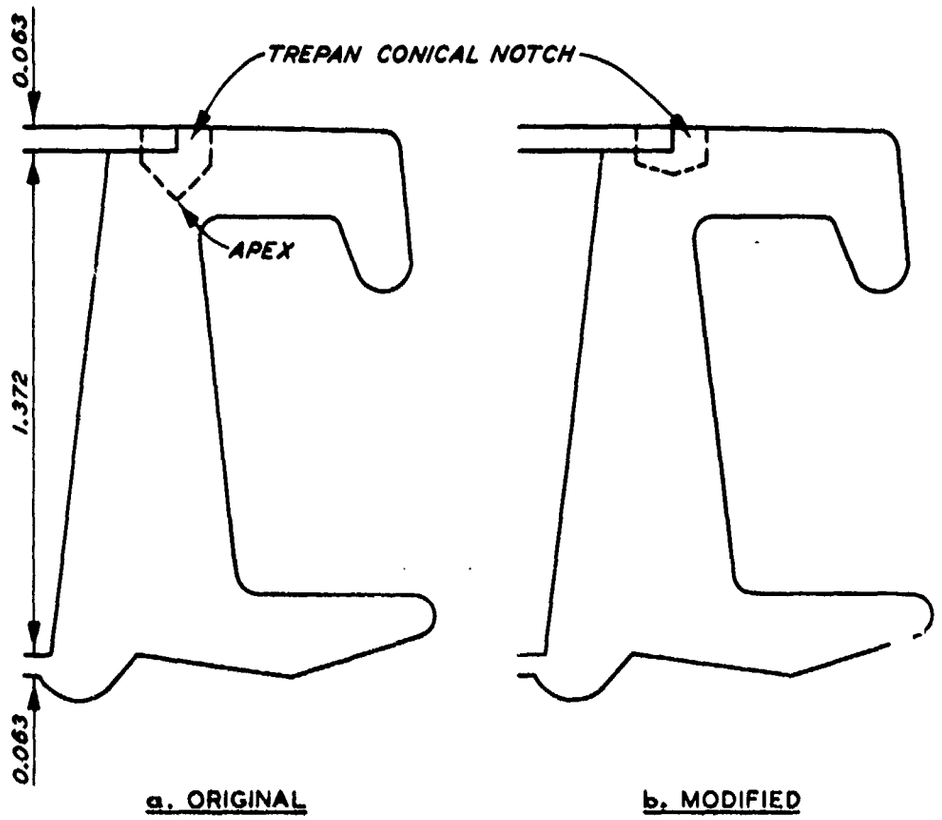


LEGEND

E END OF PANEL
C CENTER OF PANEL

PERMANENT DEFORMATION PROFILES

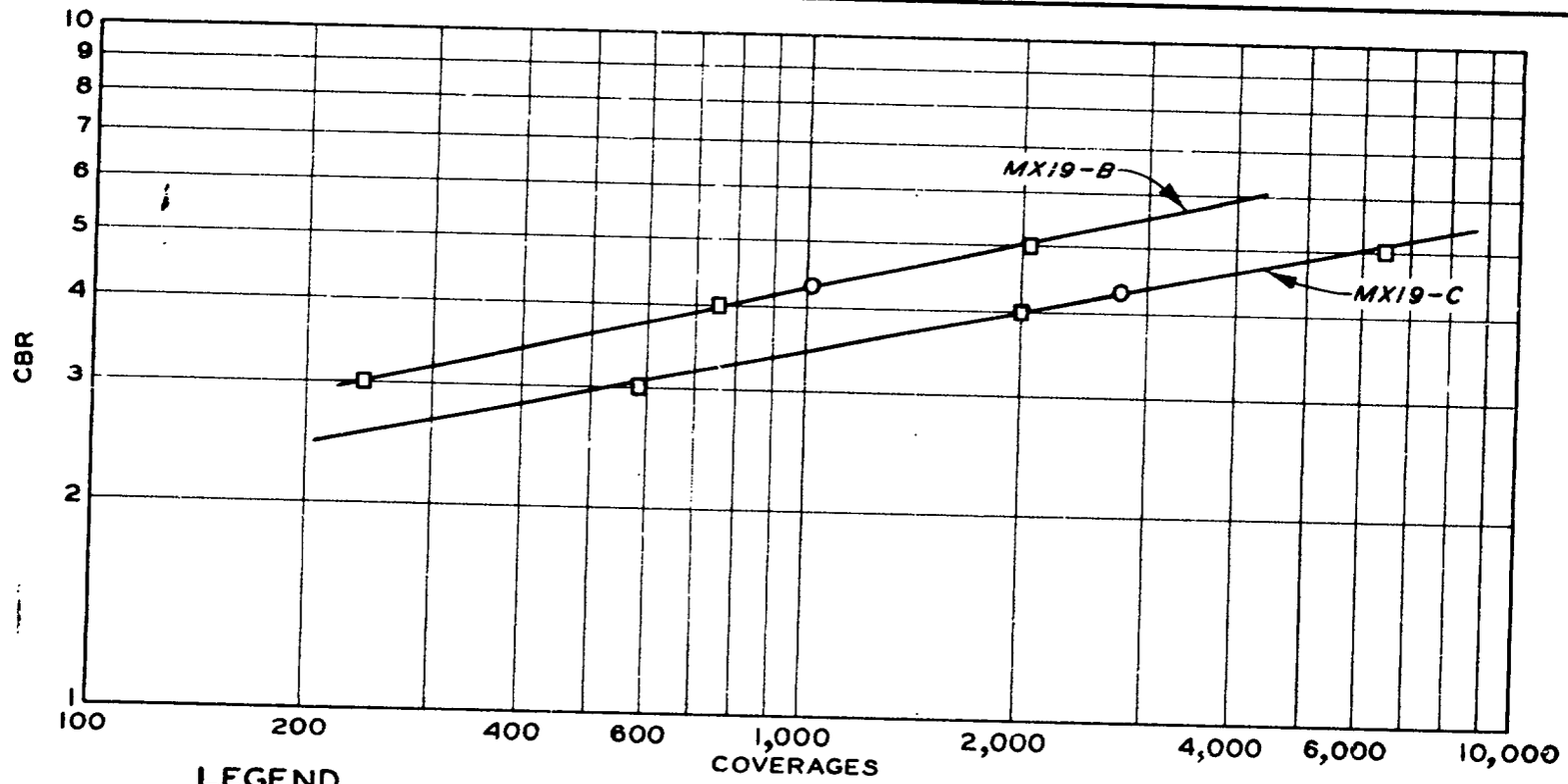
CENTER LINE OF TRAFFIC LANE



NOTE: WHEN THE TREPAN CONICAL NOTCH WAS REWELDED IN THE ORIGINAL, A VOID WAS LEFT AT THE APEX.

TREPAN CONICAL INSPECTION NOTCH

PLATE 8



LEGEND

O SECTION FAILURE POINTS

□ COMPUTED POINTS

NOTE: BASED ON CBR EQUATION FROM WES INSTRUCTION REPORT NO. 4.

STRENGTH EVALUATION OF MX19-C AND MX19-B LANDING MATS