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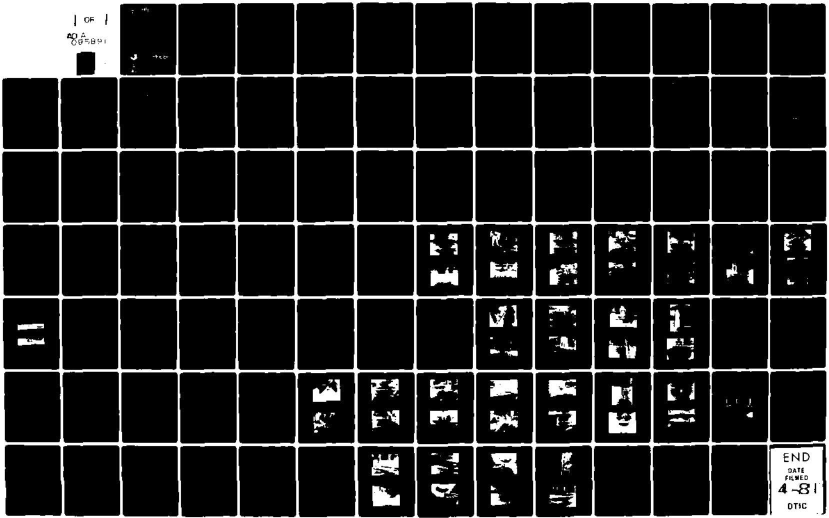

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ESL-TR-80-45



# FLUSH AM-2 MAT PATCH FOR RAPID RUNWAY REPAIR

JAMES L. GREENE

SEPTEMBER 1980

FINAL REPORT
MAY 1978 — NOVEMBER 1979





AFESC

ENGINEERING & SERVICES LABORATORY
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TYNDALL AIR FORCE BASE, FLORIDA 32403



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RAPID RUNWAY REPAIR
ANCHORING AM-2 TO CONCRETE

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a research and development program to investigate the feasibility of using AM-2 landing mats for a flush surface over bomb craters in runways. The AM-2 landing mat concept under test was designed to allow flexibility to adjust to varying crater sizes. Four systems of anchoring AM-2 mat patches to the surrounding pavement were tested. Each system, when installed over filled craters, was tested with an F-4 load cart.

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# PREFACE

This report was prepared by the Air Force Engineering and Services Center, Tyndall Air Force Base, Florida 32403. Testing was accomplished by the Rapid Runway Repair Branch under Job Order Number 20546B23 during the period from May 1978 to November 1979.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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Chief, Engineering Research
Division

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Director, Engineering and Services
Laboratory





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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONCLUDED)

## LIST OF TABLES

## SECTION I

## INTRODUCTION

### BACKGROUND

Modern aircraft dependency on high quality airfield surfaces has made the airfield runway a vulnerable target for attack. Interdiction of the runway has become an easier method of neutralizing enemy aircraft than attacking hidden aircraft shelters. To counter this threat, the Air Force Civil Engineer must be capable of providing repair within certain time constraints and compatible with tactical requirements.

The current bomb damage repair procedure for repairing portland cement concrete pavements is to backfill and then place an AM-2 landing mat section over the damaged area. The positioned AM-2 mat section extends approximately 1-1/2 inches above the pavement surface. Computer simulation predicted catastrophic aircraft failures in fighter aircraft crossing such AM-2 mat sections when placed in a multiple configuration covering several separated bomb craters. There is an urgent need to develop a capability for rapid runway repair without this roughness problem. One possible short term solution is to continue to use AM-2 mat, but to recess the mat sections so that they are essentially flush with the existing pavement. This concept is illustrated in Figures 1 through 4. As Figure 1 indicates, the first step is to cut the concrete pavement around the perimeter of the cratered area leaving a vertical face which can accommodate a modular sized, recessed AM-2 mat section. Following the cutting and removal of defective material, the crater is backfilled as illustrated in Figure 2. The appropriate mat surface elevation is achieved by building up the open area with gravel or other material (Figure 3). Figure 4 illustrates the completed patch.

### OBJECTIVE

The objective of this study was to provide a functional, test validated design of a flush AM-2 airfield landing mat system for the emergency repair of airfield runways.

### SCOPE

This study consisted of three phases as outlined below:

1. Phase I - Design of a modular, flush-mounted AM-2 airfield landing mat repair system, including all required components, as well as the means and methods for the field assembly and placement. Design and fabrication of a prototype repair kit for the repair of a 20-foot by 20-foot-square cratered opening.

2. Phase II - Testing of the prototype at the Air Force Engineering and Services Center (AFESC) Test Facility.

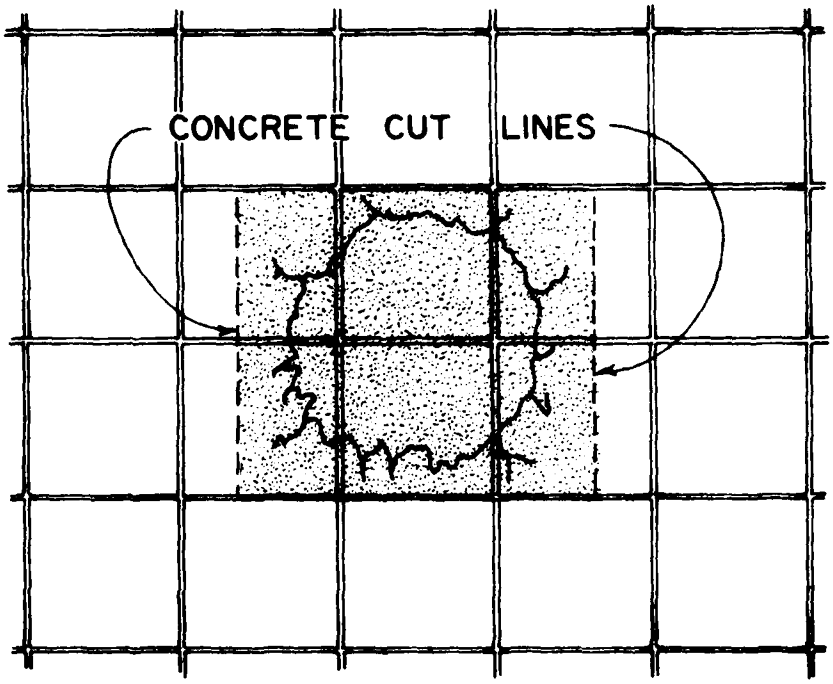



Figure 1. Illustration of Cutting Rectangular Patch

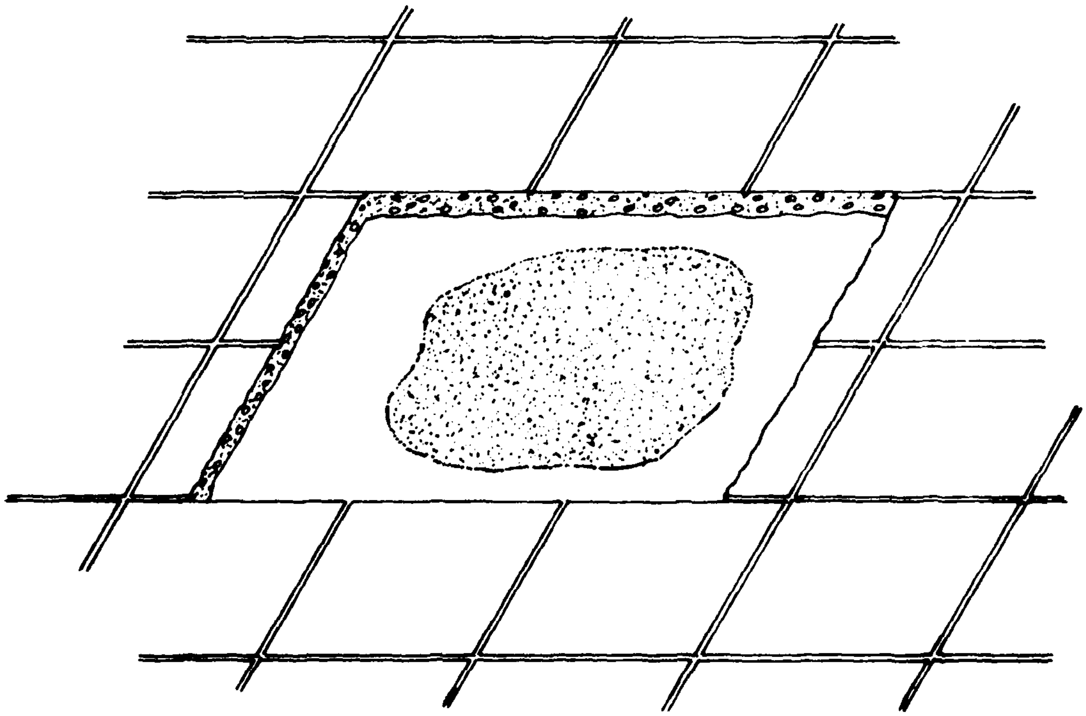


Figure 2. Illustration of Filled Crater

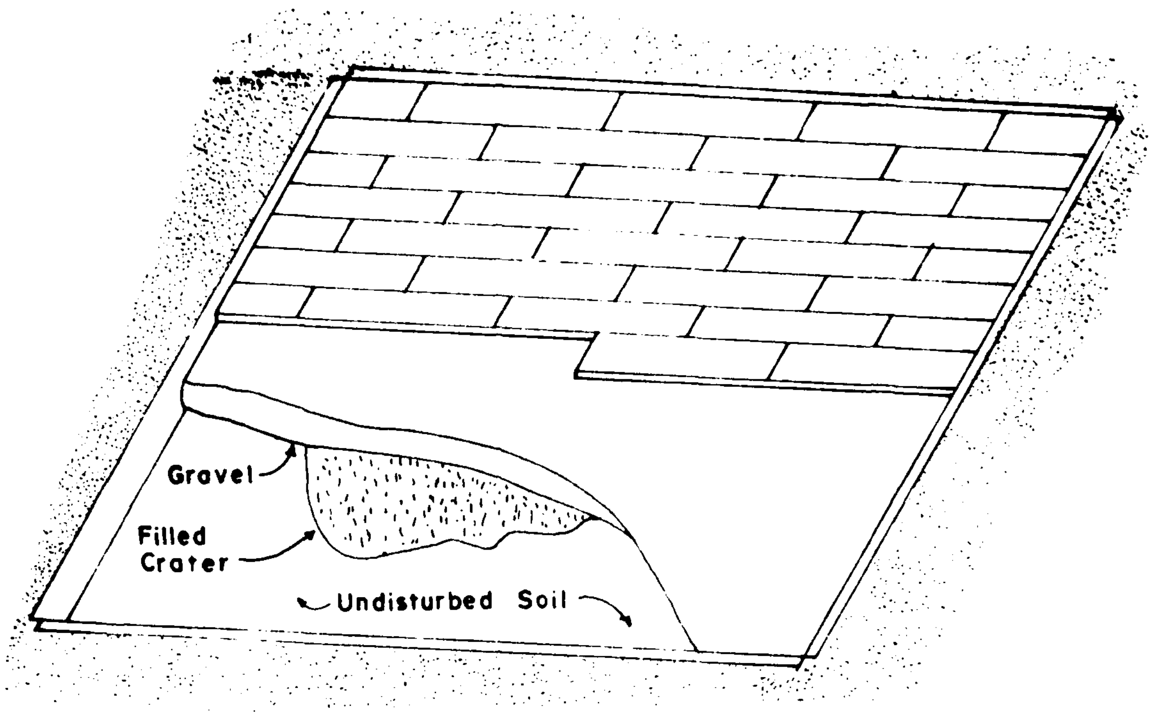



Figure 3. Patch Area Backfilled to Appropriate Elevation

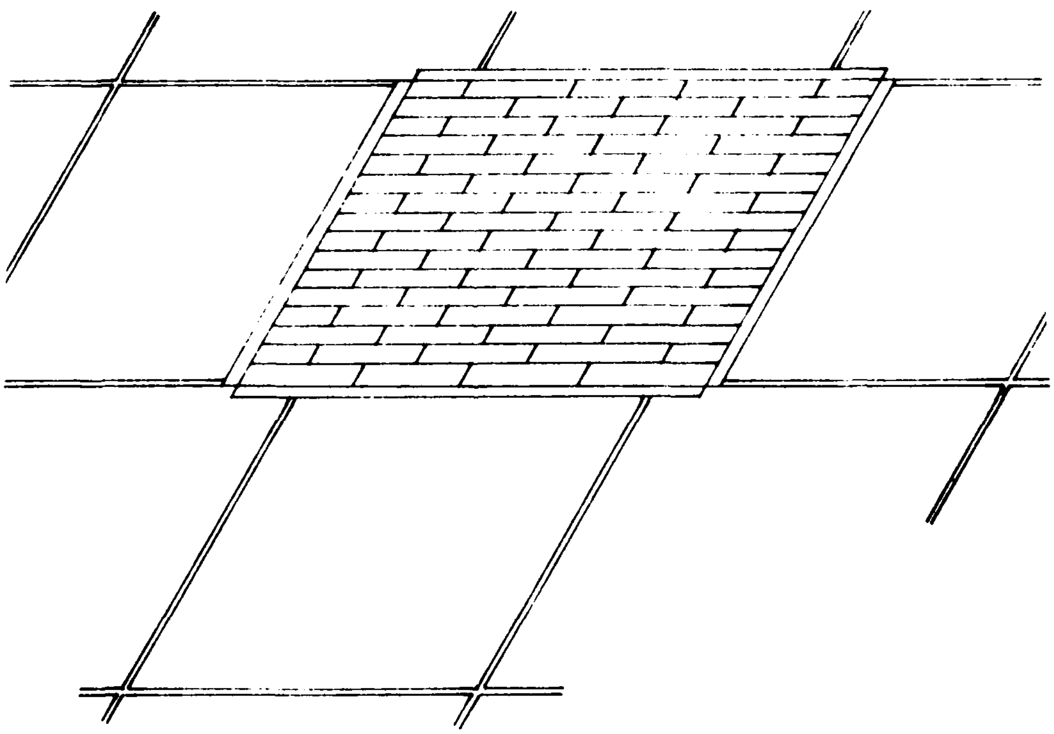


Figure 4. Completed Flush AM-2 Patch

3. Phase III - Analyze test data and finalize design of the repair patch system including completed plans and specifications adequate for repair kit commercial fabrication and subsequent kit utilization.

## SECTION II

## PHASE I: SYSTEM DESIGN

This phase of the project was accomplished under the supervision and direction of the Air Force Logistics Command (AFLC). Design of the repair system and the prototype patches was contracted to Utah State University. Fabrication of the patches was accomplished by Air Force Logistics Command at its Robbins Air Force Base facility.

A summary of guidance given to Utah State University as a basis for design of the repair system and prototype patches is given below:

(1) A method of rapidly cutting 12-inch-thick concrete to a lateral tolerance of 1 inch across the side of a 20-foot by 20-foot patch and a tolerance of 0.5 inch in the vertical plane was assumed to be available, as well as means to remove the concrete and backfill the crater. Backfill material was assumed to be a coarse gravel.

(2) The overall system design was to be modular with flexibility to adjust to varying crater sizes. Standard AM-2 panels were to be used except for perimeter panel requirements. These panels were to be modified to attach to a perimeter anchoring system to be designed by Utah State University. One concept for a perimeter anchoring system was provided, and Utah State University was given the option of designing other concepts. The mandatory concept consisted of a perimeter rail as conceptualized in Figure 5.

(3) The repair system was to be designed to withstand a minimum of 300 passes of F-4 aircraft and 20 passes of C-141 traffic considering a subgrade with a California Bearing Ratio (CBR) of 4.

(4) Figure 6 shows a suggested arrangement for the 20-foot by 20-foot prototype patch. Those panels designated "A" panels are standard AM-2 panels. The others are standard panels with altered edge connectors and panel dimensions. Due to the desired short fabrication time, the perimeter rail elements were to be built from aluminum plate sections assembled by shop welding. The platform component necessarily conforming to a particular AM-2 panel and connector was to be built up using a transition piece extrusion, manufactured by the Washington Aluminum Company (WACO) of Baltimore, Maryland as extrusion piece A-44352. Figure 7 provides details of this piece.

Based on the above guidance, Utah State University designed two repair systems: the mandatory system provided by the Air Force (perimeter rail concept) and a system based on anchoring the

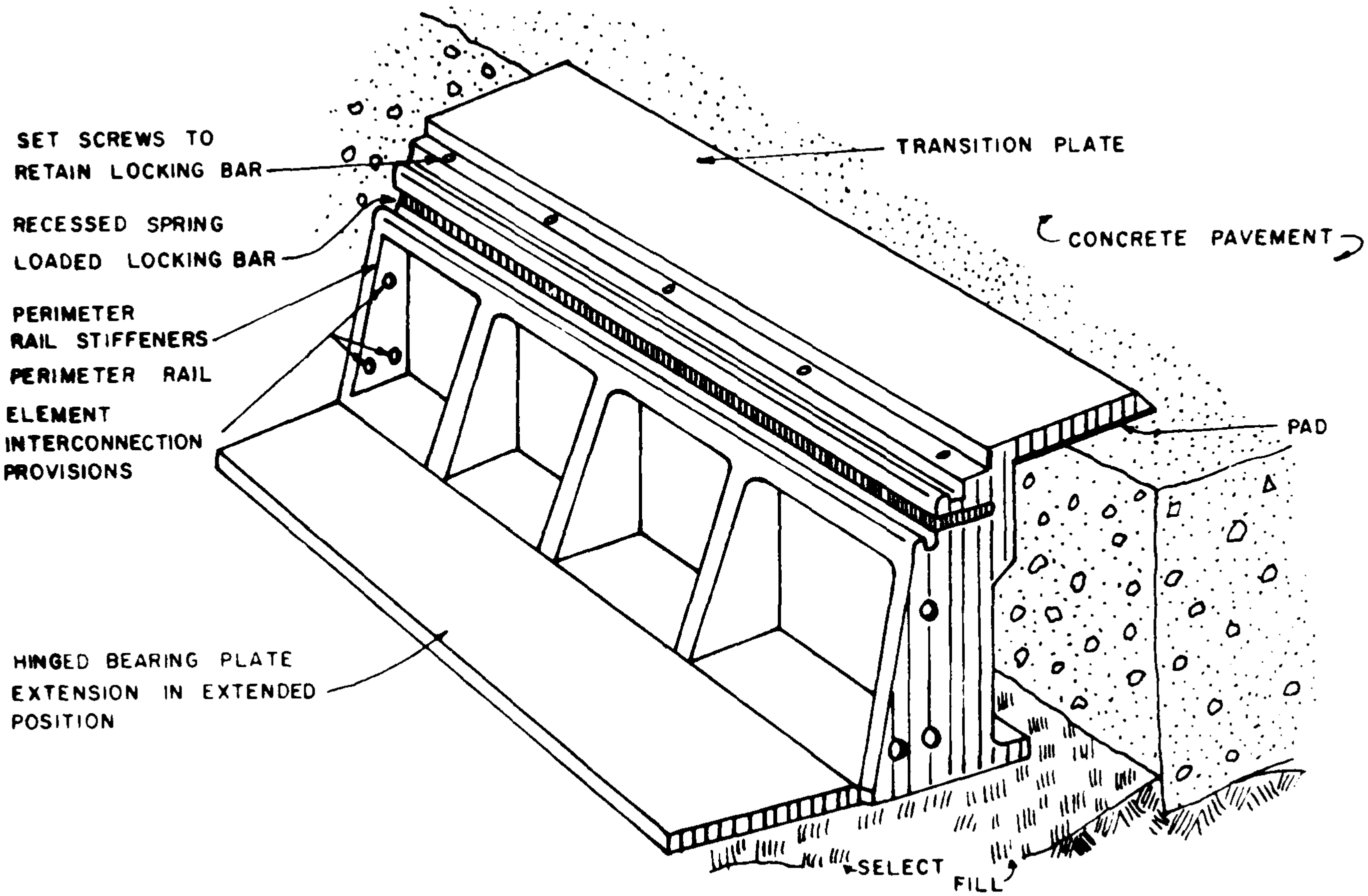



Figure 5. Perimeter Rail Concept

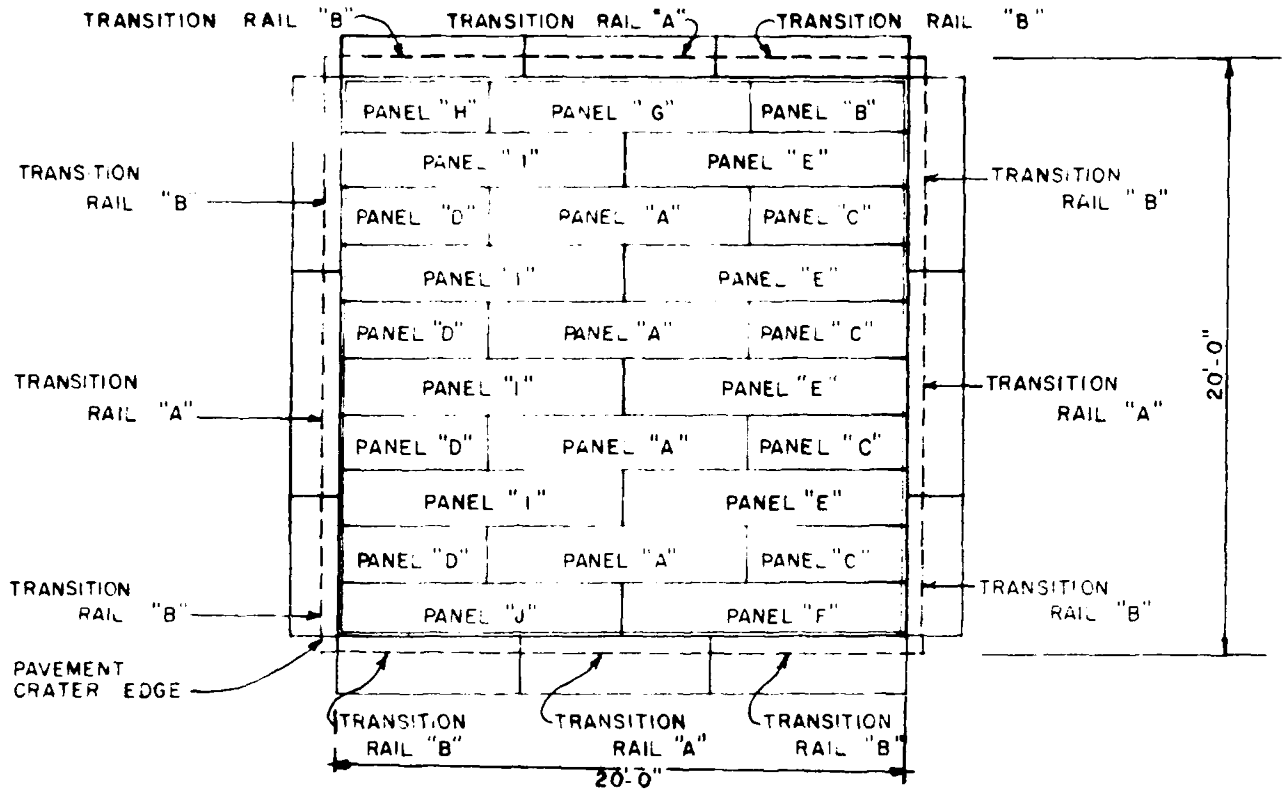
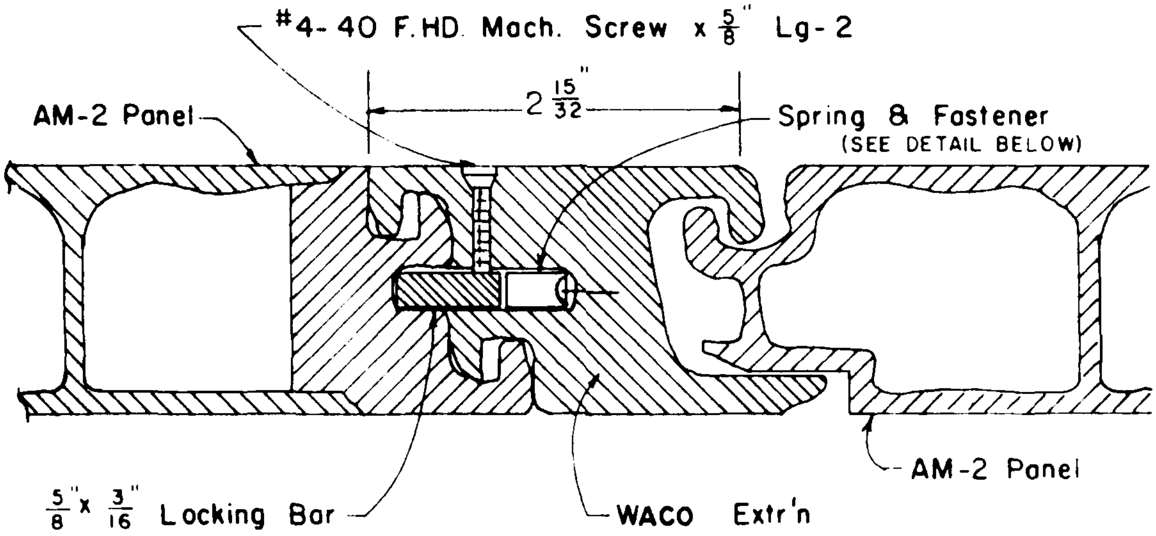
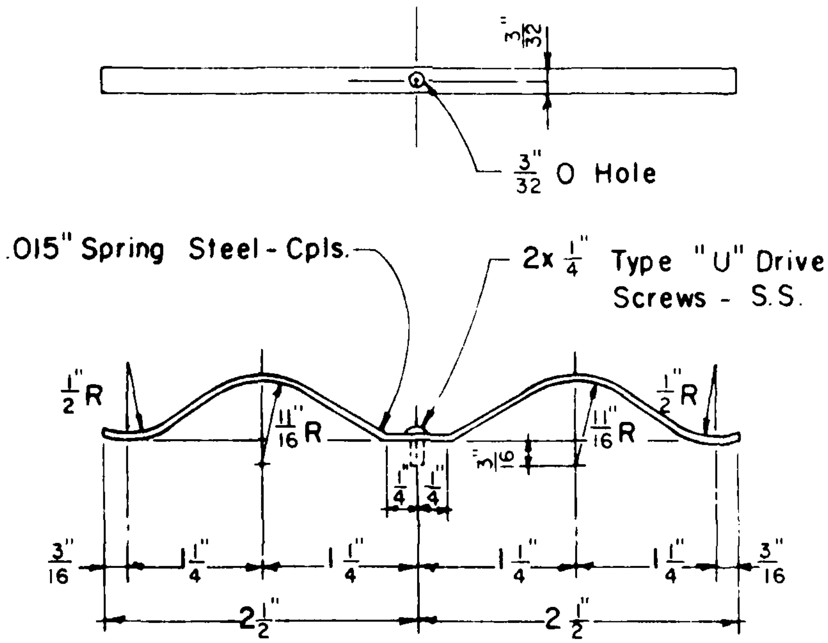



Figure 6. Suggested Arrangement of Perimeter Rail Prototype




WACO Extrusion #A-44352




Spring & Fastener Detail

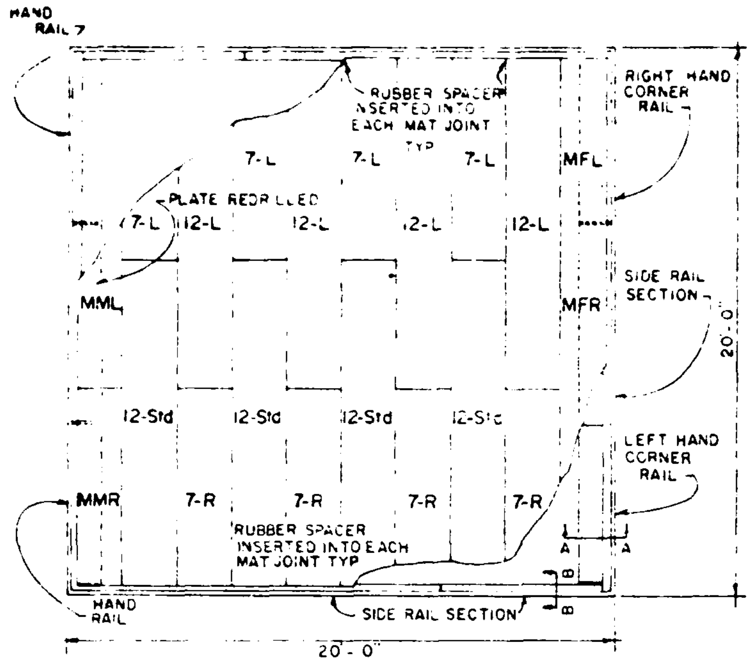
Figure 7. Detail of WACO Extrusion

patch to the concrete perimeter (side panel concept). These systems were modeled in the laboratory and in the field to assure the patches would not pull out when braking action of F-4 and C-141 aircraft was applied. The approximately 20-foot by 20-foot prototype patches of each system were then designed and fabricated.

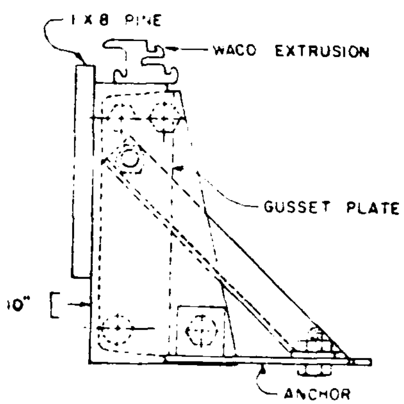
The perimeter rail system consisted of a built-up rail which was used to anchor a patch made of standard and modified AM-2 panels. The rail consisted of a 10-inch aluminum 6061-T6 channel with WACO extrusion No. 44352 welded on top to receive the AM-2 panels. An anchor plate was attached to the bottom of the channel to resist pullout of the rail assembly when braking action is applied. A rubber spacer was inserted between adjacent AM-2 panel connectors to prohibit the panels from closing up in the direction of traffic and possibly pull the patch away from the other end. A 1-inch x 8-inch pine board was attached to the channel to prevent debris from filling the cavity between the rail and the concrete. A plan view, parts list, and details are shown on Figure 8.

In the side panel prototype, standard AM-2 panels were laid around the perimeter of the pit with the top surface flush with the top of the base course. Panels which had been modified by welding a WACO extrusion on the side were placed on top of those panels to which transverse panels were connected. In order to connect, the connectors on one end of the transverse panels had to be inverted. The anchoring system consisted of an angle which prevented uplift of the mat. The angle locked into a locking assembly which was fastened to the perimeter concrete. Details of the prototype are shown on Figure 9.

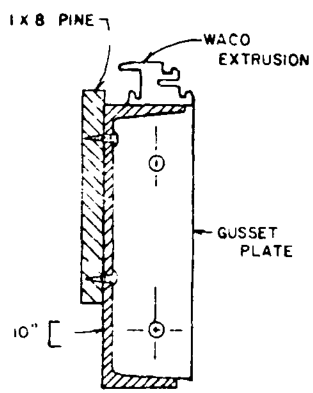
Since installation time is a major factor, AFESC also decided to test two simpler systems. One system consisted of standard AM-2 panels cut to fit the 20-foot by 20-foot pit. The anchoring system designed for the side panel concept was used to anchor this prototype. Details are shown in Figure 10. The other system was tested using Silikal®, a polymer concrete, to anchor the AM-2 mat. This system consisted of standard 6-foot and 12-foot AM-2 panels used to form an 18-foot by 18-foot mat. Z-Shaped clips approximately 4 inches wide and 6 inches long on one end and 12 inches long on the other were fastened to the top of the panels and anchored in Silikal® (approximately 12 inches wide and 6 inches deep). Details of this concept are shown in Figure 11.




PLAN




Section A-A




Section B-B

Parts List

| NO RECD | SYMBOL | DESCRIPTION |
|---|---|---|
| 1 | 12-MML | 12' MODIFIED MALE LEFT HAND AM-2 MAT |
| 1 | 7-MMR | 7'-3 1/8 MODIFIED MALE RIGHT HAND AM-2 MAT |
| 4 | STD | 12' STANDARD AM-2 MAT |
| 4 | 7-L | 7'-3 1/8" LEFT HAND AM-2 MAT |
| 4 | 12-L | 12' LEFT HAND AM-2 MAT |
| 4 | 7-R | 7'-3 1/8" RIGHT HAND AM-2 MAT |
| 1 | 7-MFL | 7'-3 1/8" MODIFIED FEMALE LEFT HAND AM-2 MAT |
| 1 | 12-MFR | 12' MODIFIED FEMALE RIGHT HAND AM-2 MAT |
| 4 | | 6' SIDE RAIL SECTION |
| 4 | | 7'-3 1/4" SIDE RAIL SECTION |
| 2 | | RIGHT HAND CORNER RAIL |
| 2 | | LEFT HAND CORNER RAIL |
| 18 | | RUBBER SPACERS 12 LG |

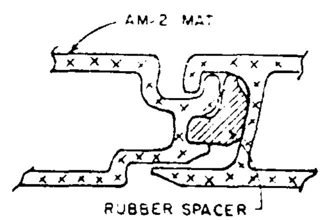



Figure 8. Perimeter Rail System

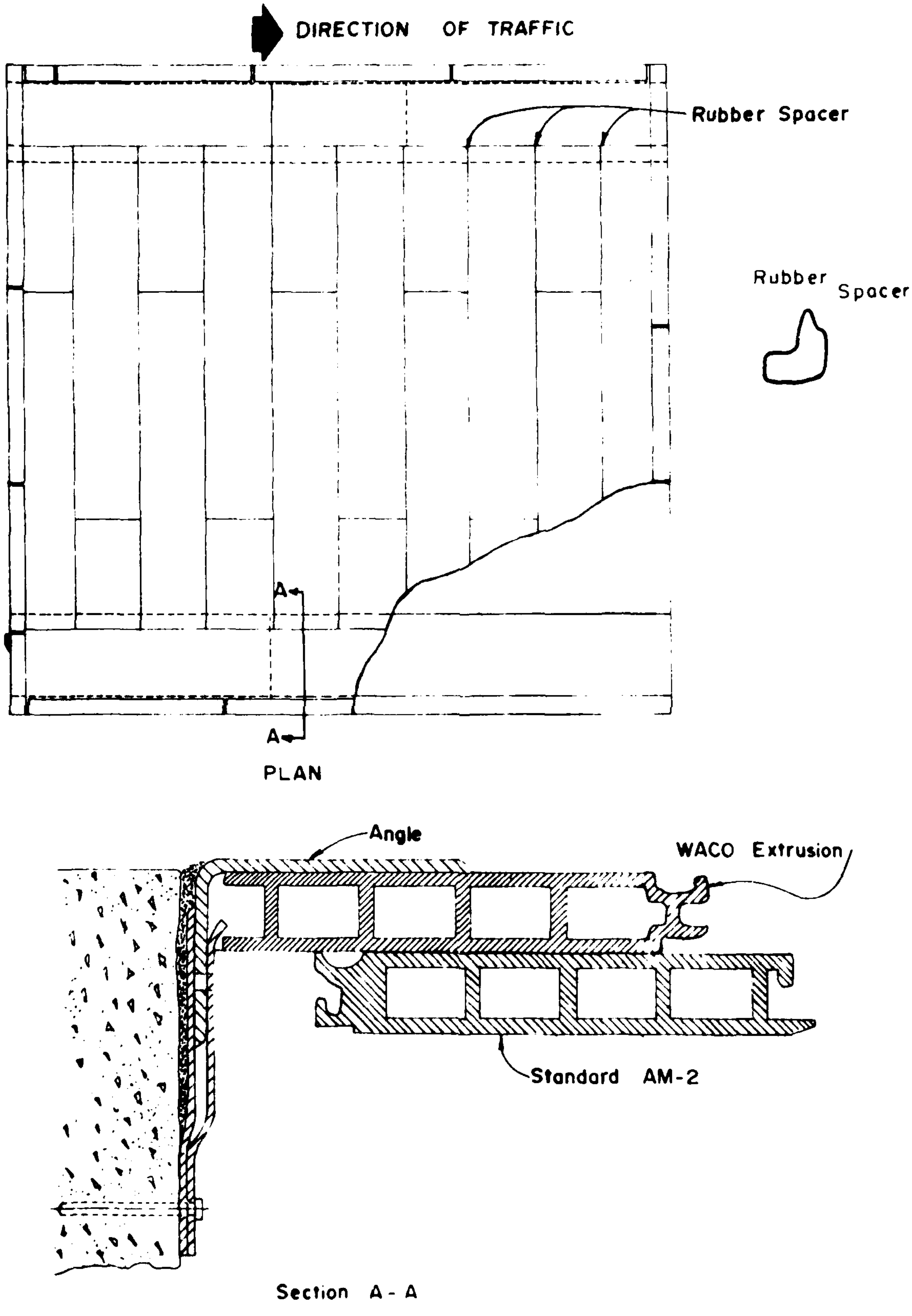



Figure 9. Side Panel System

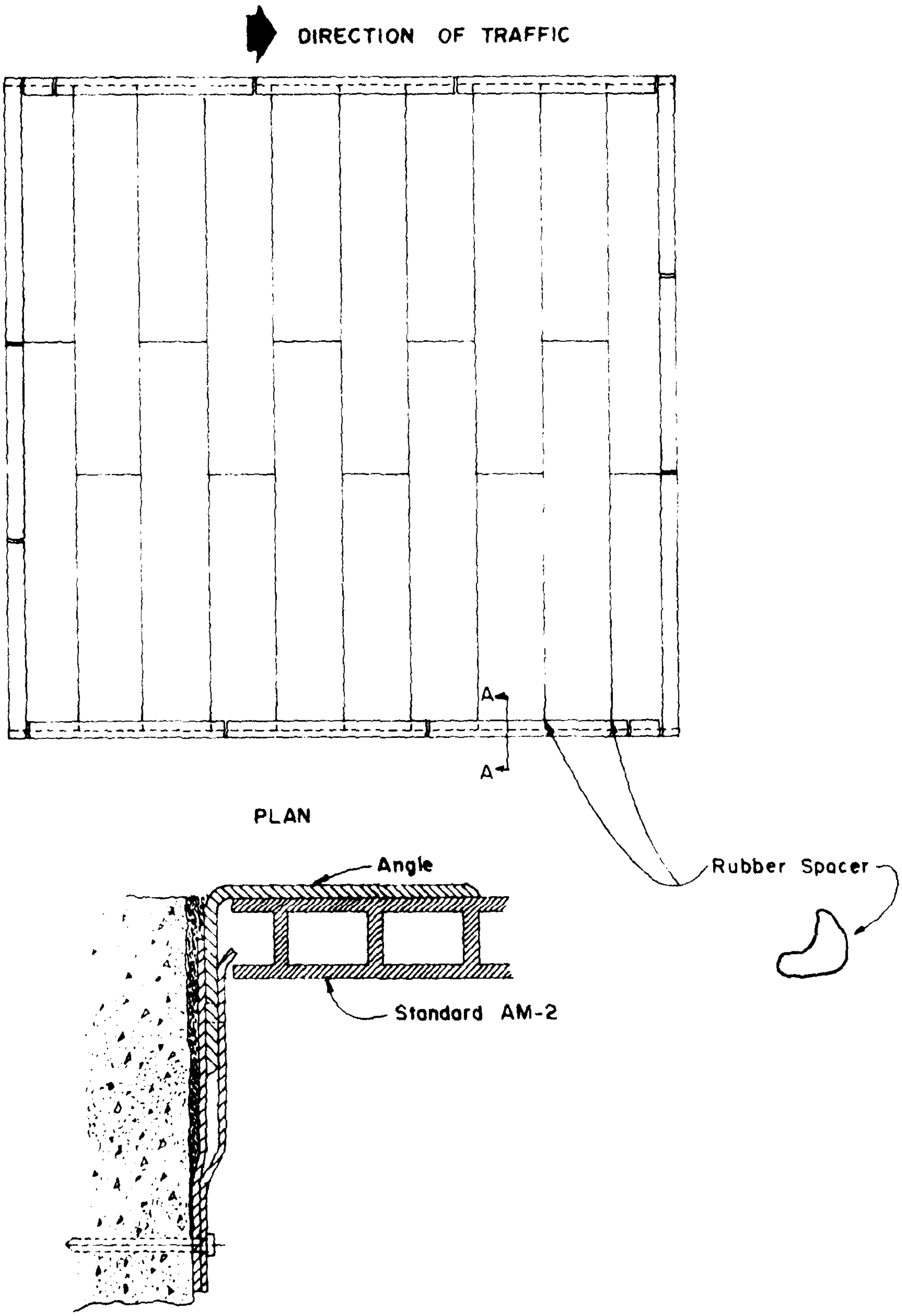
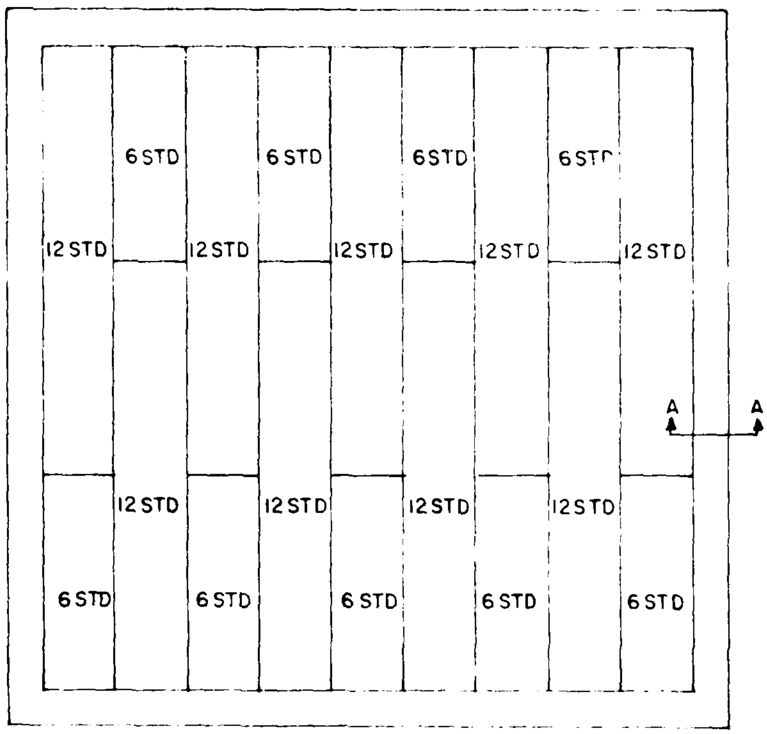



Figure 10. Standard AM-2 Mat System

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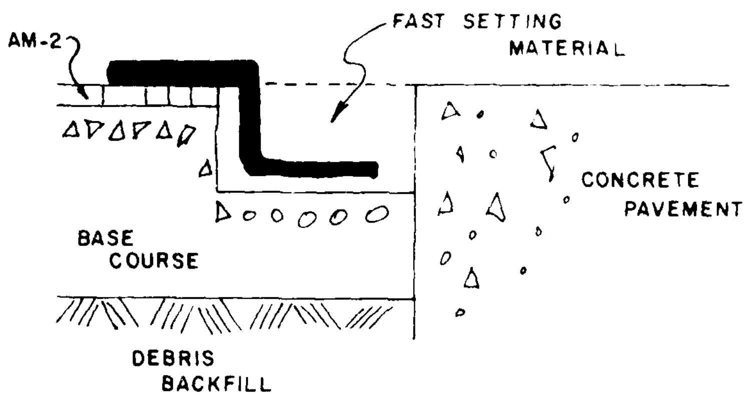



Section A - A
NOT TO SCALE

Figure 11. Z-Clip System

## SECTION III

### PHASE II: TESTING

TEST PLAN

The pits for all tests were prepared in the same manner. All tests were conducted in pit 2 of the Small Crater Test Facility at Tyndall Air Force Base, Florida (Figure 12). Pit 2 is a 20-foot by 20-foot square opening in a section of portland cement concrete pavement 12 inches thick. The subgrade of pit 2 is a clay with a CBR of approximately 4. Twelve inches of crushed limestone base were placed on the pit 2 clay subgrade. The base was compacted with a RayGo 400 Vibratory Compactor in order to achieve a density of approximately 90 percent of maximum (modified AASHO). The prototype patches were placed on the compacted base and the patch trafficked with the F-4 and C-141 load carts at weights of 27,000 and 140,000 pounds, respectively. The traffic patterns used to traffic the patch are shown on Figures 13 and 14. After completion of the trafficking, a 70,000-pound force was applied to the patch to represent braking action of the C-141. The clay subgrade used in the tests was a local clay obtained near Wewahitchka, Florida. The clay had the following characteristics:

| | |
|---|---|
| Gradation | See Figure 15 |
| Specific Gravity | 2.61 |
| Liquid Limit | 65% |
| Plasticity Index | 41% |
| Unified Soil Classification | CH |
| Maximum Dry Density (Modified AASHO) | 113 pounds per cubic feet (pcf) |
| Optimum Moisture Content | 14.5% |

Previous tests on the clay revealed that a moisture content of approximately percent would produce a CBR of approximately 4.

The crushed limestone base course used in the tests had the following characteristics:

| | |
|---|---|
| Gradation | See Figure 16 |
| Specific Gravity | 2.76 |
| Liquid Limit | Non-Plastic |
| Plasticity | Non-Plastic |
| Unified Soil Classification | GW-GM |
| Maximum Dry Density (Modified AASHO) | 145.6 pcf |
| Optimum Moisture Content | 5.1% |

The average moisture content and dry unit weight were determined for the base and subgrade before placing the AM-2 mat. Test results are given in Table 1.

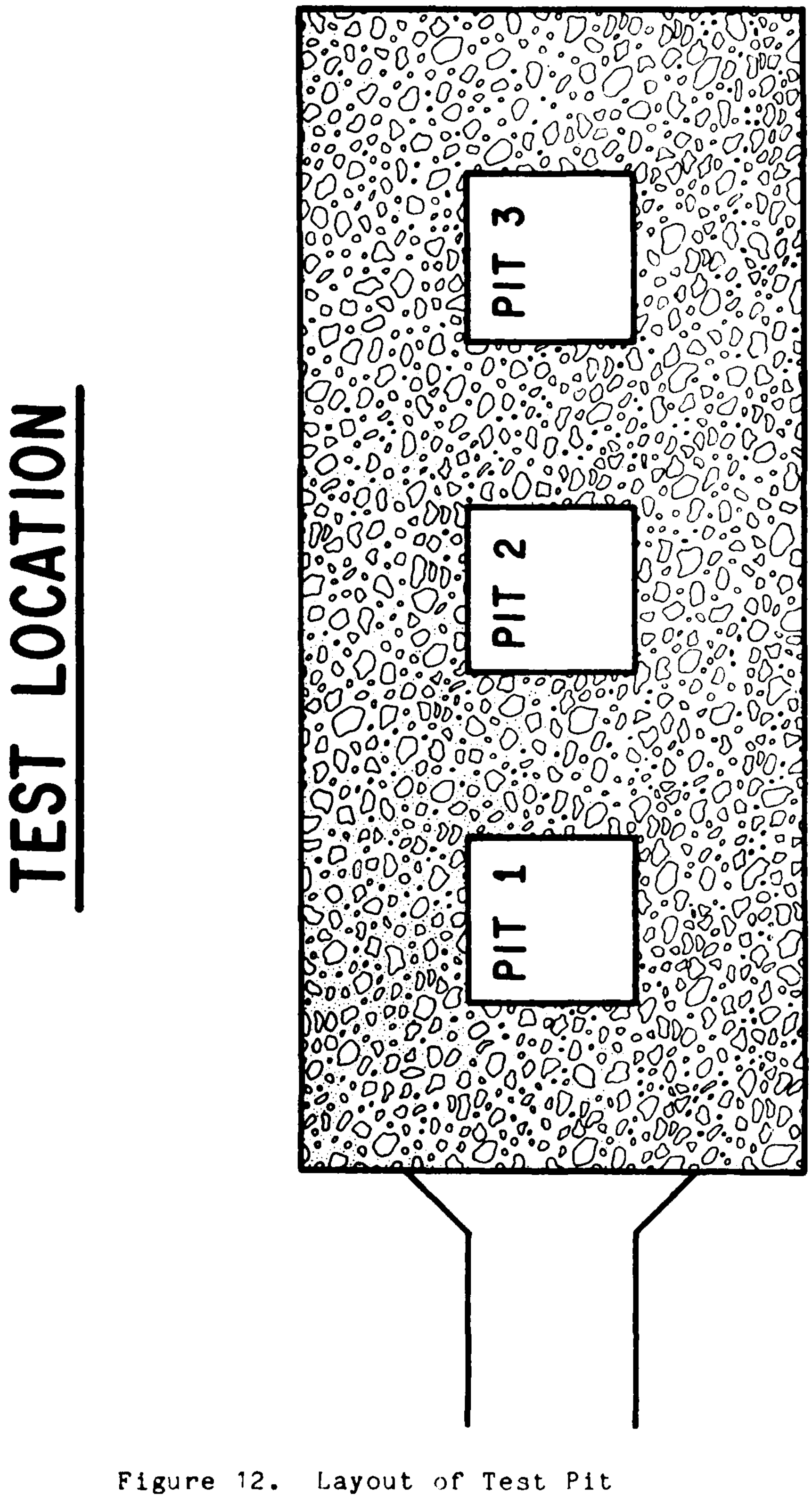



Figure 12. Layout of Test Pit

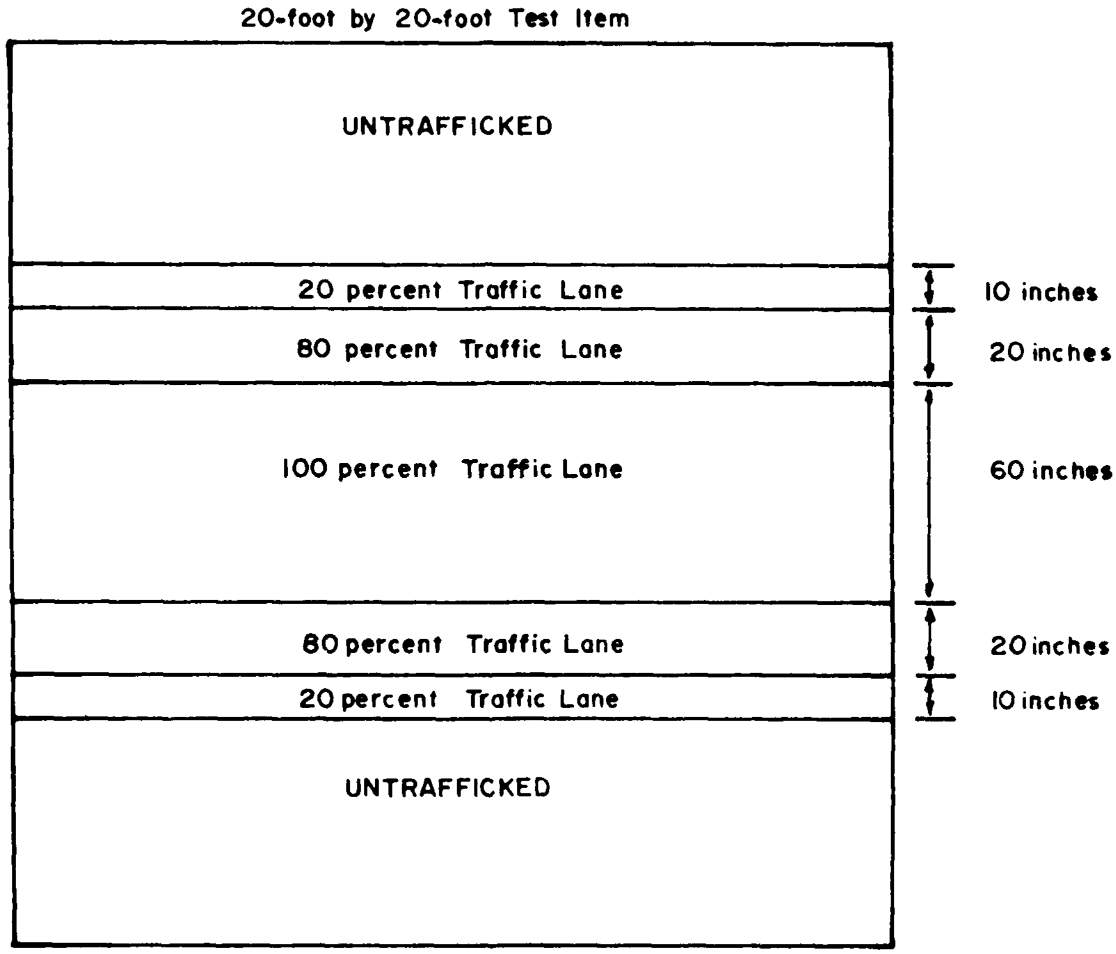



Figure 13. Traffic Pattern for F-4 Load Cart

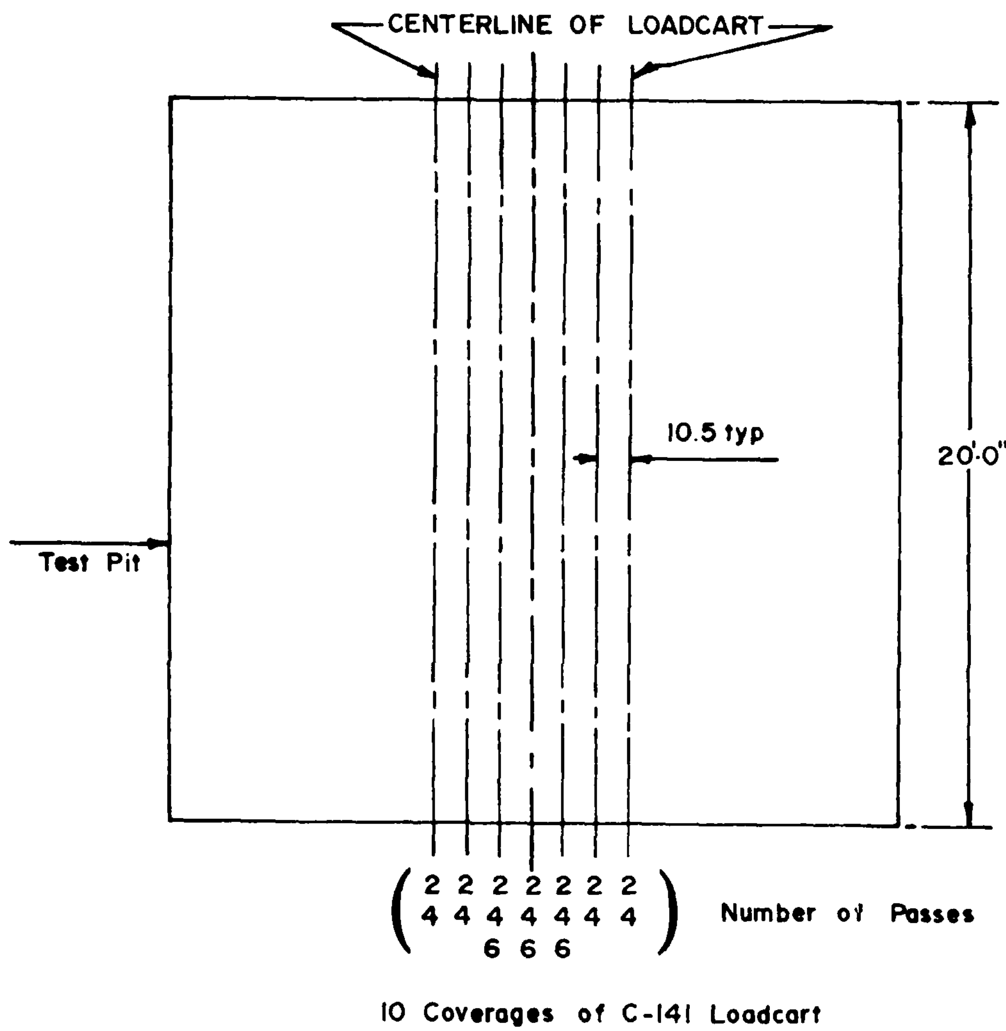



Figure 14. Traffic Distribution Pattern for the C-141 Load Cart

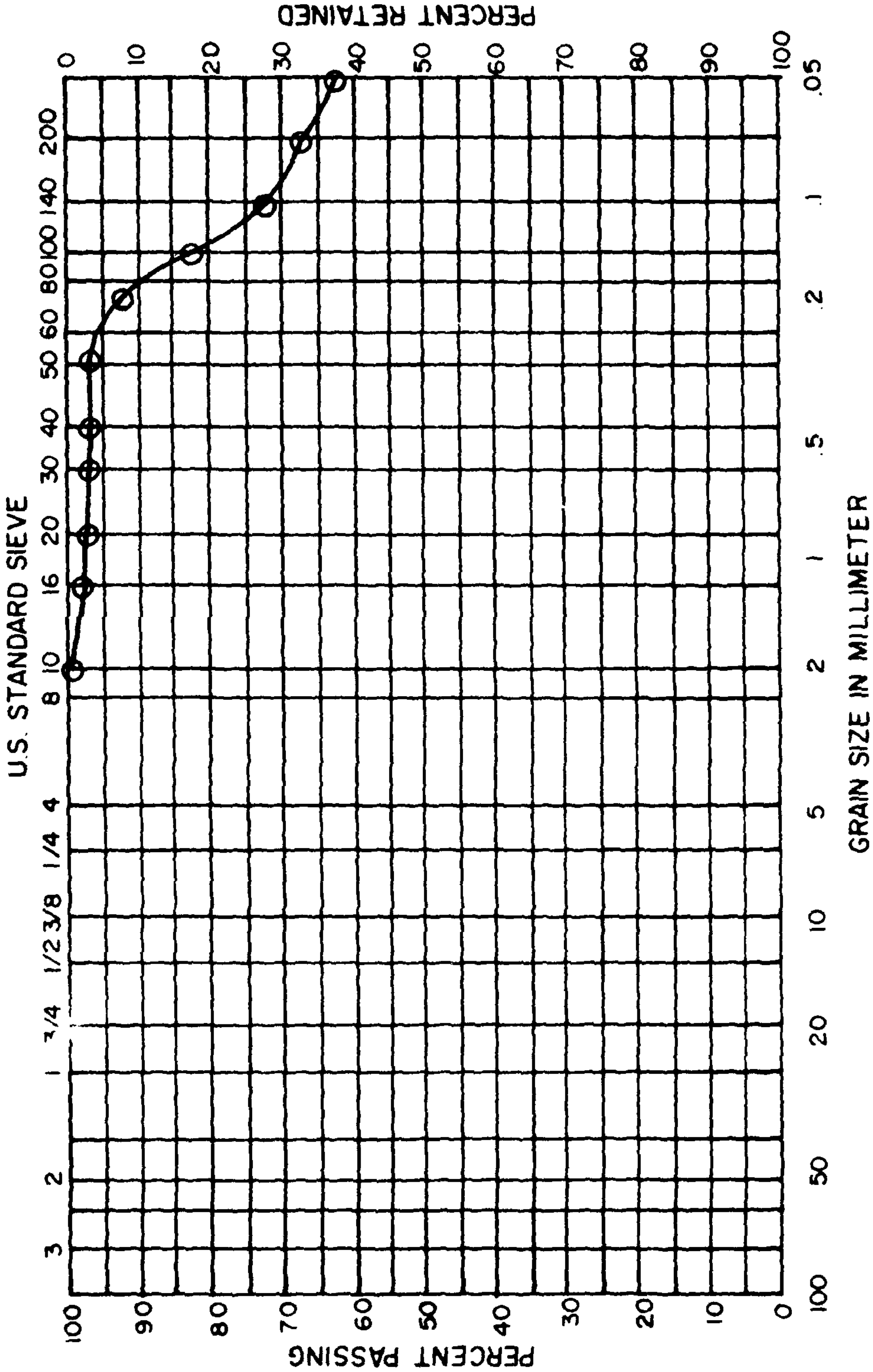



Figure 15. Wewahitchka Clay Gradation

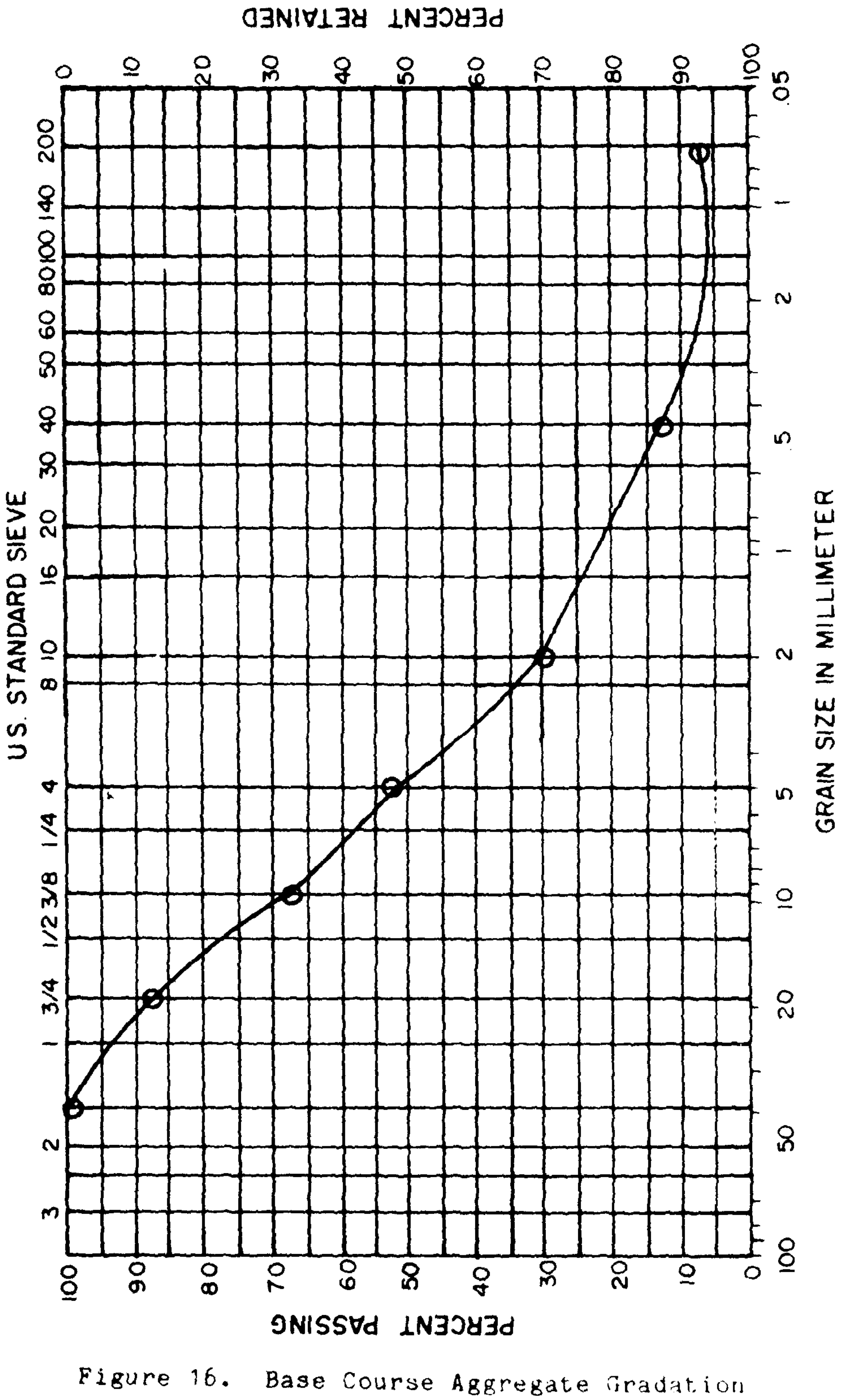



Figure 16. Base Course Aggregate Gradation

TABLE 1. RESULTS OF BASE AND SUBGRADE TESTS

TEST #1 (Z-Clips)

SUBGRADE

| | |
|---|---|
| Average Wet Density | 120.2 pcf |
| Average Dry Density | 92.2 pcf |
| Average Percent Moisture | 30.3 |

BASE COURSE

| | |
|---|---|
| Average Wet Density | 134.5 pcf |
| Average Dry Density | 132.4 pcf |
| Average Percent Moisture | 1.7 |

TEST #2 (Perimeter Rail)

BASE COURSE

| | |
|---|---|
| Average Wet Density | 139.8 pcf |
| Average Dry Density | 136.0 pcf |
| Average Percent Moisture | 2.75 |

TEST #3 (Side Panel)

SUBGRADE

| | |
|---|---|
| Average Wet Density | 120.5 pcf |
| Average Dry Density | 92.9 pcf |
| Average Percent Moisture | 30.3 |

BASE COURSE

| | |
|---|---|
| Average Wet Density | 135.0 pcf |
| Average Dry Density | 131.0 pcf |
| Average Percent Moisture | 3.1 |

Original elevations of the subgrade, base, and mat were taken at one-foot intervals along three base lines in the direction of traffic and in the center of the mat in a transverse direction. Elevations were taken on the mat along the same base lines at specified intervals during the trafficking and on the base course after completion of the trafficking. The structural status of the patch was monitored throughout the testing. A layout of the base lines is shown on Figure 17. Figures 18 through 45 show elevations taken during each test.

FAILURE CRITERIA

The patches were designed to support 300 passes of F-4 and 20 passes of C-141 aircraft. Subsequent to design of the patches it was determined that a requirement exists for a patch that will support 150 coverages (1440 passes) of an F-4 and 20 coverages of C-141 aircraft. The patches discussed in this report were tested at this level even though designed for the lower level. Failure criteria were arbitrarily established as a 3-inch deflection of the mat as load is applied or deterioration of the mat or anchoring system to such an extent that the patch is no longer functional.

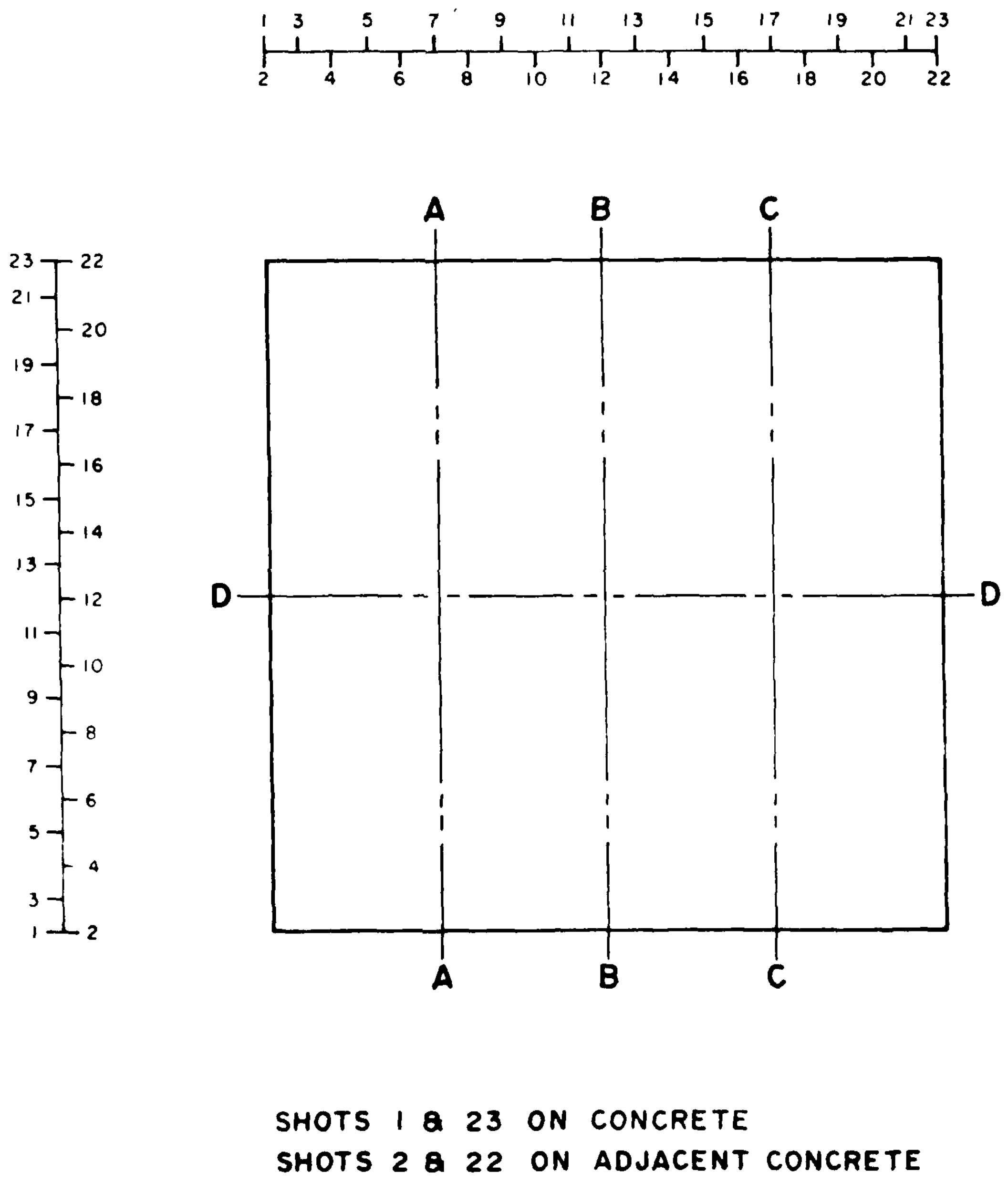



Figure 17. Base Lines

AM-2 FLUSH PATCH TEST 1 (Z-Clips)

Soil tests were completed and initial elevations determined on the subgrade. Twelve inches of compacted base coarse were installed and required soil tests completed and elevations determined. Before completing the base course, a wooden frame, 12 inches wide and 6 inches deep, was installed around the perimeter of, and flush with, the top of the existing concrete. This frame would later be removed and this area filled with Silikal®. The 18- by 18-foot mat was installed in the pit. This effort took a crew of from 5 to 6 people approximately 30 minutes. One problem encountered was that aggregate from the base course kept getting into the connector in the panels, slowing the effort. The wooden frame was then removed, and a two-man crew with one explosive nail driving gun fastened the steel Z-clips to the top of the AM-2 panels. The clips were spaced at approximately one foot intervals around the perimeter of the mat. This was a rather slow procedure taking about 2-1/2 hours. The Silikal® which anchored the Z-clips was then placed in the void created by the wooden frame. The material was mixed in bags with two men working with each bag. It took 55 minutes to place the 80 linear feet of Silikal® using approximately 100 bags of material.

Trafficking with the F-4 load cart began two hours after completion of the patch. Periodically, elevations along the base lines were measured and visual observations made to determine the structural integrity on the patch. Plots of the elevations are shown on Figures 18 through 27. Visual observations are noted below:

(1) 10 Coverages: Several of the clips had pulled loose from the panels. Maximum separation was 1/4 inch.

(2) 20 Coverages: A few hairline cracks were noted around the inside edge of the Silikal®.

(3) 40 Coverages: There were a few more hairline cracks and minor spalling of the Silikal® in the traffic lane.

(4) 60 Coverages: The patch appeared to be deteriorating quite rapidly. There was considerable spalling caused by the action of the adjacent AM-2 panels. Some clips were beginning to bend and nails were beginning to pop up. Due to consolidation of the material beneath the mat, there was more wave action of the panels as the load cart passed.

(5) 74 Coverages: Some nails had to be hammered back in. The spalled concrete was swept from the traffic lane.

(6) 80 Coverages: Spalling of the Silikal® had increased. Many clips in the traffic lane were loose. Nails were constantly being hammered in to prevent damage to the tire.

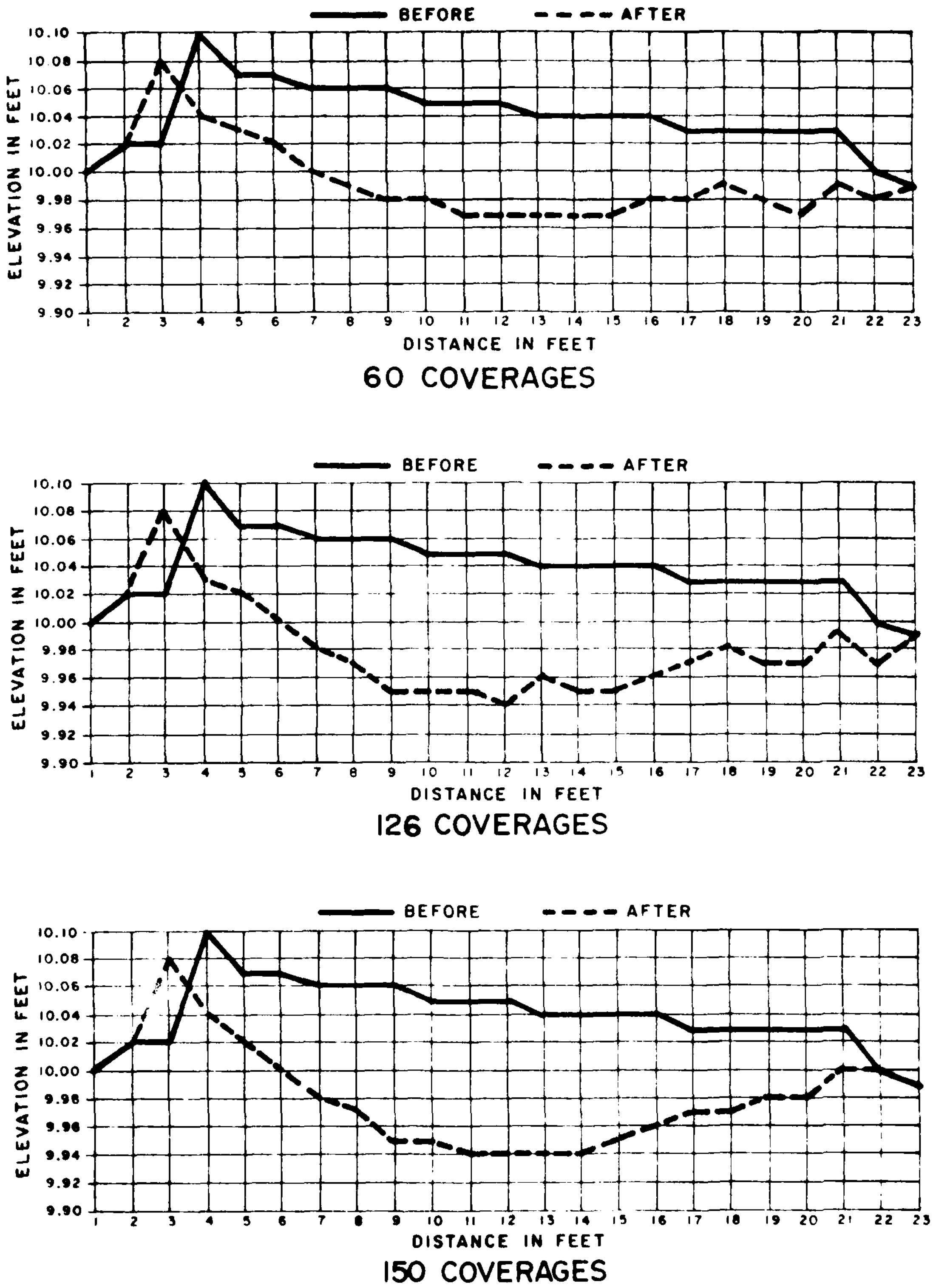
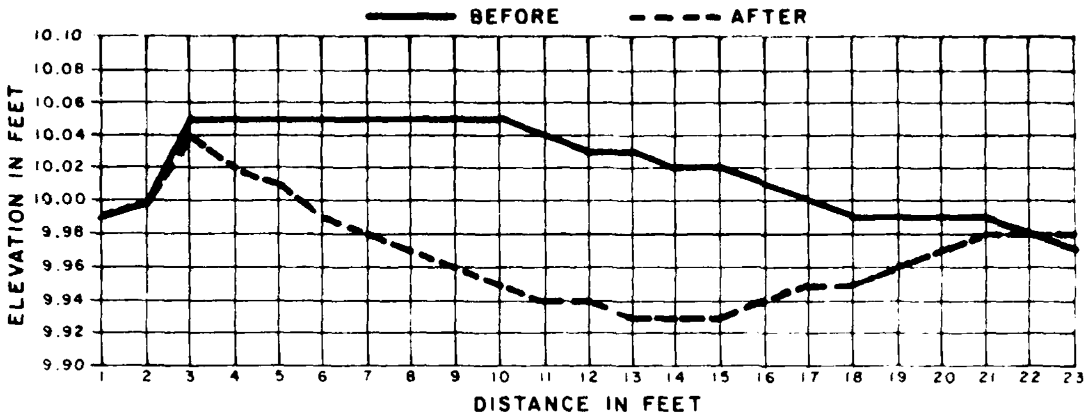



Figure 18. Coverages on Z-Clip System,
F-4 Aircraft, Base Line A-A

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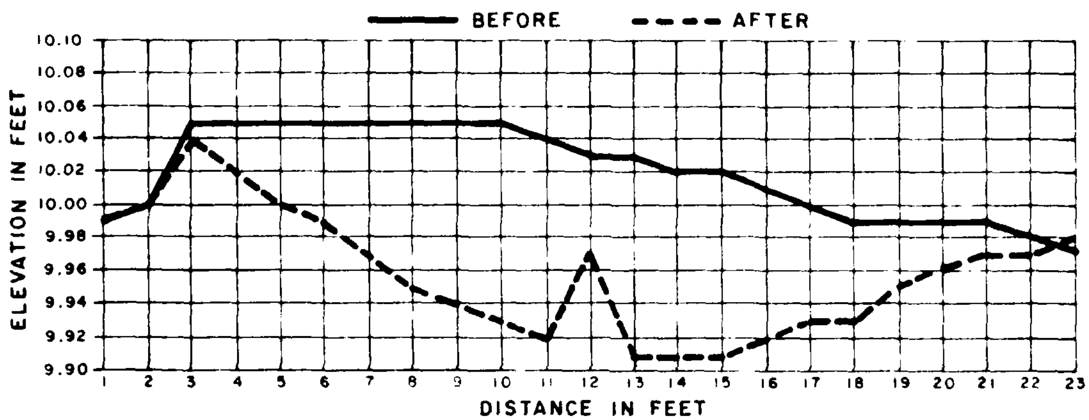


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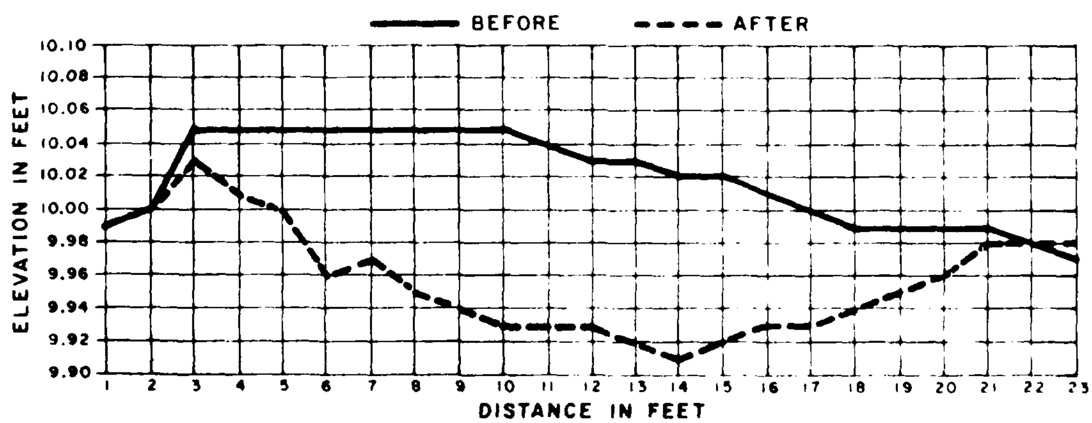
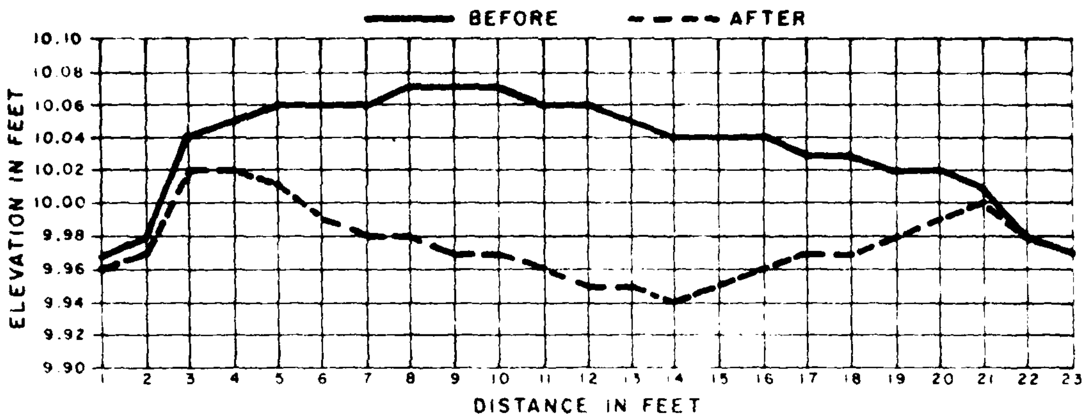
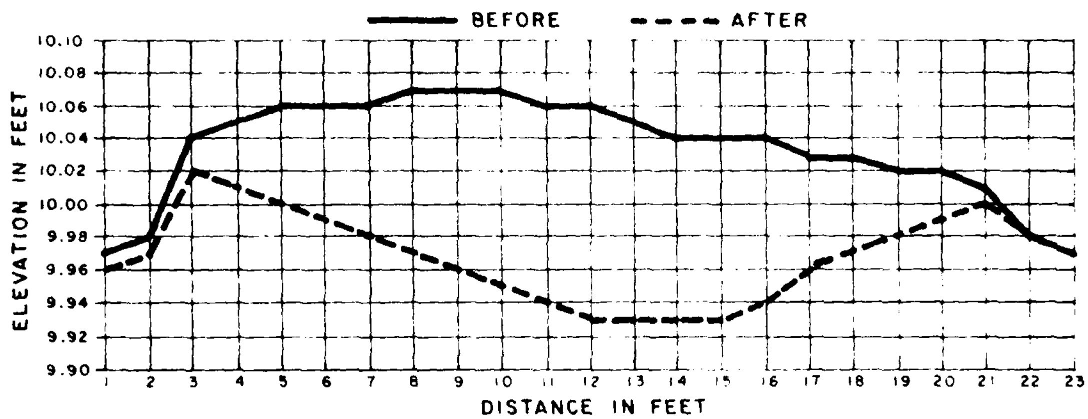



150 COVERAGES

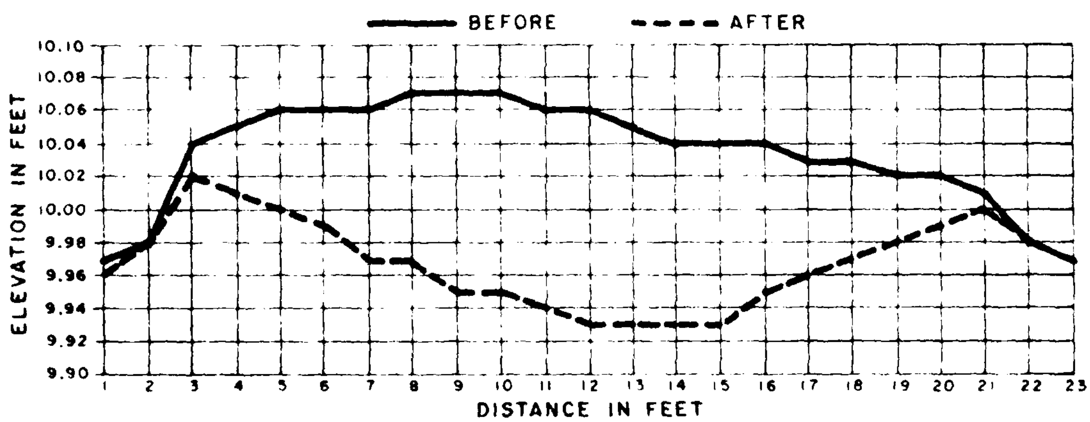
Figure 19. Coverages on Z-Clip System,
F-4 Aircraft, Base Line B-B




60 COVERAGES




126 COVERAGES




150 COVERAGES

Figure 20. Coverages on Z-Clip System,
F-4 Aircraft, Base Line C-C

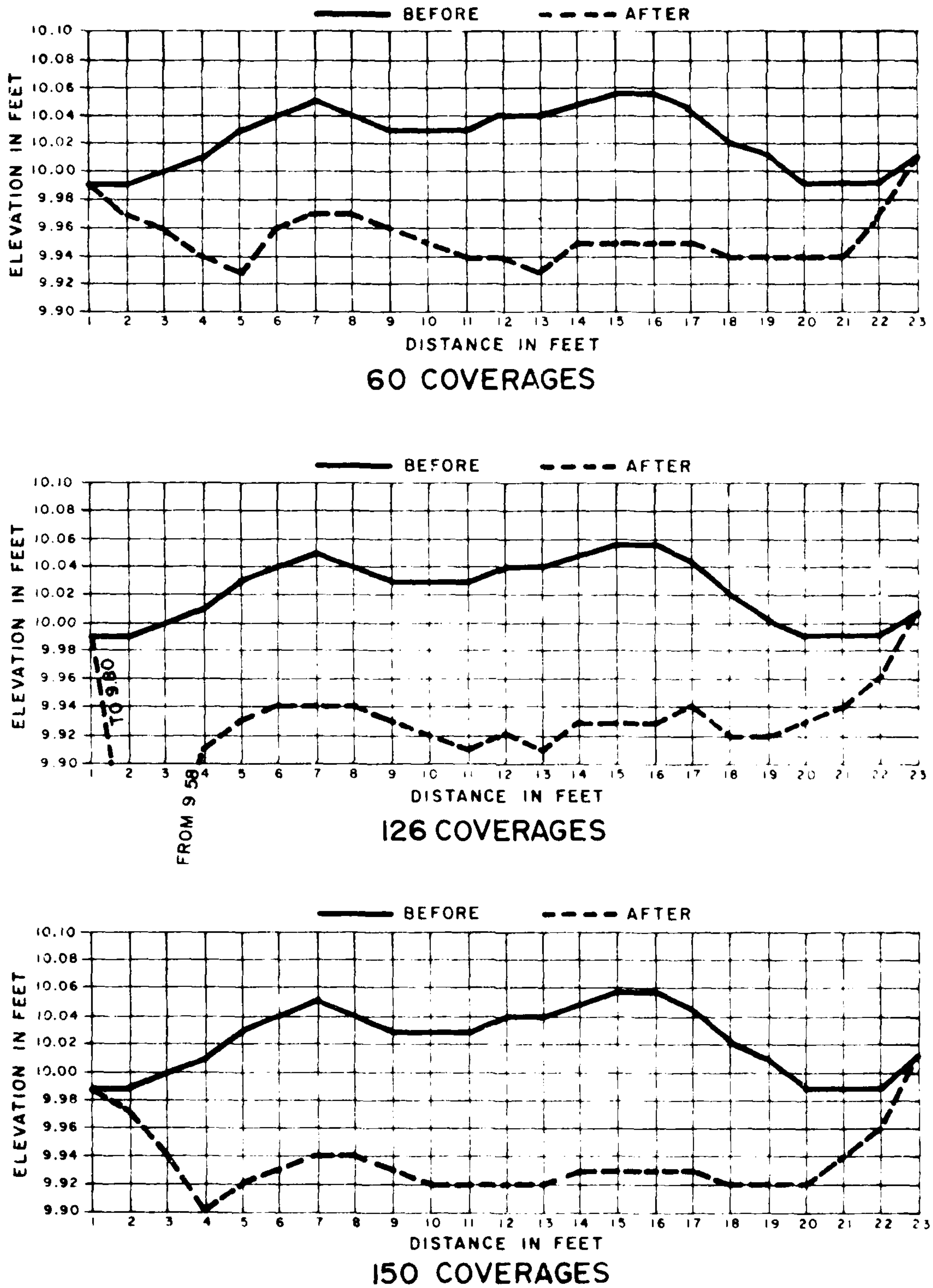



Figure 21. Coverages on Z-Clip System, F-4 Aircraft, Base Line D-D

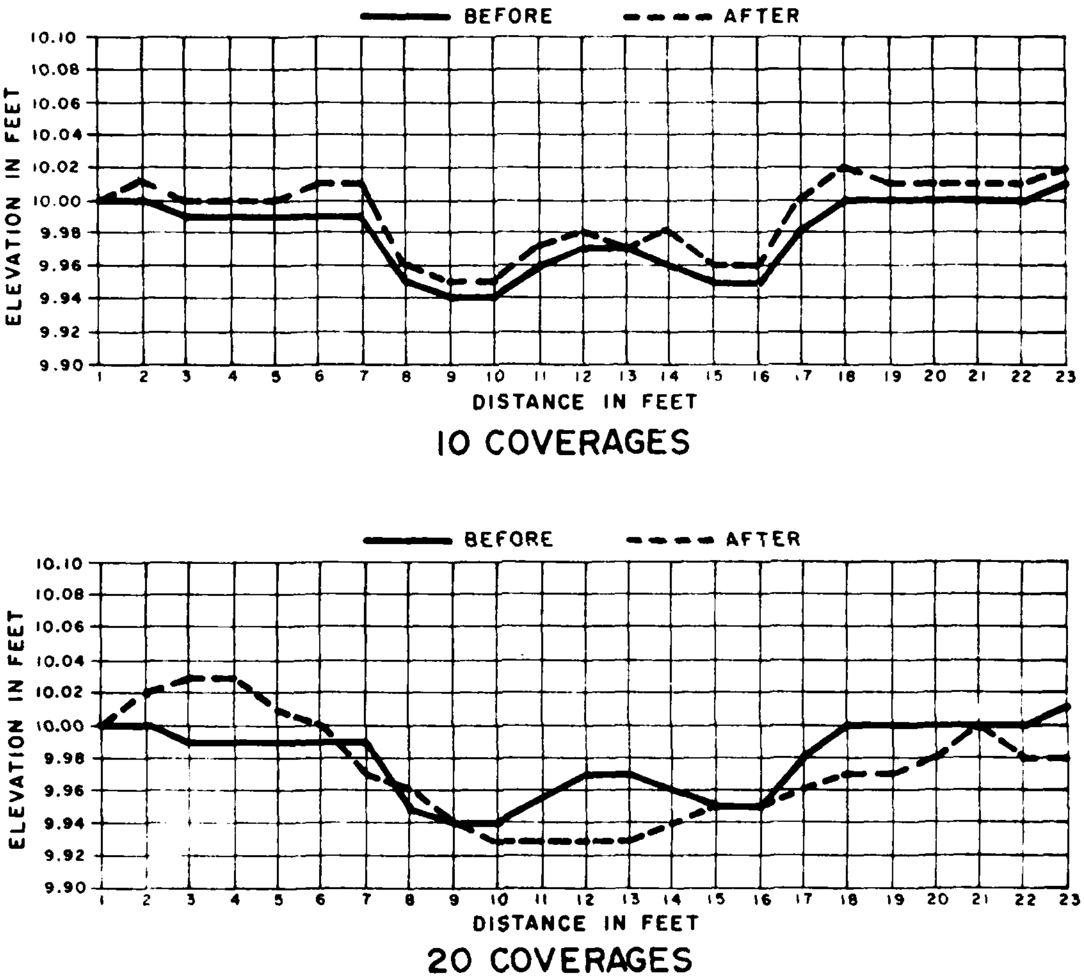



Figure 22. Coverages on Z-Clip System, C-141 Aircraft, Base Line A-A

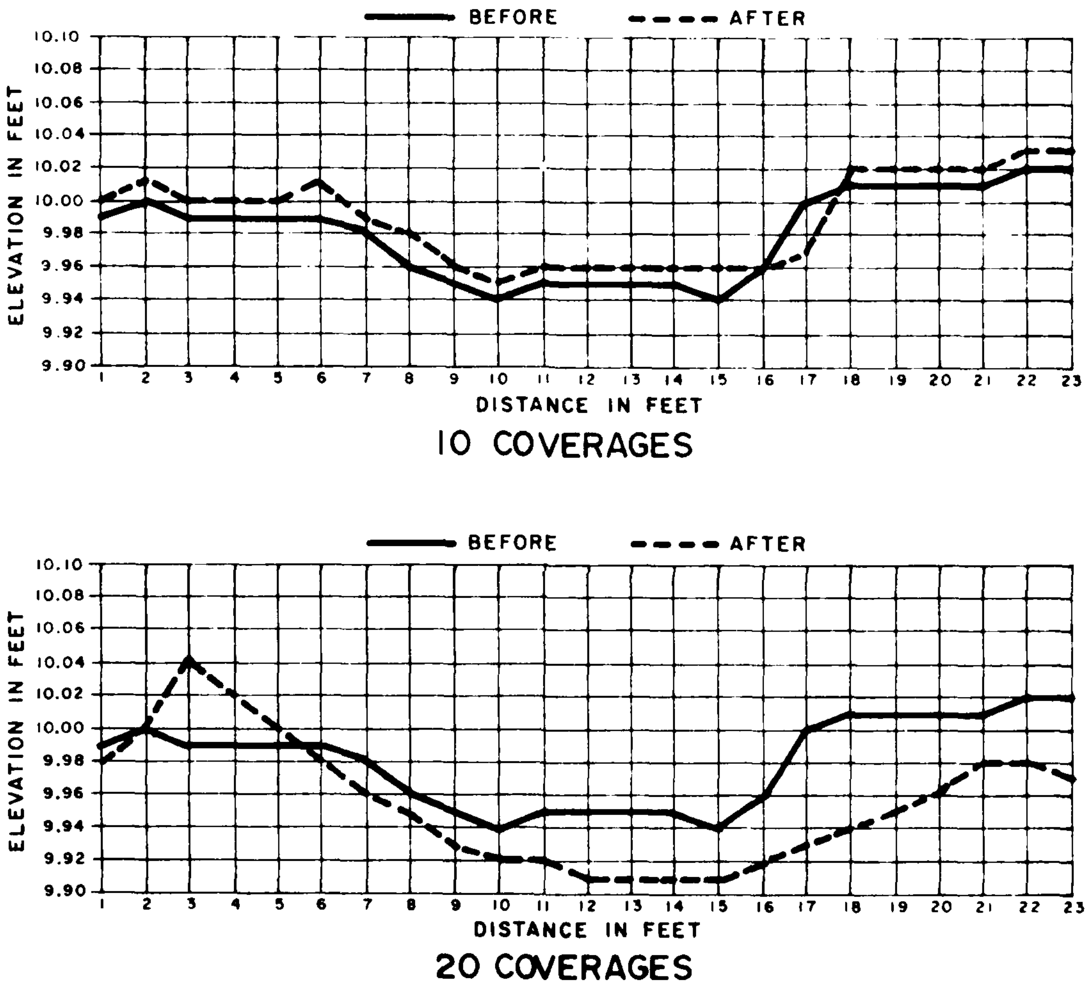
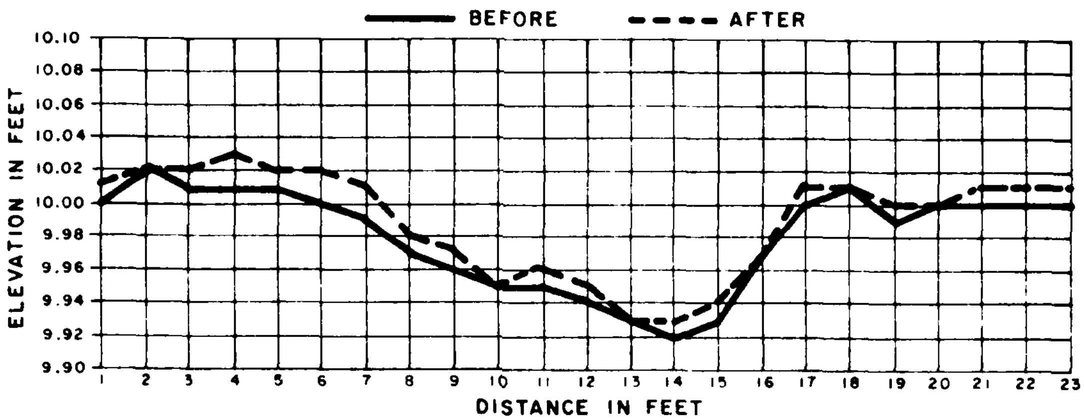
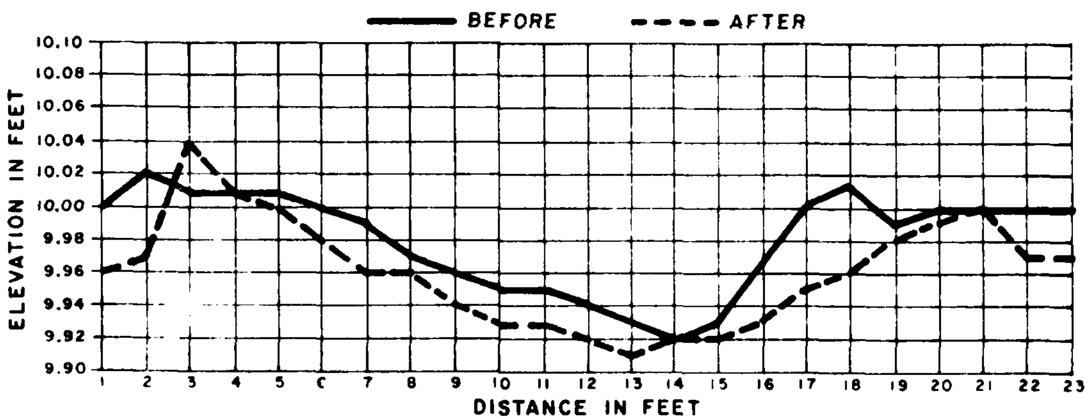



Figure 23. Coverages on Z-Clip System, C-141 Aircraft, Base Line B-B




10 COVERAGES




20 COVERAGES

Figure 24. Coverages on Z-Clip System, C-141 Aircraft, Base Line C-C

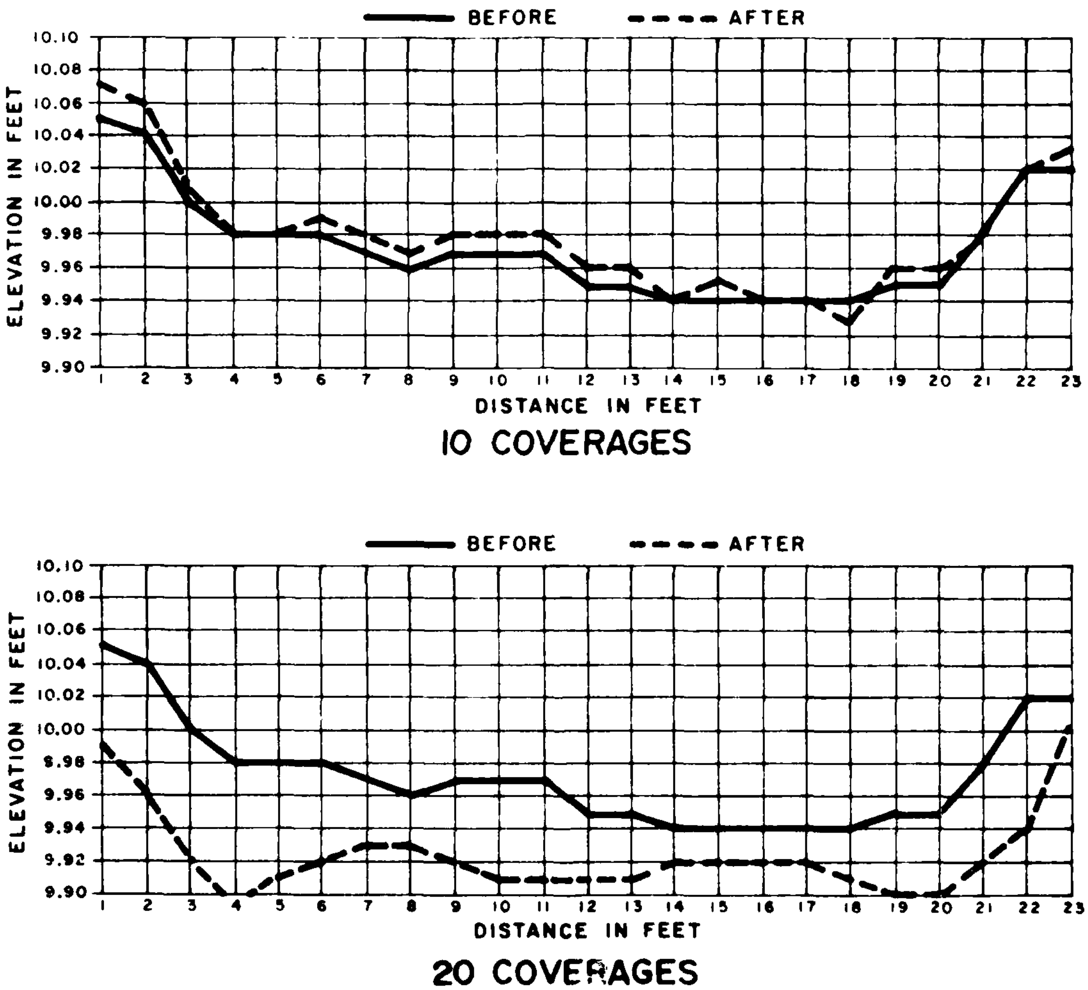
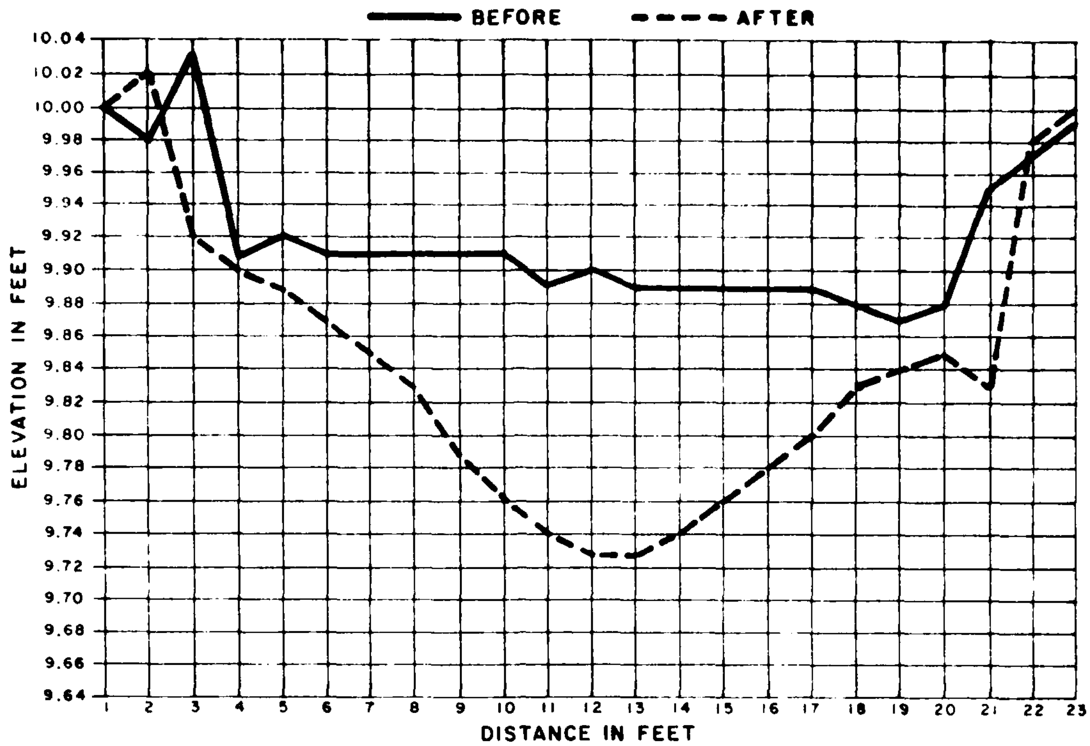
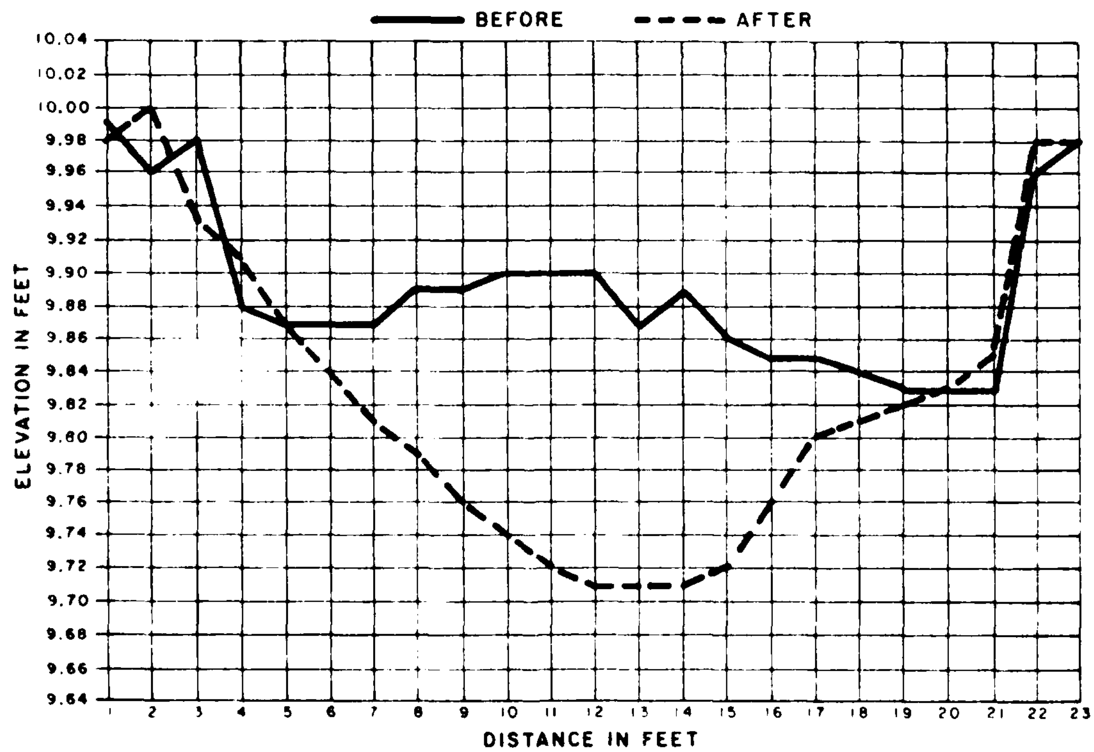



Figure 25. Coverages on Z-Clip System, C-141 Aircraft, Base Line D-D

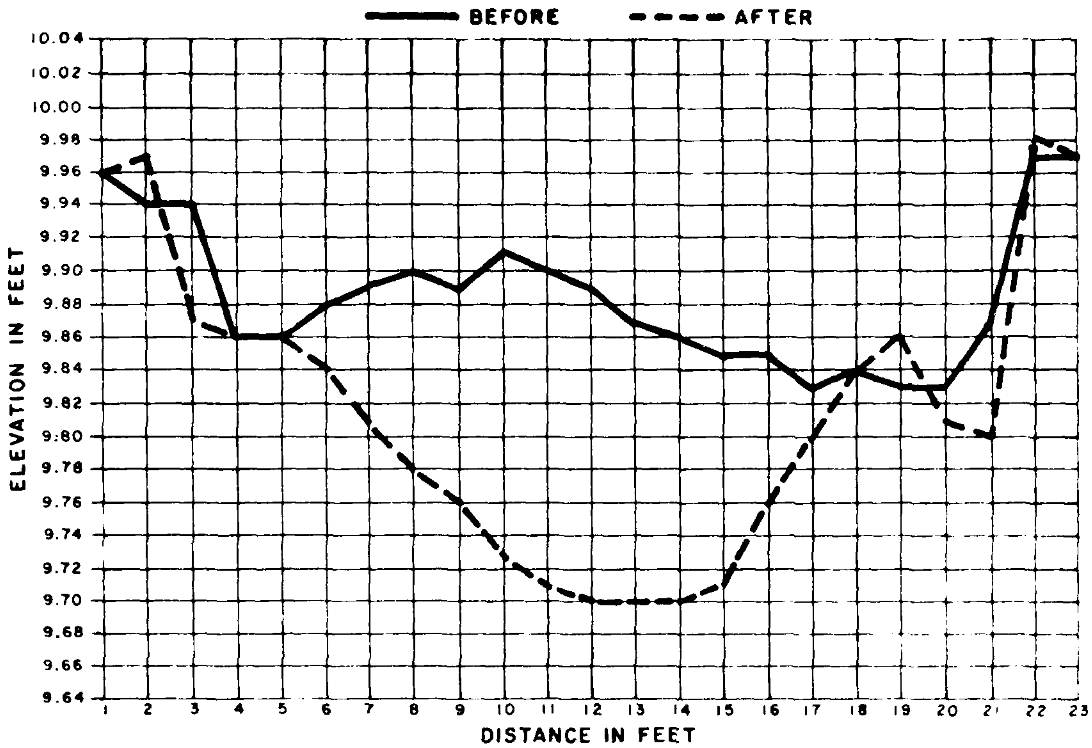



**BASE LINE A-A**

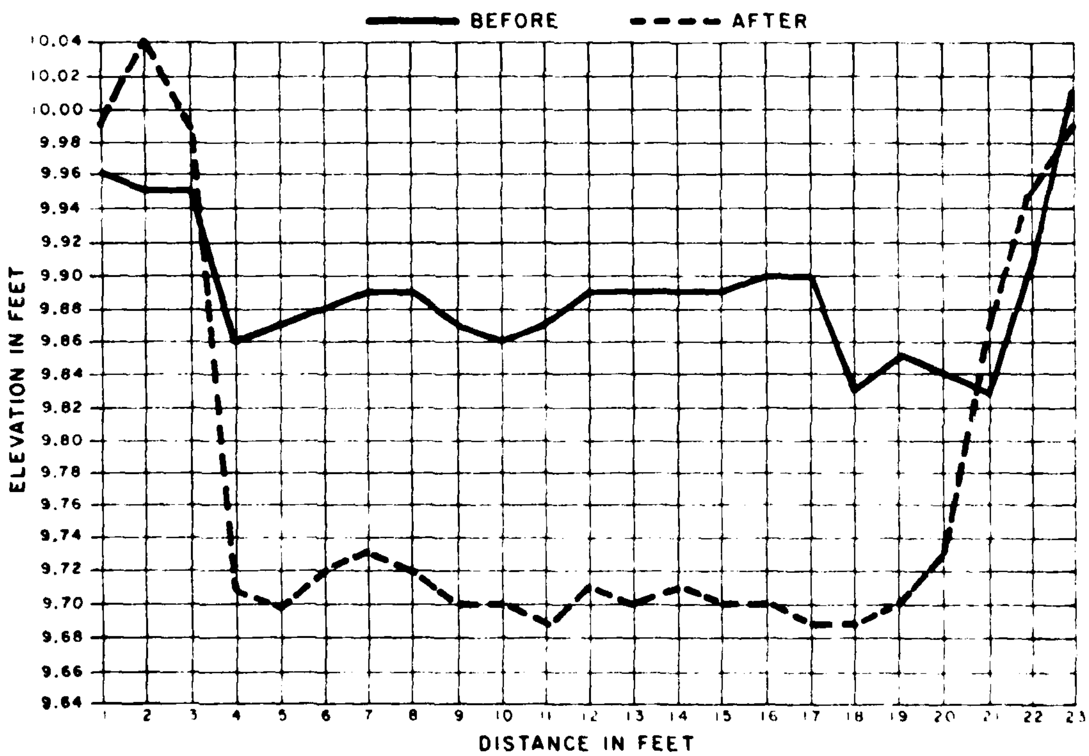



**BASE LINE B-B**

Figure 26. Coverages on Z-Clip System,
150 Cov. F-4/20 Cov. C-141,
Base Lines A-A and B-B




BASE LINE C-C




BASE LINE D-D

Figure 27. Coverages on Z-Clip System,
150 Cov. F-4/20 Cov. C-141,
Base Lines C-C and D-D

(7) 126 Coverages: Structural failure of the patch had occurred. The Silikal® was badly spalled with 3- or 4-inch pieces readily removed by hand. A sizeable deflection of the panels was noted as the load cart crossed.

At this point, it was decided to repair the badly spalled areas in order to get 150 coverages of the F-4 and the required coverages of the C-141 load cart. Two bags of Silikal® were required to complete the repair.

(8) 150 Coverages: Repaired area had minor spalls. The nail holes had enlarged to such an extent that the clips were no longer bonded to the AM-2 panels. However, the patch was considered to be functional.

Trafficking with the C-141 load cart began. After ten coverages the previous repair had completely spalled out. After 20 coverages spalling was much worse and a large deflection of the patch under load was noted.

The spalled areas were repaired with 2-1/2 bags of Silikal® prior to the 70,000-pound pull test. For this test a plate was glued to the AM-2 mat. Through a combination of pulleys, a four-part line was attached to a wrecker. The wrecker and plate were braced and supported by various pieces of equipment. The glue failed, and the plate came off at 68,000 pounds. Since the patch remained in place, the test was considered to be successful.

Visual observations are shown in Figures 28 through 42.

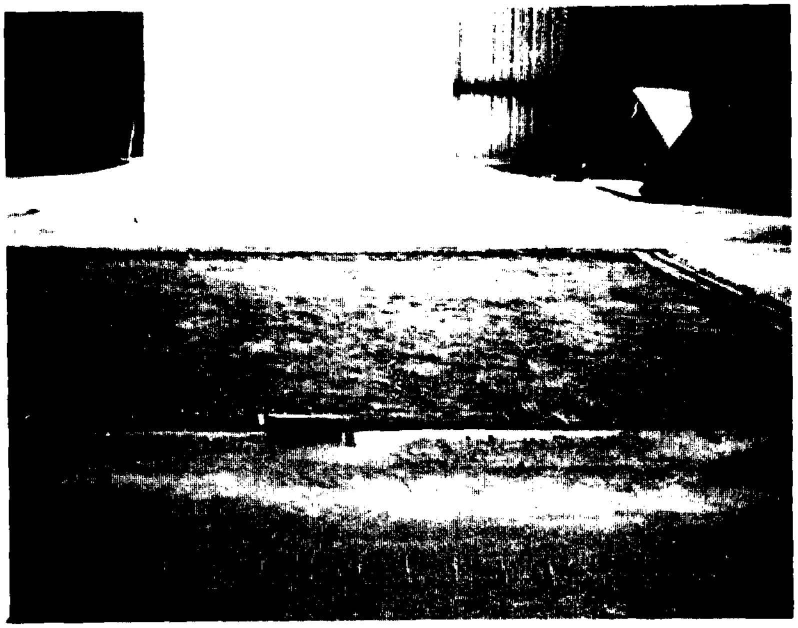


Figure 28. Test 1 (Z-Clip)-Compacted Base Course in Place

Figure 29. Test 1 (Z-Clip)-Assembling AM-2 Mat

Figure 30. Test 1 (Z-Clip)-Removing Wooden Box (Form for Placing Silikal®)

Figure 31. Test [illegible] (Z-Clip)- Setting Z-Clip

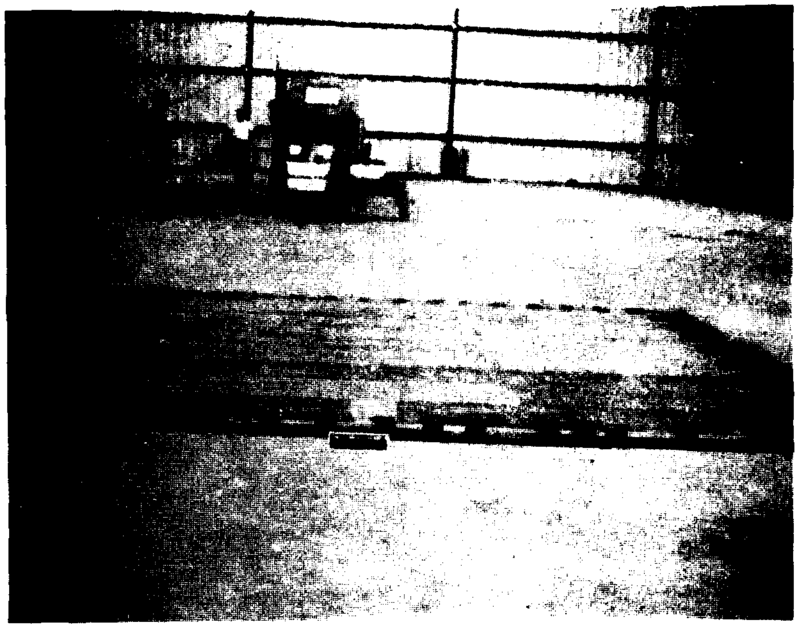


Figure 32. Test 1 (Z-Clip)-Z-Clips in Place

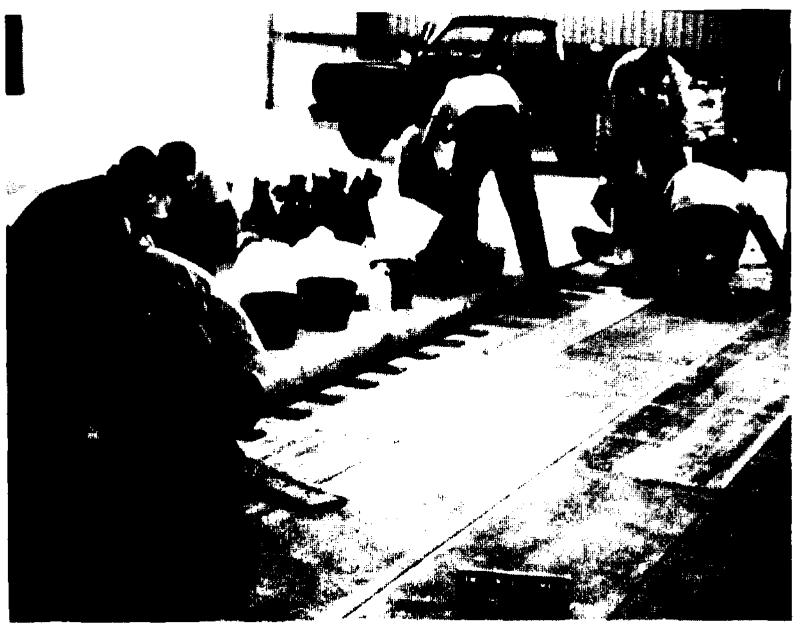


Figure 33. Test 1 (Z-Clip)-Placing Silik ®

Figure 34. Test 1 (Z-Clip)-Placing Silikal®

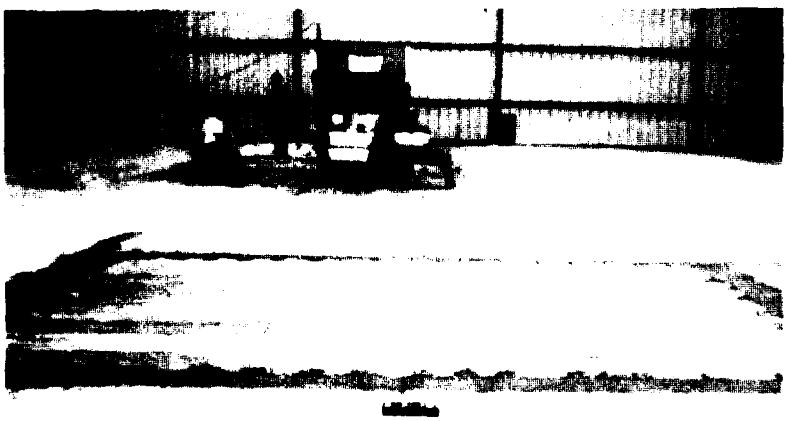


Figure 35. Test 1 (Z-Clip)-Completed Patch; Silikal® Curing

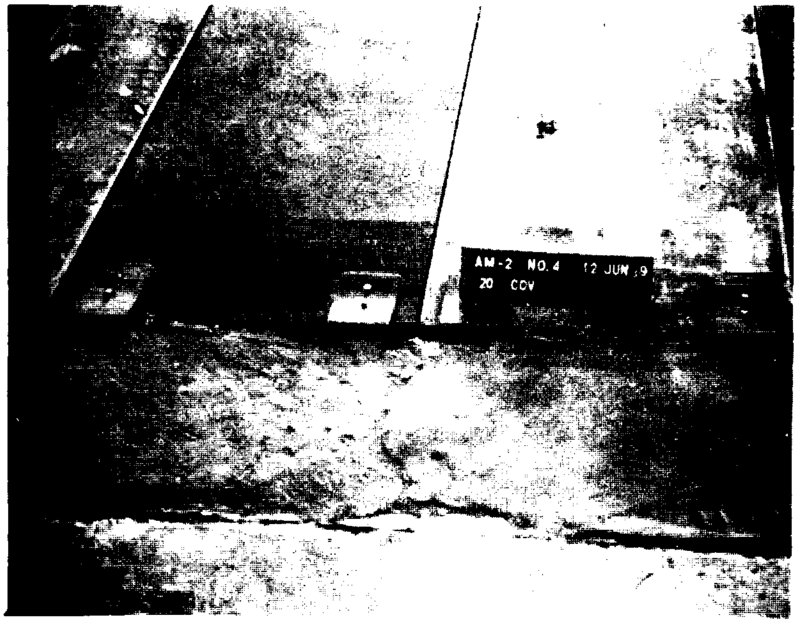



Figure 36. Test 1 (Z-C11a)-20 Coverages of F-4

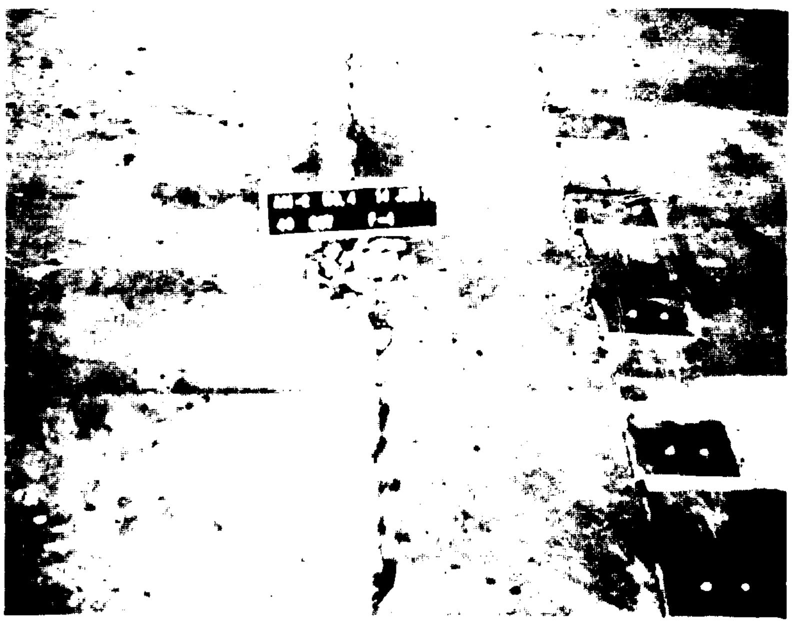


Figure 37. Test 1 (Z-C11a)-40 Coverages of F-4

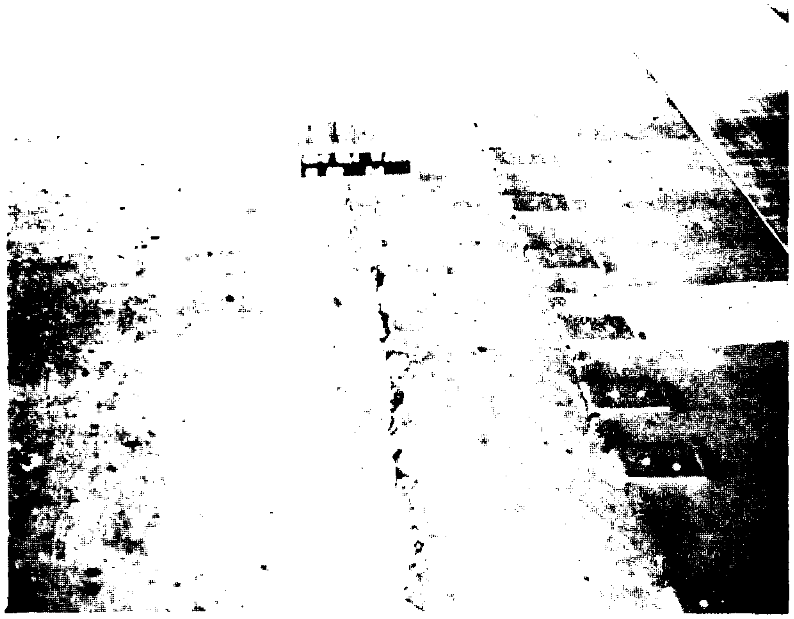


Figure 38. Test 1 (Z-C[illegible] of F-4
(Loose Nail[illegible]

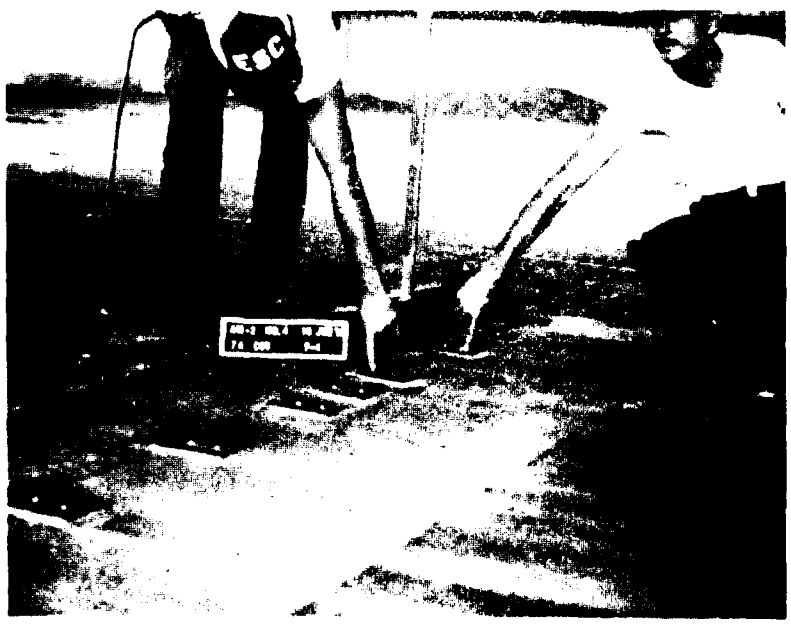


Figure 39. Test 1 (Z-C[illegible])-74 Coverages of F-4
(Loose Nails

Figure 40. Test 1 (Z-Clip)-126 Coverages of F-4 (Failure)

Figure 41. Test 1 (Z-Clip)-20 Coverages of C-141

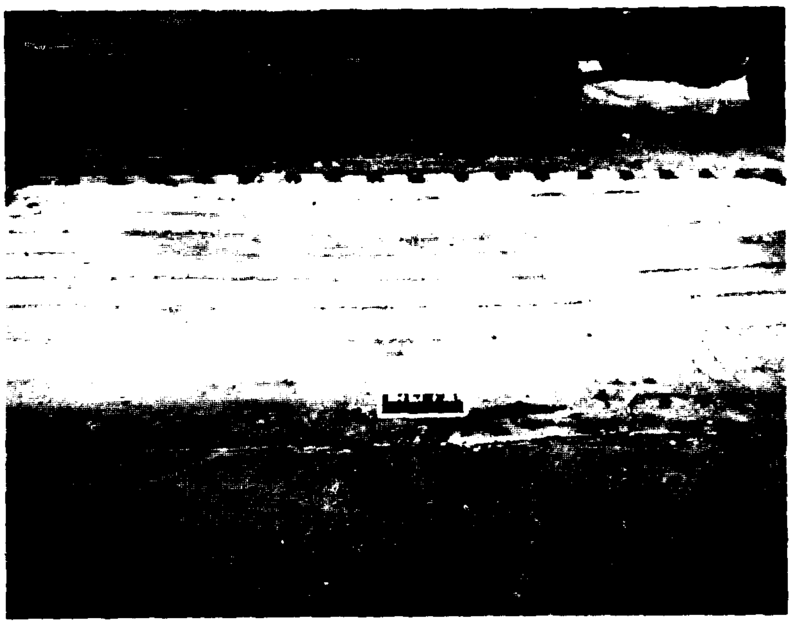


Figure 42. Test 1 (Z-Clip)-Base Course
After Completion of Tests

AM-2 FLUSH PATCH TEST 2 (PERIMETER RAIL)

Fabrication of the perimeter rail system in pit 2 began on 9 July 1979. Some of the anchor plates and rails had to be redrilled to allow holes to match. The rail was placed around the perimeter of the pit directly on the clay subgrade. It was difficult to align the rail and bring it to the proper elevation. Tolerance in the bolt holes allowed the rails to be bolted out of alignment, resulting in numerous adjustments. Due to previous reconstruction of the sides of the pit, the rail would not fit properly in the pit. The base course was added and compacted. Screeding the base course and obtaining the proper elevation was tedious and time consuming. The panels were then installed. Again this was time consuming as all connectors had to be cleaned and each panel massaged and adjusted into place. The rubber spacers were inadvertently left out, and the tests were completed without them. An oversized locking bar was fabricated and used to connect the panels to the rail in lieu of the spring assembly specified. Although work was not continuous, portions of four days were used to assemble the patch, place the base course, and patch and perform the initial surveys and tests.

It was apparent immediately after trafficking began with the F-4 load cart that this system was weak. The rail, resting directly on the subgrade, settled after a few coverages causing the load cart to bounce as it came on or off the patch. This also exposed the sharp edge of the concrete posing possible damage to the F-4 tire. It was noted that after 20 coverages there were several short tears where the extrusion was welded to the ends of the panels. There was about a one inch lip at the edge of the concrete. Failure was determined at 60 coverages due to the amount of deflection of the rail and the resulting possibility of tire damage. Since failure occurred in the early stages of testing with the F-4, the C-141 trafficking was not accomplished.

Test data for this concept is shown on Figures 43 through 48. Visual observations during testing are shown in Figures 49 through 56.

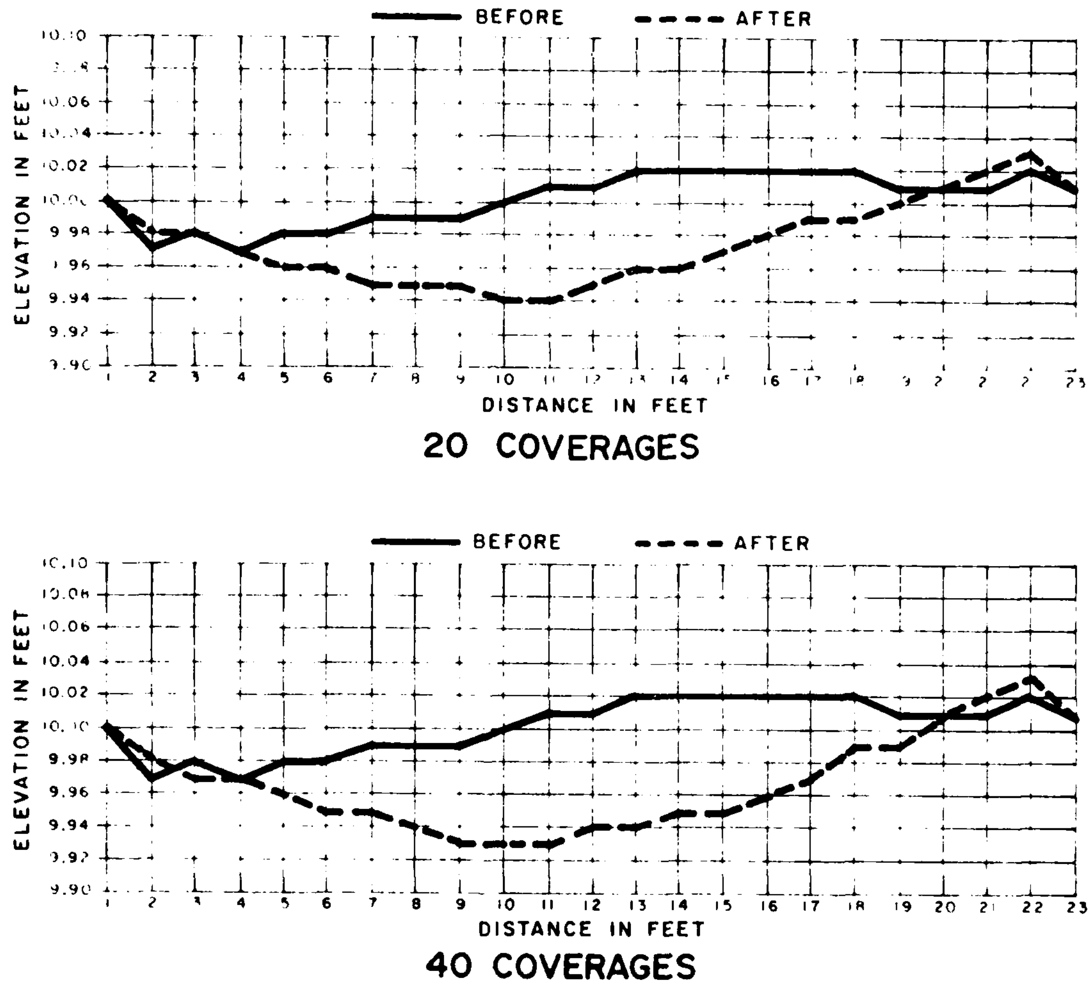



Figure 43. Coverages on Perimeter Rail System, F-4 Aircraft, Base Line A-A

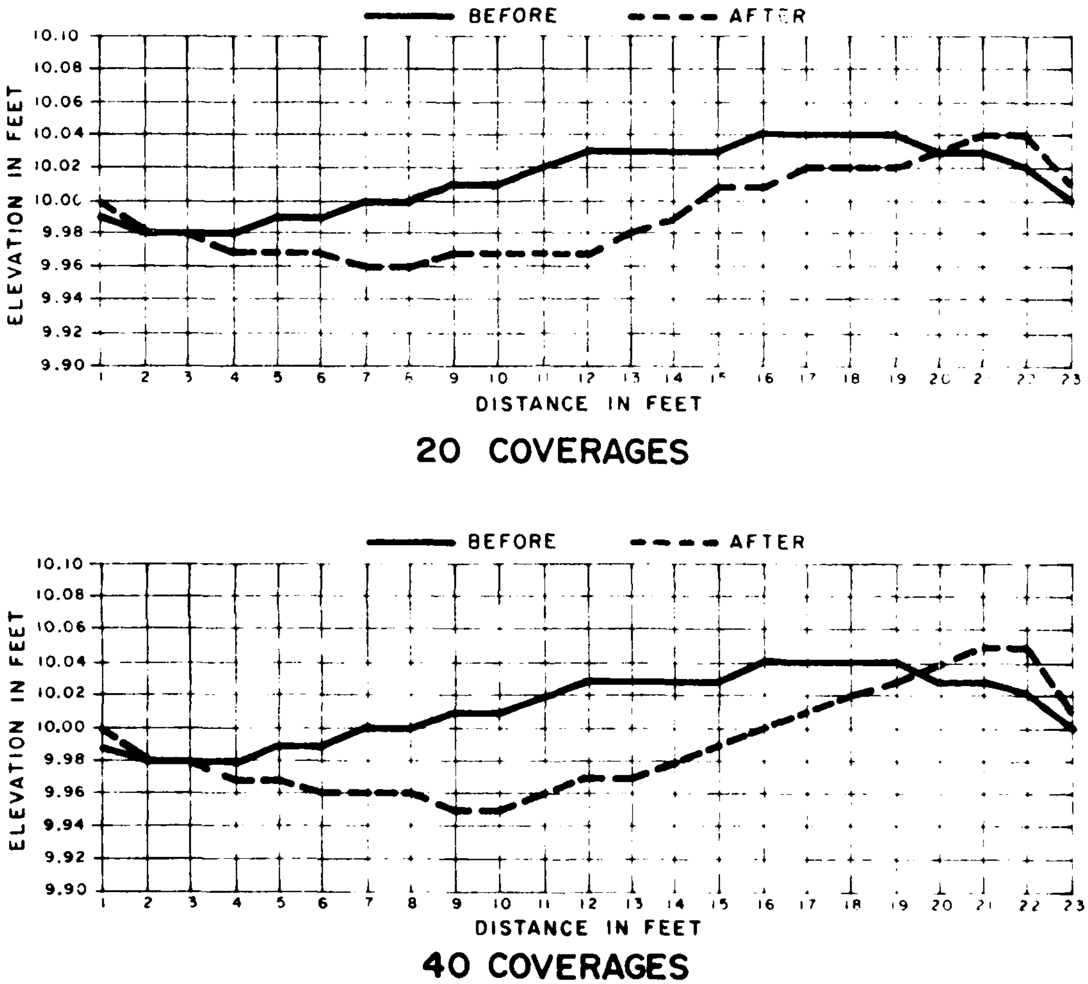
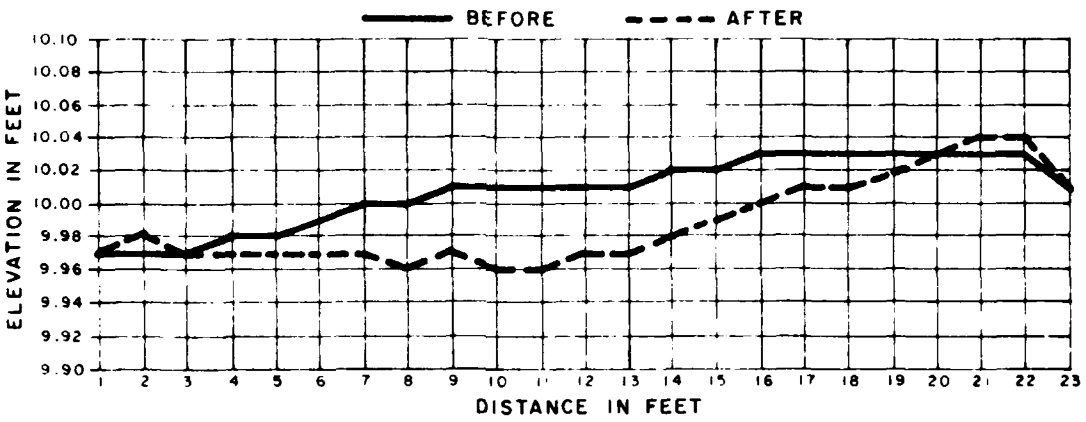
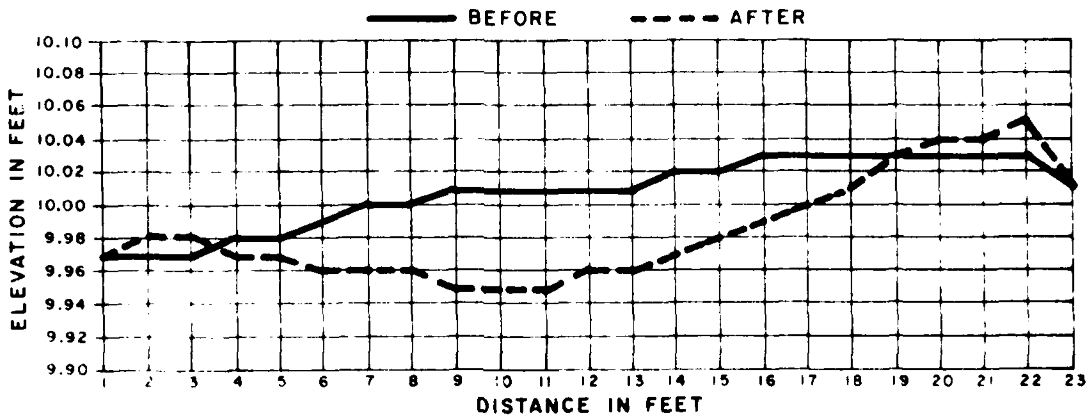



Figure 44. Coverages on Perimeter Rail System, F-4 Aircraft, Base Line B-B




20 COVERAGES




40 COVERAGES

Figure 45. Coverages on Perimeter Rail System, F-4 Aircraft, Base Line C-C

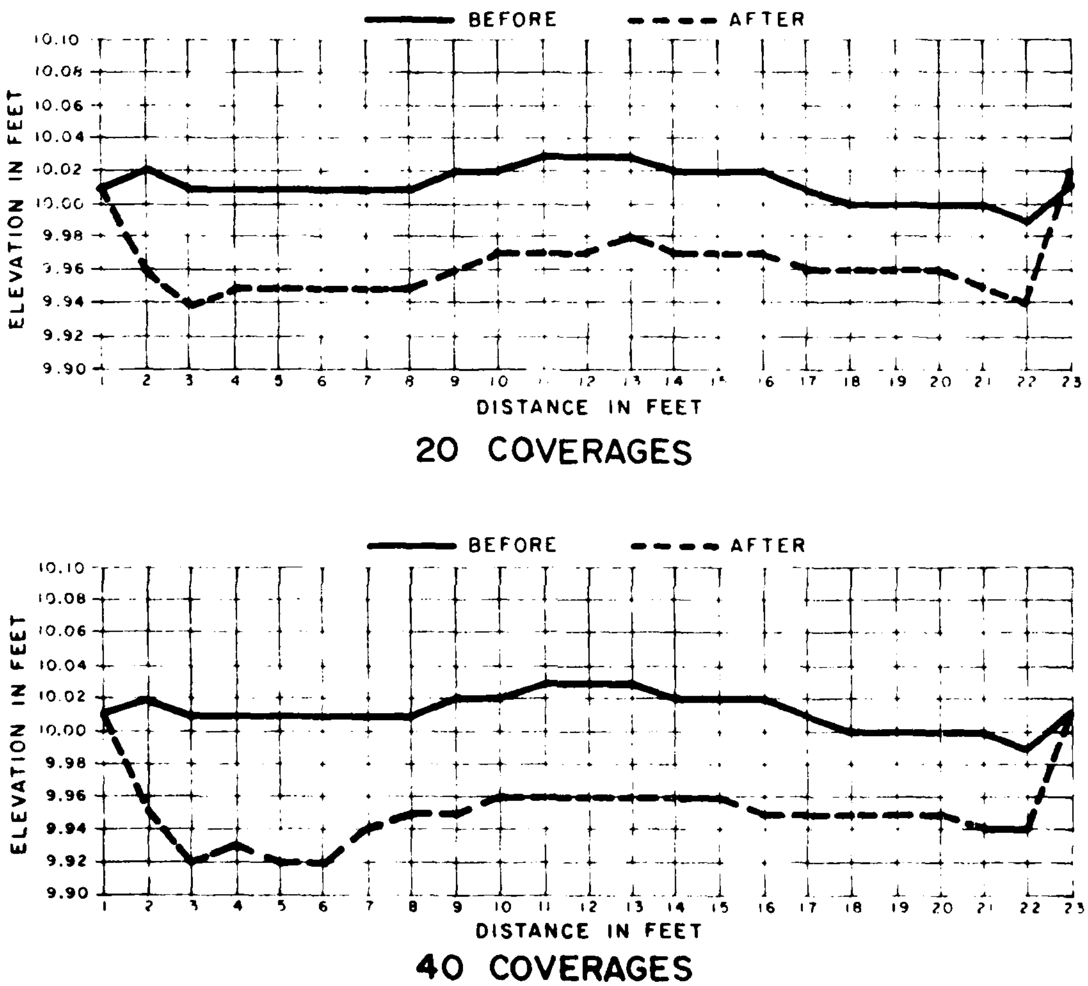
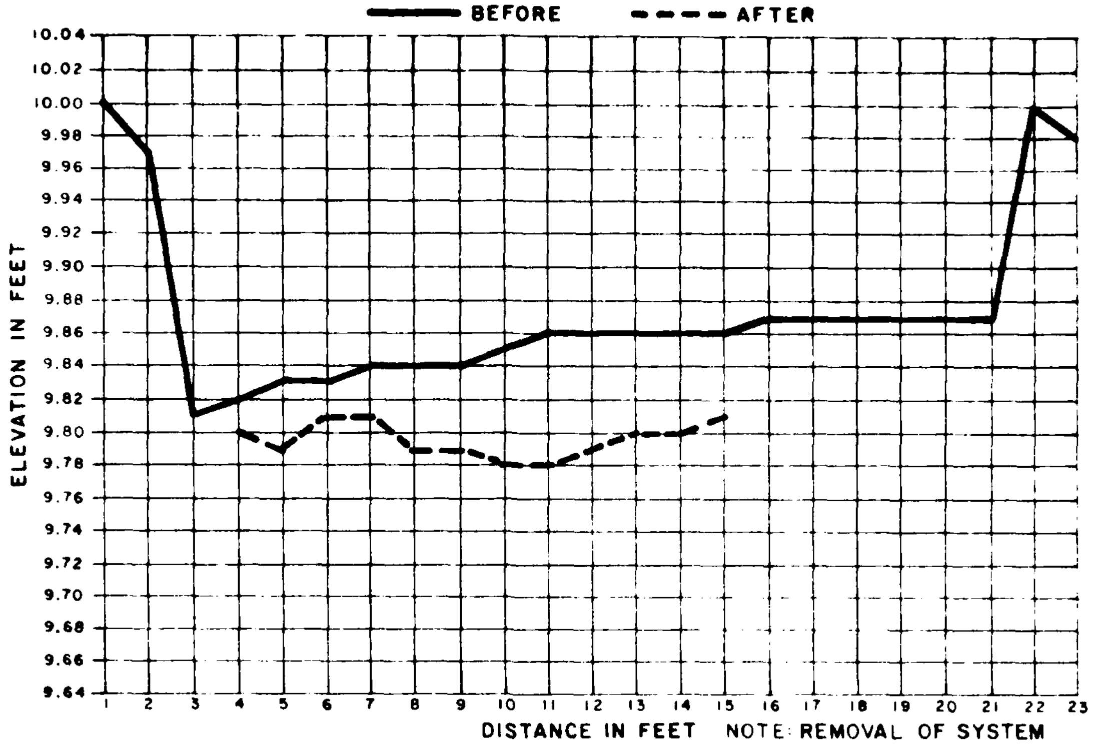
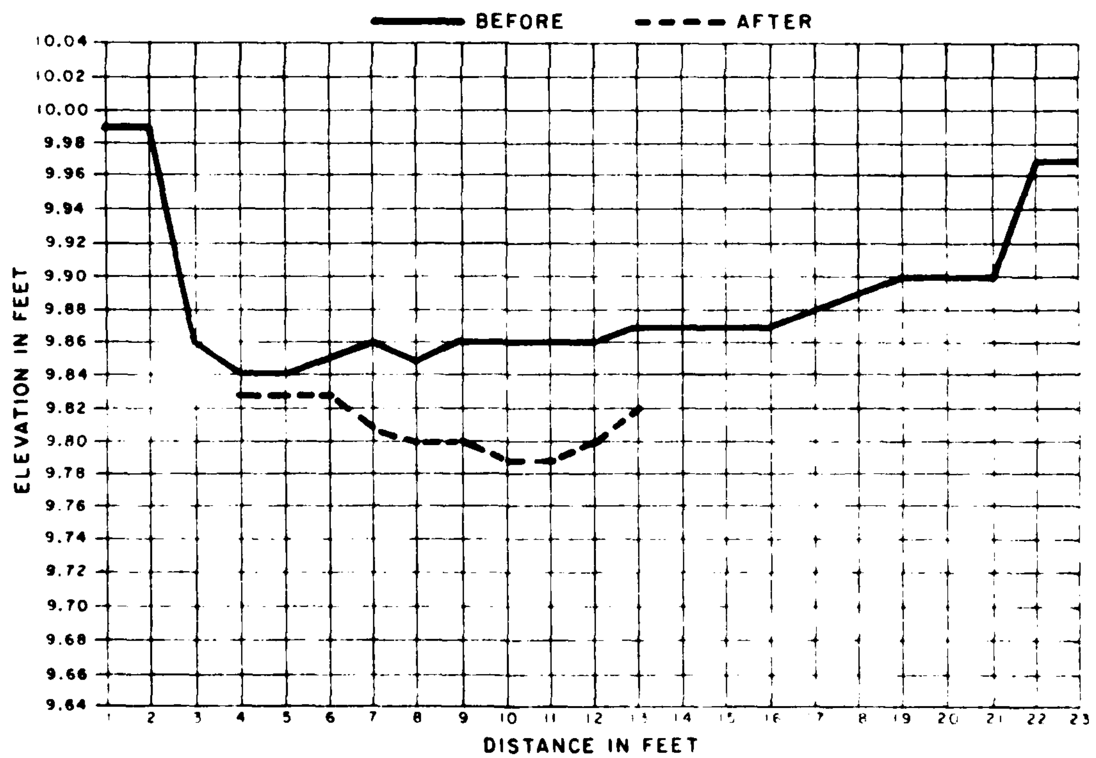



Figure 46. Coverages on Perimeter Rail System, F-4 Aircraft, Base Line D-D

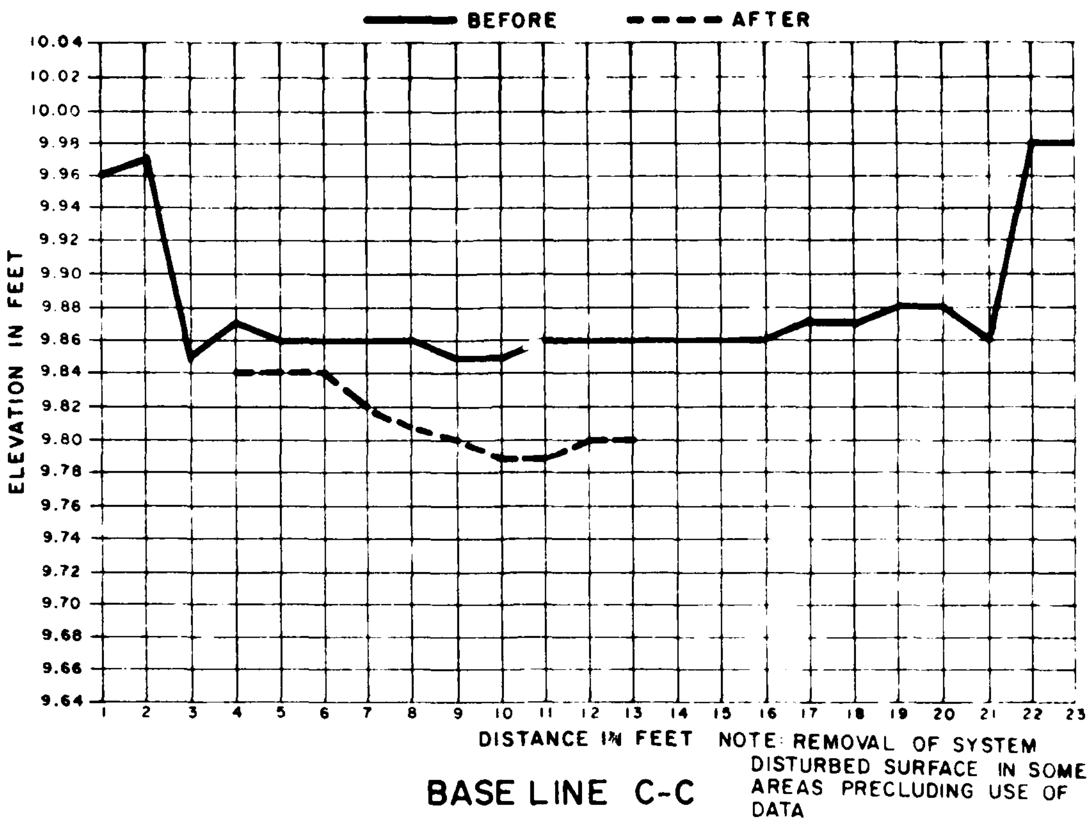



BASE LINE A-A




BASE LINE B-B

Figure 47. Coverages on Perimeter Rail System, F-4 Aircraft, 60 Coverages, Base Lines A-A and B-B



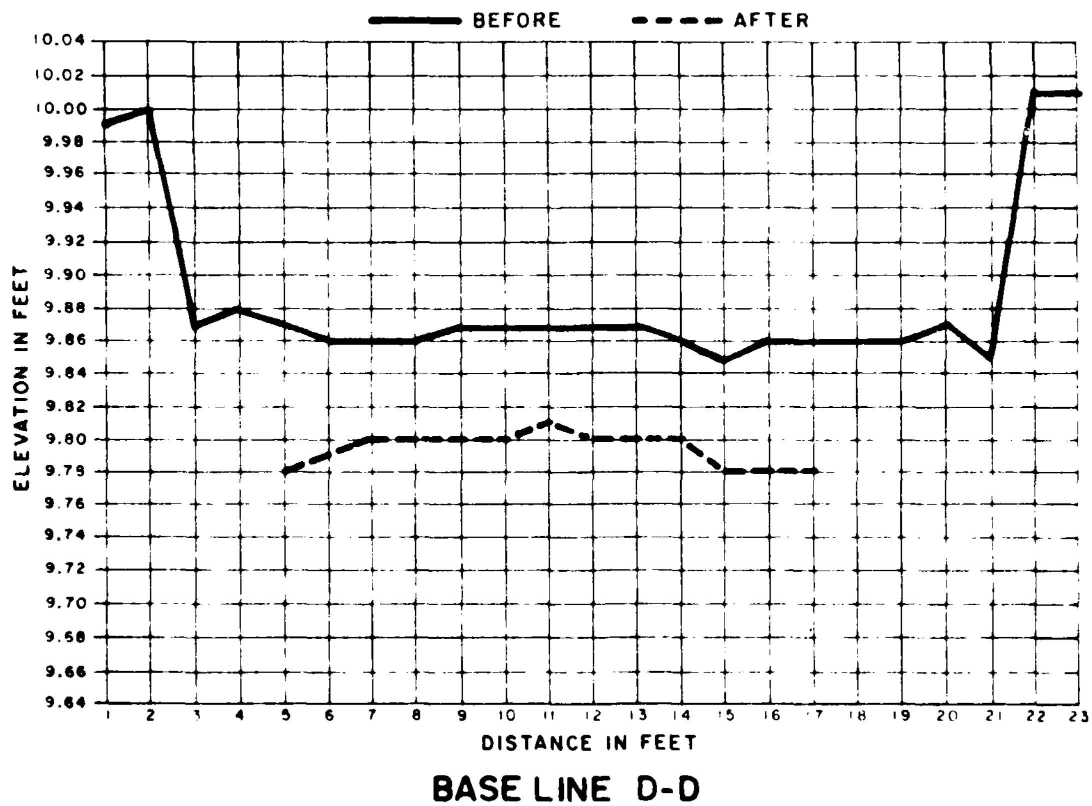




Figure 48. Coverages on Perimeter Rail System, F-4 Aircraft, 60 Coverages, Base Lines C-C and D-D

Figure 49. Test 2 (Perimeter Rail)-Installing Perimeter Rail

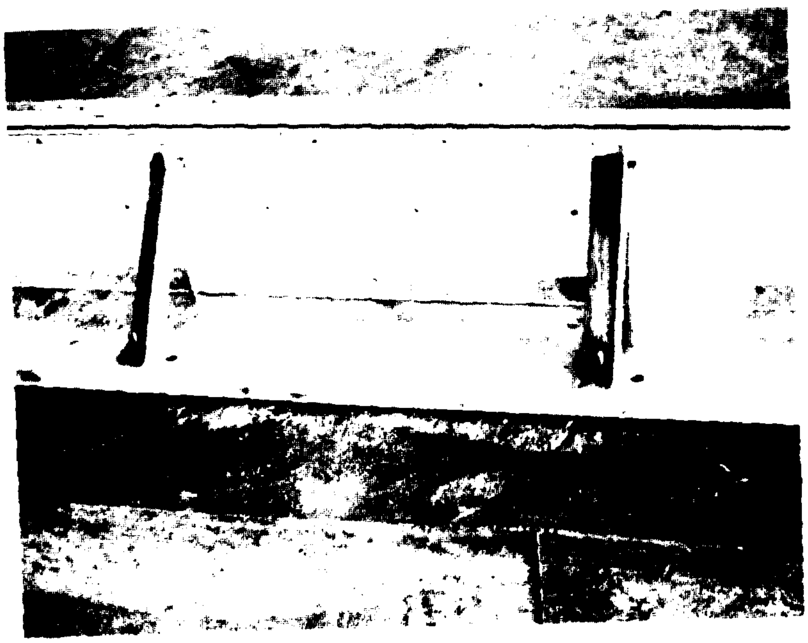


Figure 50. Test 2 (Pe imeter Rail)-Perimeter Rail With ase Plate

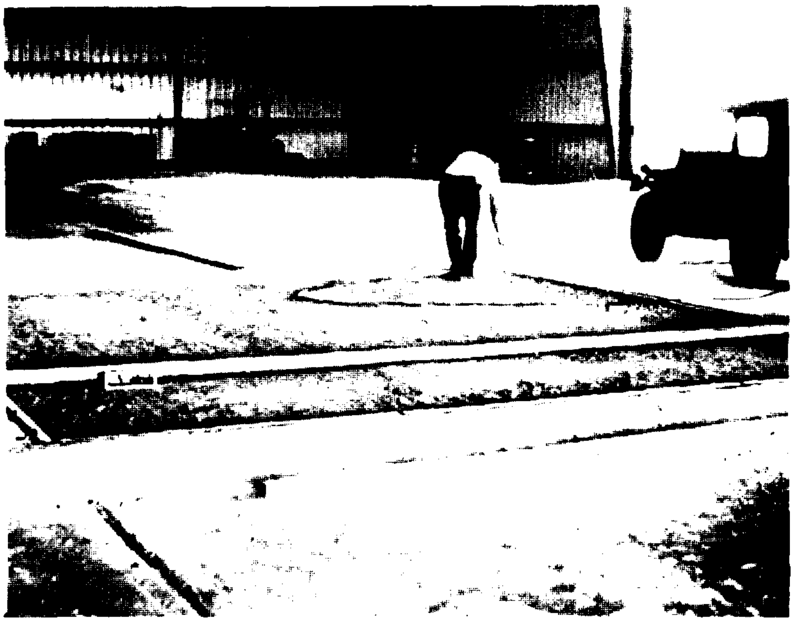


Figure 51. Test 2 (Perimeter Rail)-Blowing Aggregate From Perimeter Rail Locking Assembley

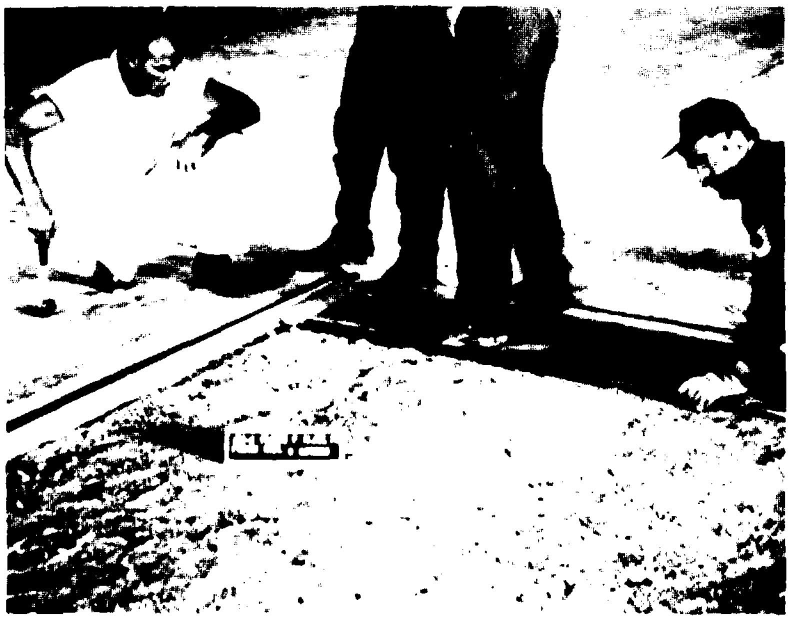


Figure 52. Test 2 (Perimeter Rail)- Installing AM-2 Mat

Figure 53. Test 2 (Perimeter Rail)-
20 Coverages of F-4

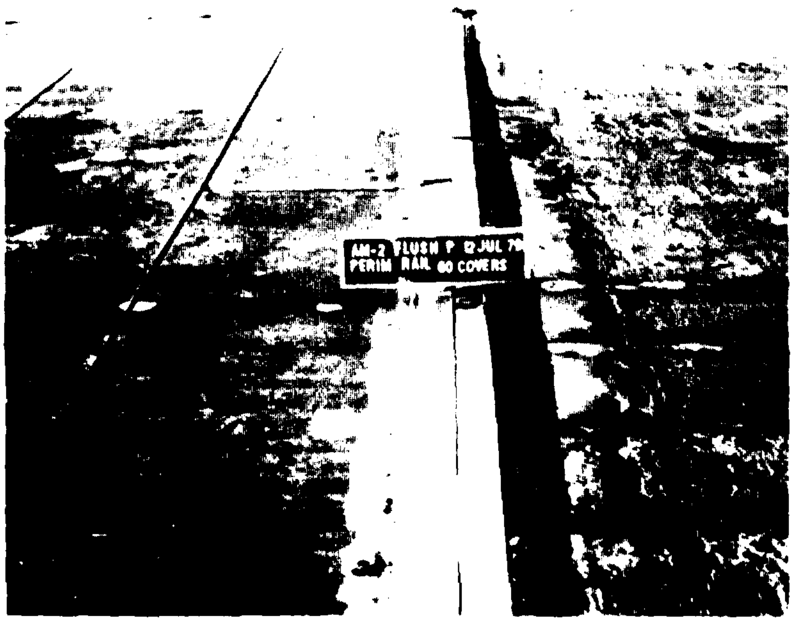



Figure 54. Test 2 (Perimeter Rail)-
60 Coverages of F-4

Figure 55. Test 2 (Perimeter Rail)-Perimeter Rail Removed From Pit After Testing

Figure 56. Test 2 (Perimeter Rail)-Base Course After Testing

## AM-2 FLUSH PATCH TEST 3 (SIDE PANEL SYSTEM)

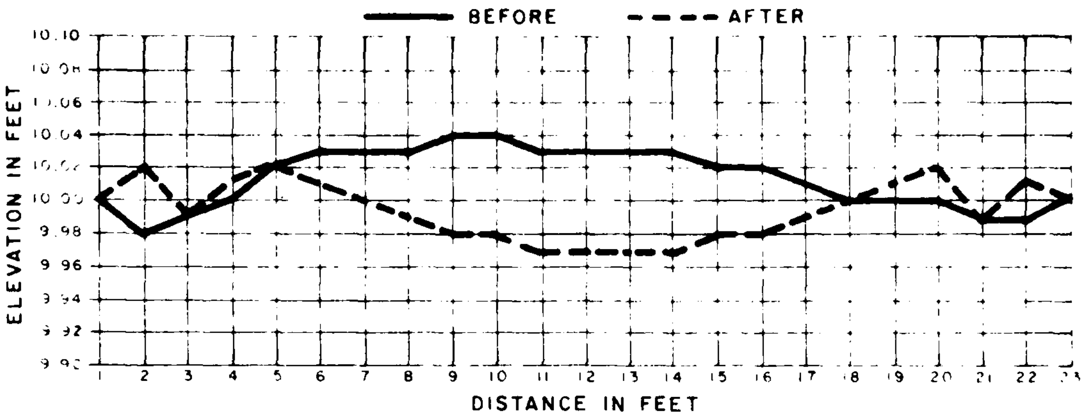
Testing of this system began on 16 July 1979. The locking assembly was explosively nailed to the concrete wall of pit 2. Concurrently the mat was assembled beside the pit. The rubber spacers were glued in the joints during assembly. The base course was brought to an elevation 1-1/2 inches from the top of the concrete and compacted with the RayGo 400 Vibratory compactor. The support panels were then recessed into the base course and additional compactive effort applied. This procedure involved a lot of tedious handwork. The mat was sawed and placed in the pit. The aggregate was removed and the angles inserted into the locking assembly of the anchoring system. The assembly and installation for this test went faster than Test 2, primarily because the mat was assembled while the locking assembly was being explosively nailed to the concrete. Assembly, installation, and initial testing took portions of three days.

After six coverages of the F-4, it appeared the nails were beginning to loosen as deflection was noted in the locking assembly as the load cart passed. Several times during trafficking, an angle would come loose. This could have been prevented by making the projection on the angle longer so that it would not slip from the locking assembly when the assembly deflects under load. At 40 coverages the inside plate on the locking assembly was beginning to permanently bend towards the center of the pit. A total of 150 coverages of the F-4 were completed with only minor problems encountered.

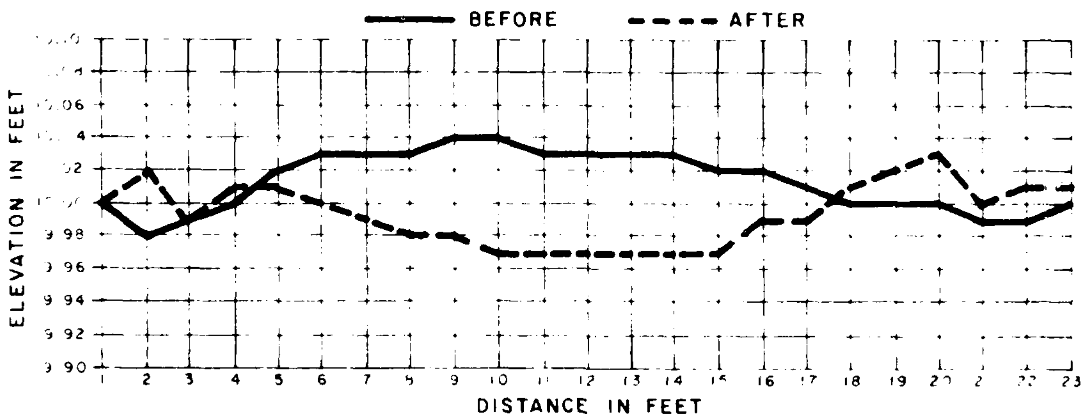
The patch was then trafficked with the C-141 load cart. After four passes one of the angles on the side of the patch was severely bent and had to be removed. Trafficking continued to completion without this angle with no noticeable effect on the patch.

For this 70,00 pound pull test, the plate was bolted to the mat with 6-1/2-inch bolts. At 50,000 pounds the bolts sheared and the plate was pulled from the matting. There was no way to resecure the plate so the test was terminated.

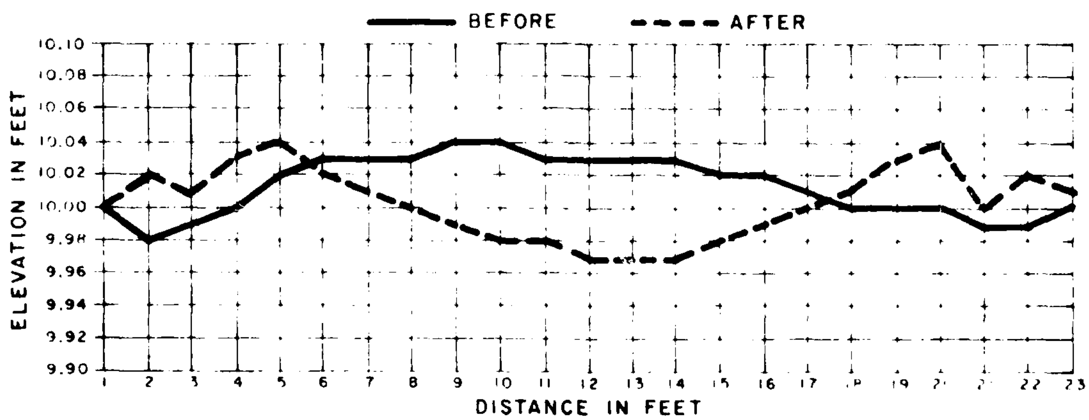
Test data for this concept during testing are shown in Figures 57 through 62. Visual observations during testing are shown in Figures 63 through 77.




**60 COVERAGES**
**F-4**




**150 COVERAGES**
**F-4**




**20 COVERAGES C-141**

Figure 57. Coverages on Side Panel System, F-4 Aircraft and C-141 Aircraft, Base Line A-A

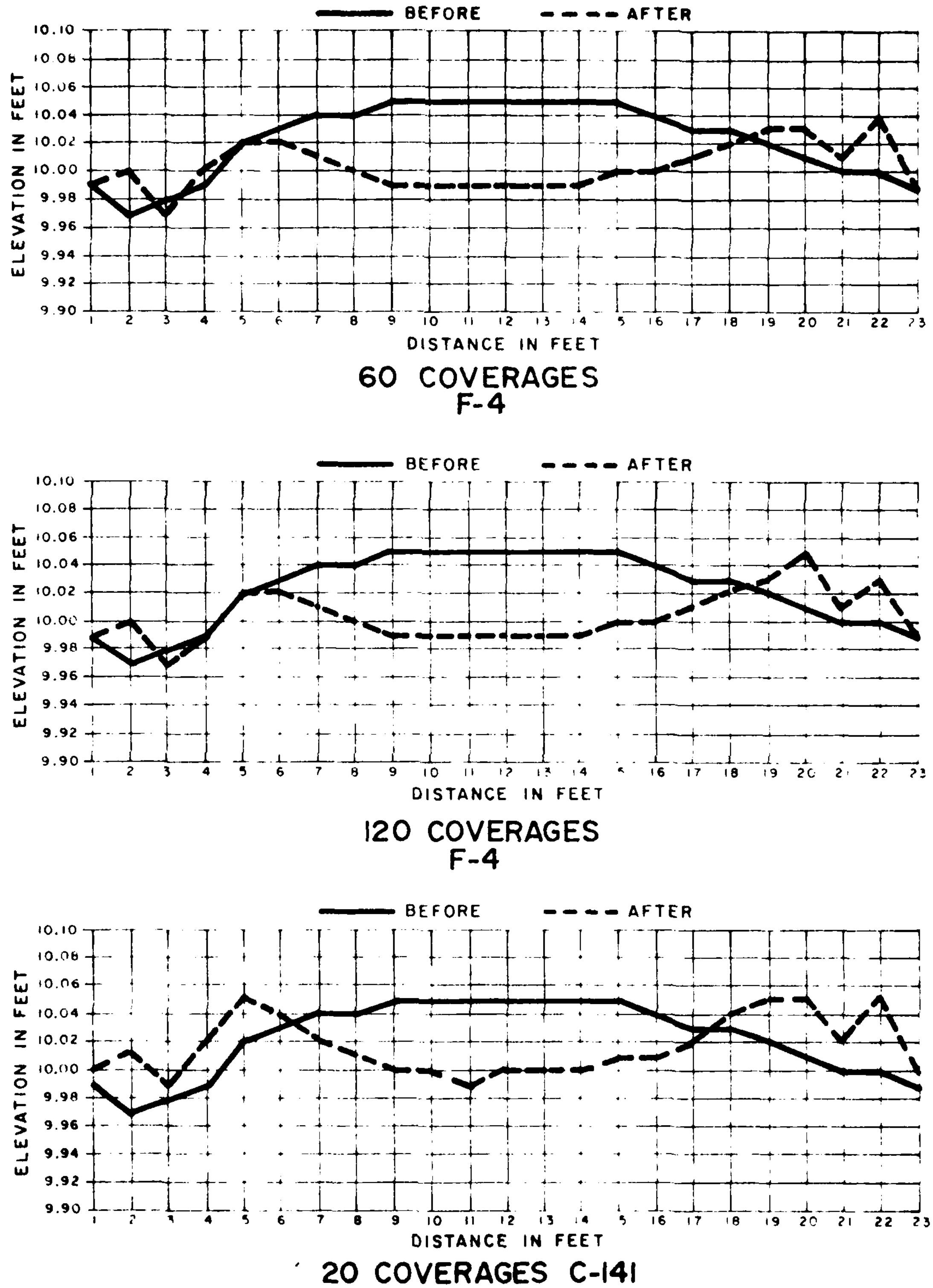
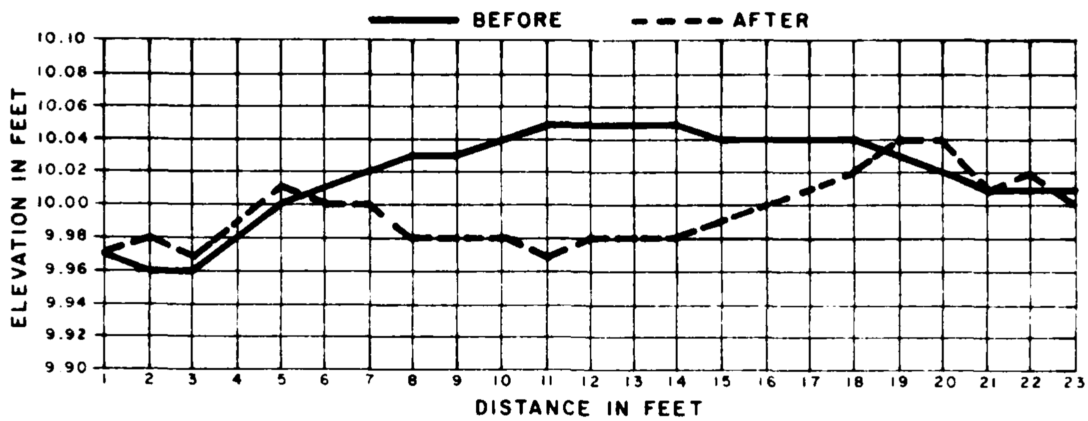
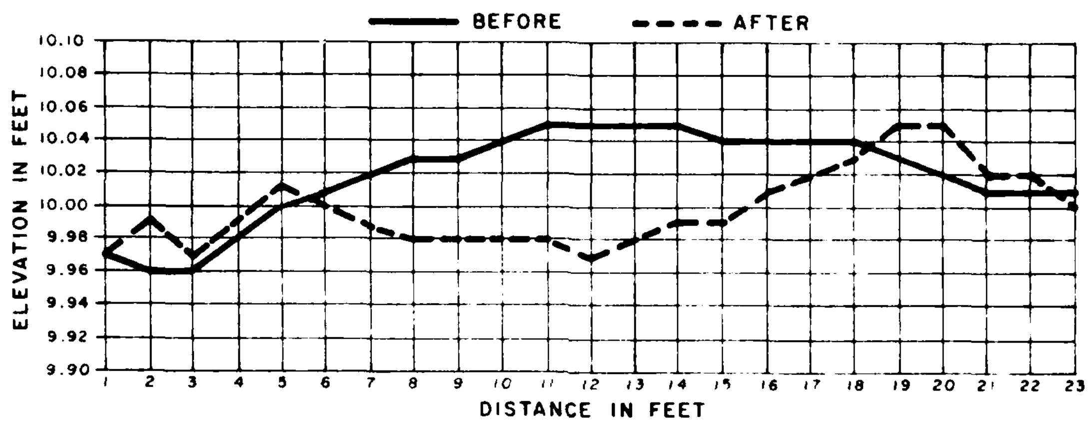


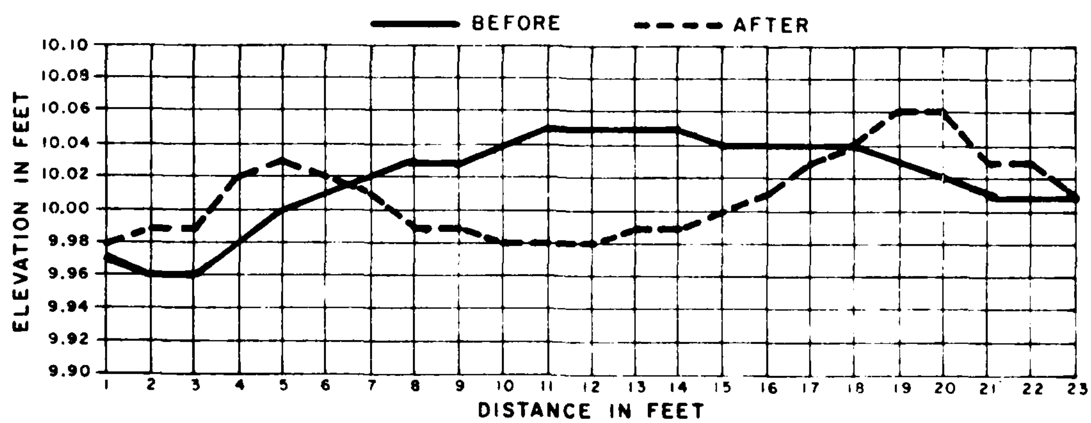

Figure 58. Coverages on Side Panel System, F-4 Aircraft and C-141 Aircraft, Base Line B-B




60 COVERAGES
F-4




150 COVERAGES
F-4




20 COVERAGES C-141

Figure 59. Coverages on Side Panel System, F-4 Aircraft and C-141 Aircraft, Base Line C-C

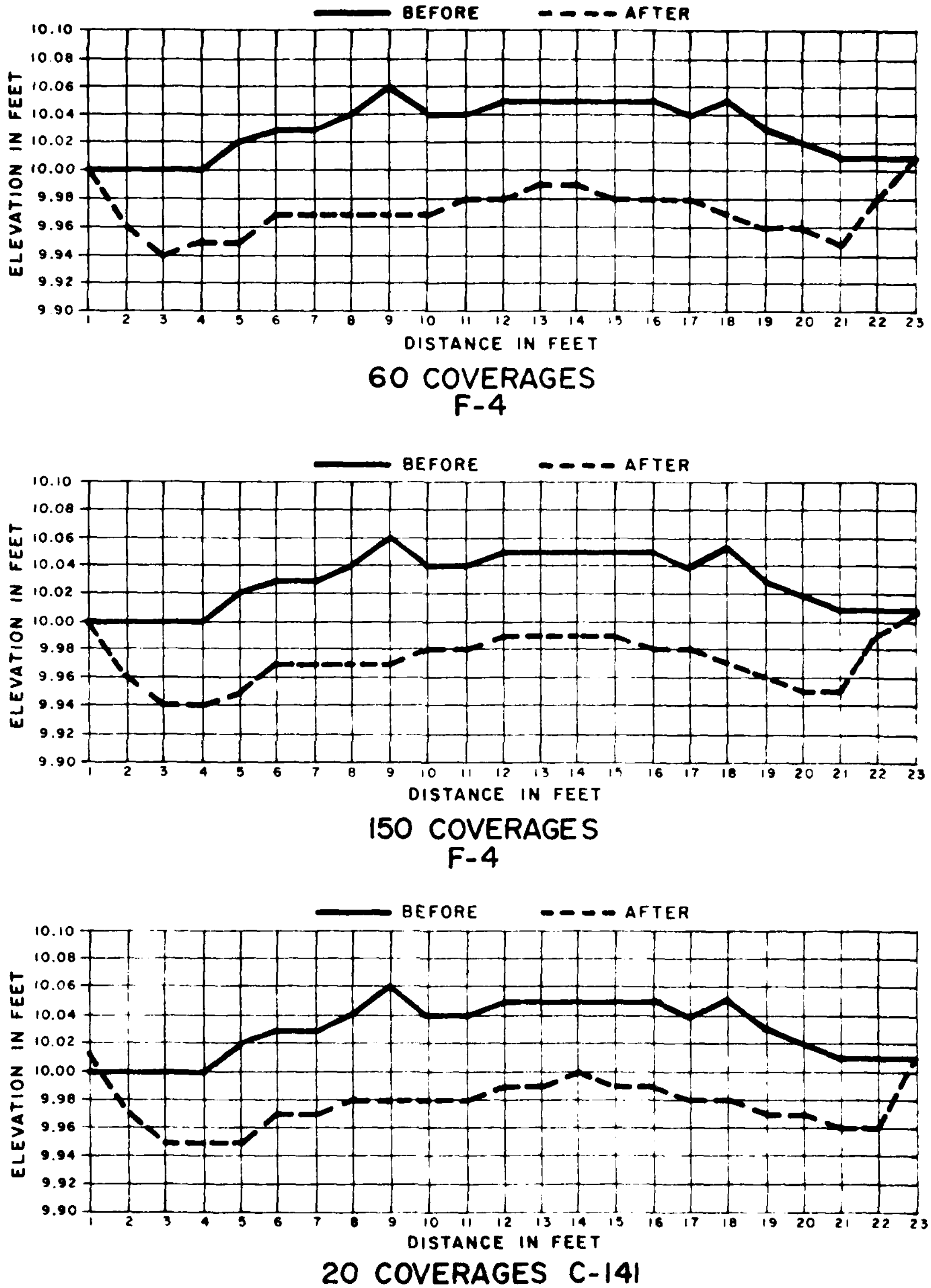



Figure 60. Coverages on Side Panel System, F-4 Aircraft and C-141 Aircraft, Base Line D-D

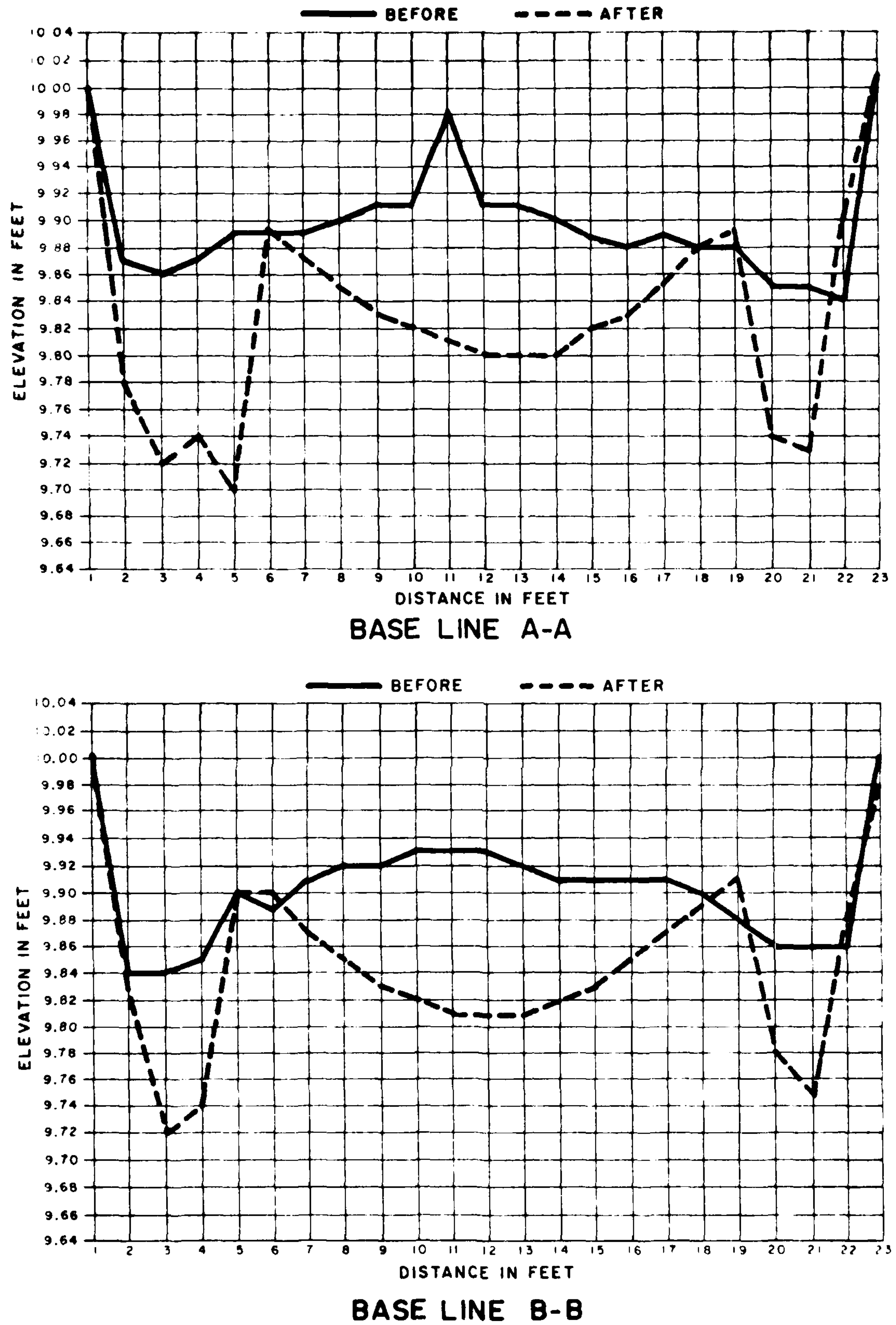
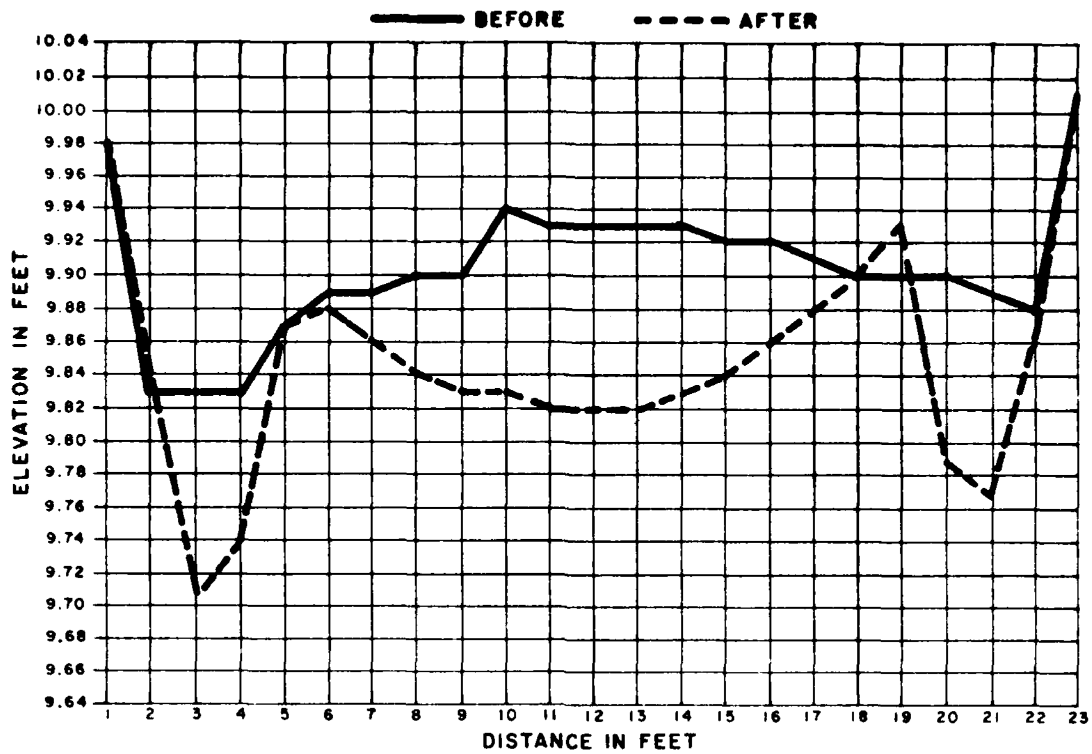
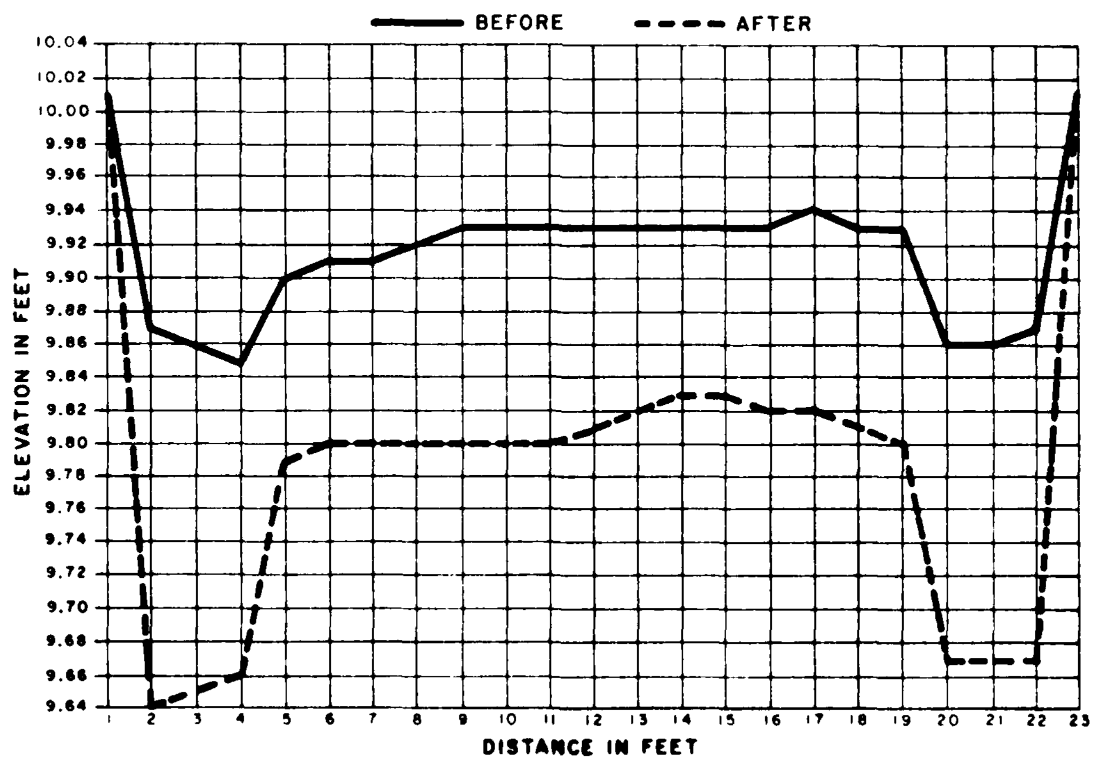



Figure 61. Coverages on Side Panel System, 150 Cov. F-4/20 Cov. C-141, Base Lines A-A and B-B




BASE LINE C-C




BASE LINE D-D

Figure 62. Base Course - Side Rail, 150 Cov. F-4/20 Cov. C-141, Base Lines C-C and D-D

Figure 63. Test 3 (Side Panel)- Installing Locking Assembly to Perimeter of Pits

Figure 64. Test 3 (Side Panel)-Screeding Base Course

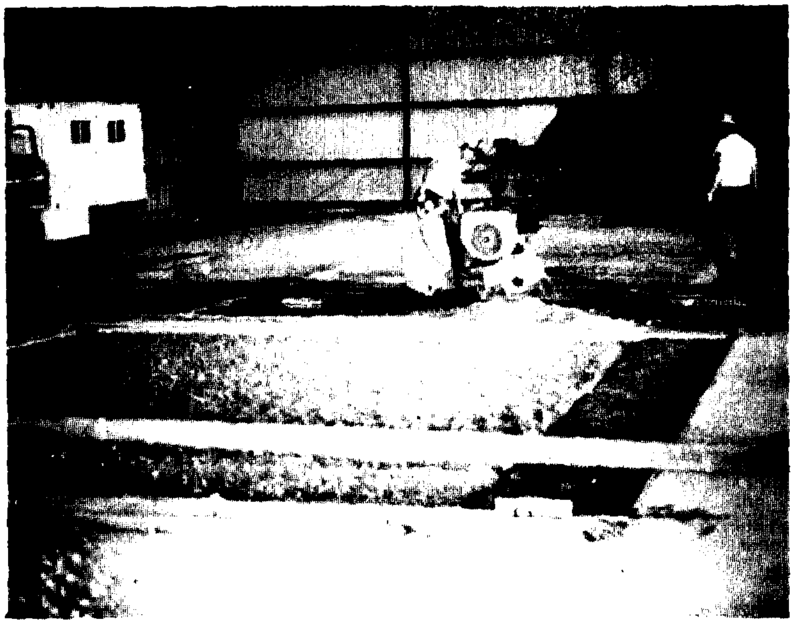


Figure 65. Test 3 (Side Panel)-Placing Bottom AM-2 Panel

Figure 66. Test 3 (Side Panel)-Placing Bottom AM-2 Panel

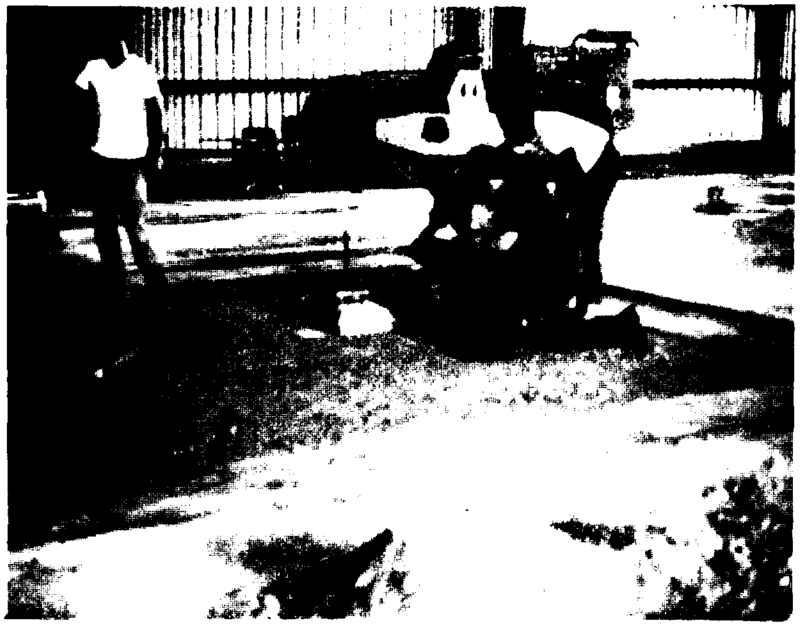


Figure 67. Test 3 (Side Panel) Determining Density With Nuclear Density Device

Figure 68. Test [illegible] (Side Panel)- Installing AM-[illegible] Mat

Figure 69. Test 3 (Side Panel)-
Installing AM-2 Mat

Figure 70. Test 3 (Side Panel)-
Installing Locking Angle

Figure 71. Test 3 (Side Panel)-
Installing Locking Angle

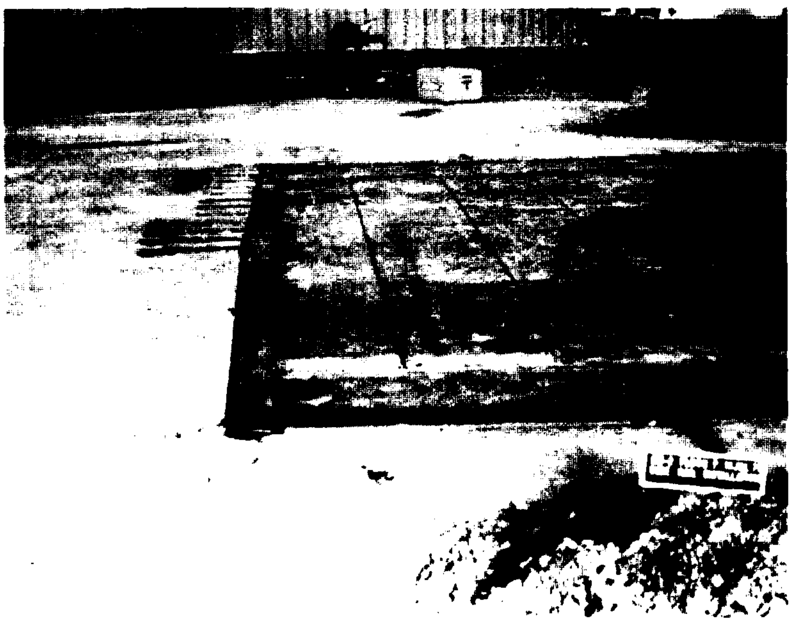


Figure 72. Test (Side Panel)-
Completed Patch

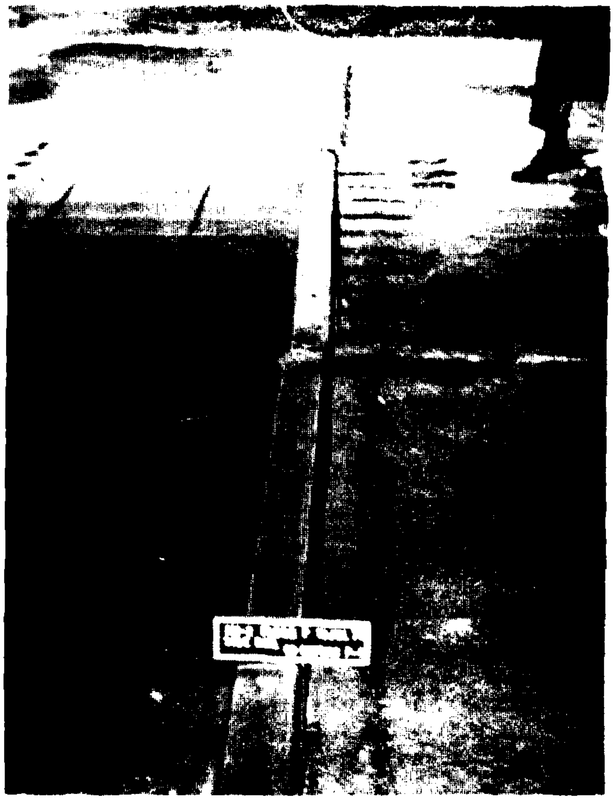


Figure 73. Test [illegible] ([illegible] Panel)-
60 Coverages of F-4

Figure 74. Test [illegible] (Side Panel)-
100 Coverages of F-4

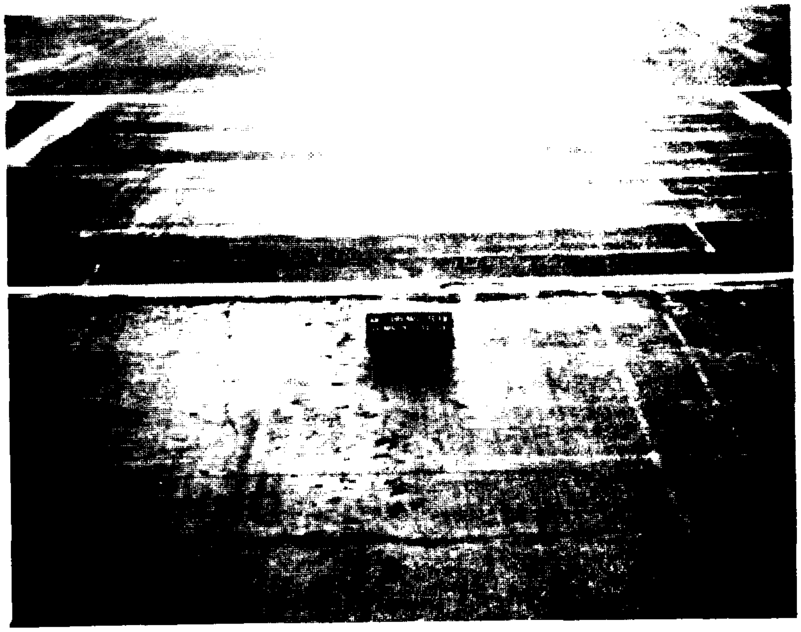


Figure 75. Test 3 (Side Panel)-
150 Coverages of F-4

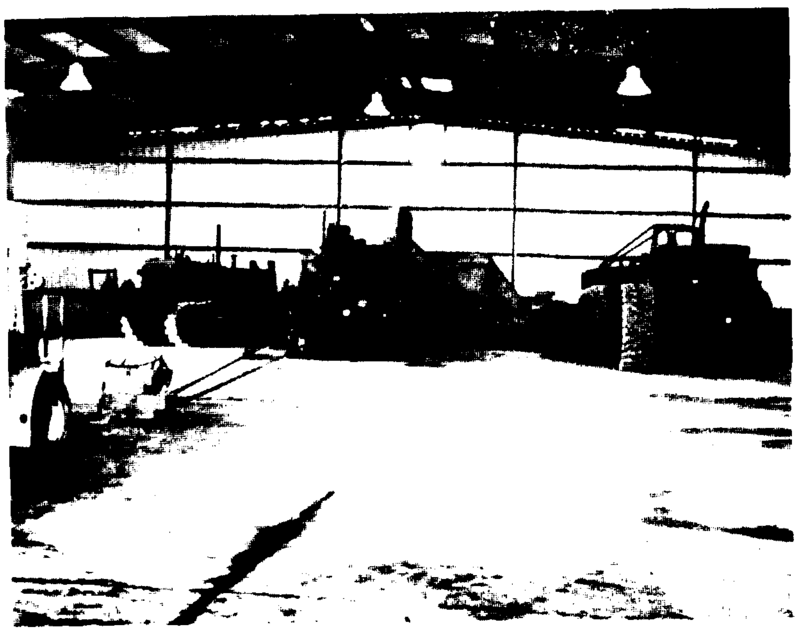


Figure 76. Te[illegible] 3 (Side Panel)-
60-[illegible] Pull Test

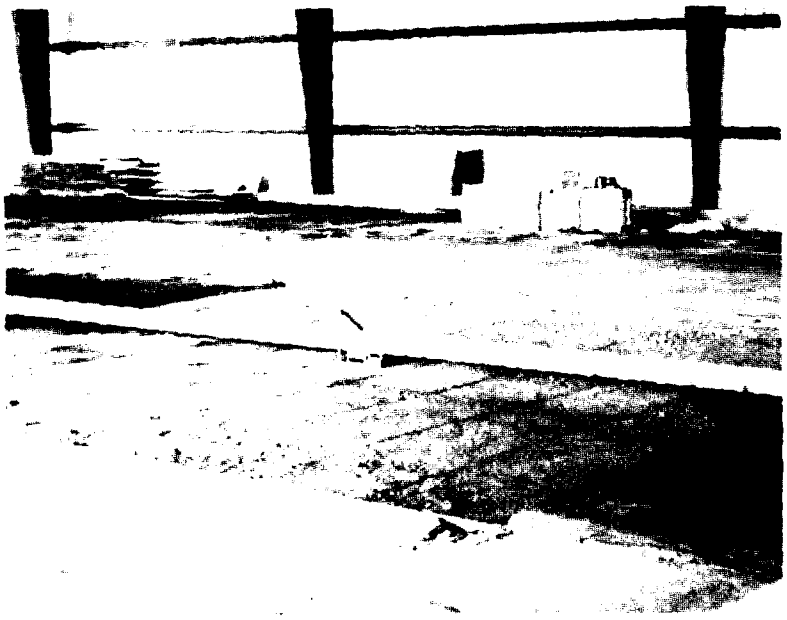


Figure 77. Test 3 (Side Panel)-Base Course
After Testing

## AM-2 FLUSH PATCH TEST 4 (MODIFIED SIDE PANEL SYSTEM)

Testing of this patch began on 9 November 1979. As on test 3, initial surveying and testing were accomplished on the clay core, the locking assembly was explosively nailed to the concrete walls of the pit, and the base course was placed, compacted, and surveyed. The required panels were sawed, the mat assembled and placed in the pit, and the anchoring angle inserted. The projection on the angle had been lengthened from 1/8 inch to 1/4 inch since test 3 and performed satisfactorily during this test. The rubber spacers were not inserted for this test. It took approximately three days to assemble and place the patch and perform the initial surveying and testing.

Considerable consolidation was noted after ten coverages of the F-4 load cart. The side angles were bending towards the center and, as a result, bending the back plate of the locking assembly. After 20 coverages the nails were beginning to pull out. It appeared the base course was being pushed out of the traffic lane and mounding on the sides. At 40 coverages the angle and assembly were experiencing considerable deflections, indicating the nails had pulled out of the concrete. This caused the load cart to bounce as it came off the edge of the concrete. Sufficient deflection had taken place at 60 coverages that the patch was determined to have failed. Observations made during removal of the patch are as follows:

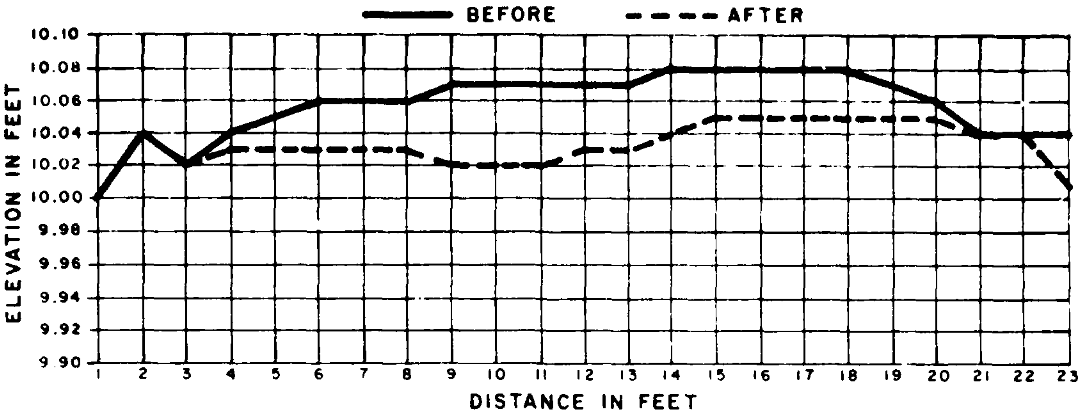
(1) The locking assembly was bent considerably in the traffic lane allowing the angle to be easily removed.

(2) The base course in the traffic lane was well compacted; however, outside the traffic lane the material was very loose.

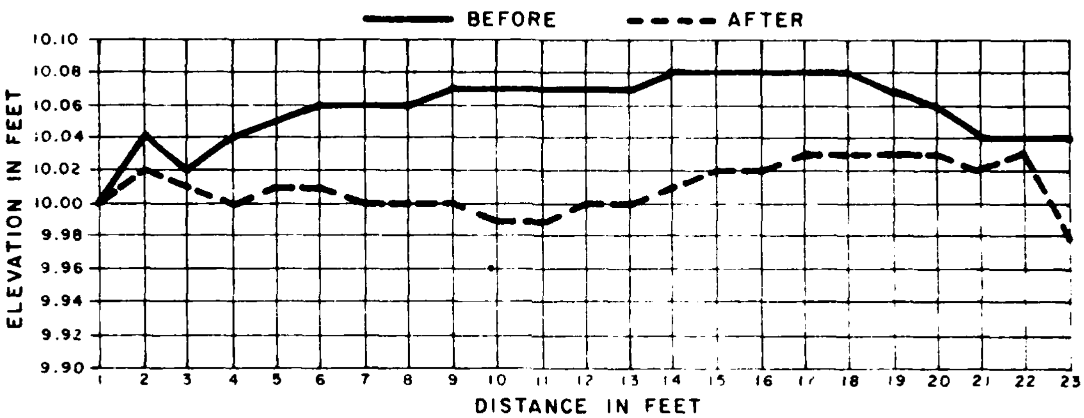
(3) The nails in the traffic lane had broken loose.

(4) The 1/4-inch projection came off the angles as they were being removed.

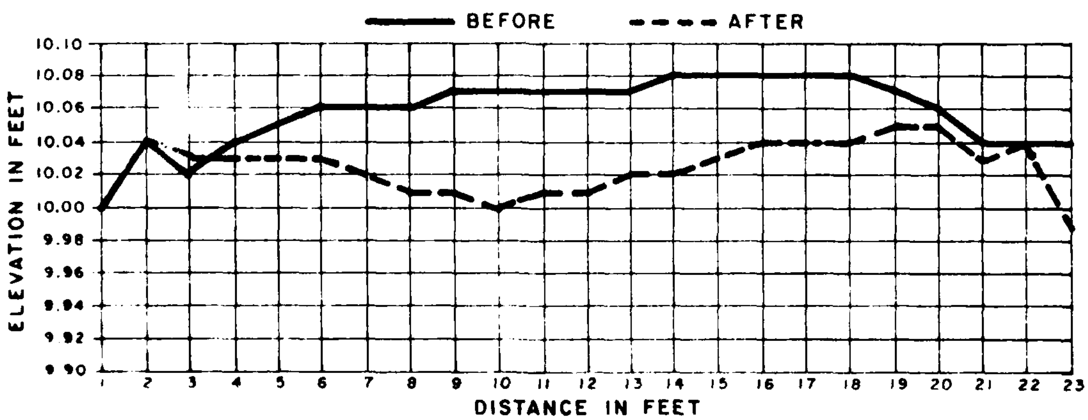
Elevations of the mat and base course after trafficking are shown in Figures 78 through 83. Photographs taken during testing are included as Figures 84 through 91.




20 COVERAGES




40 COVERAGES




60 COVERAGES

[illegible] 4. Coverages on Modified Side Panel System, F-4 Aircraft, Base Line A-A

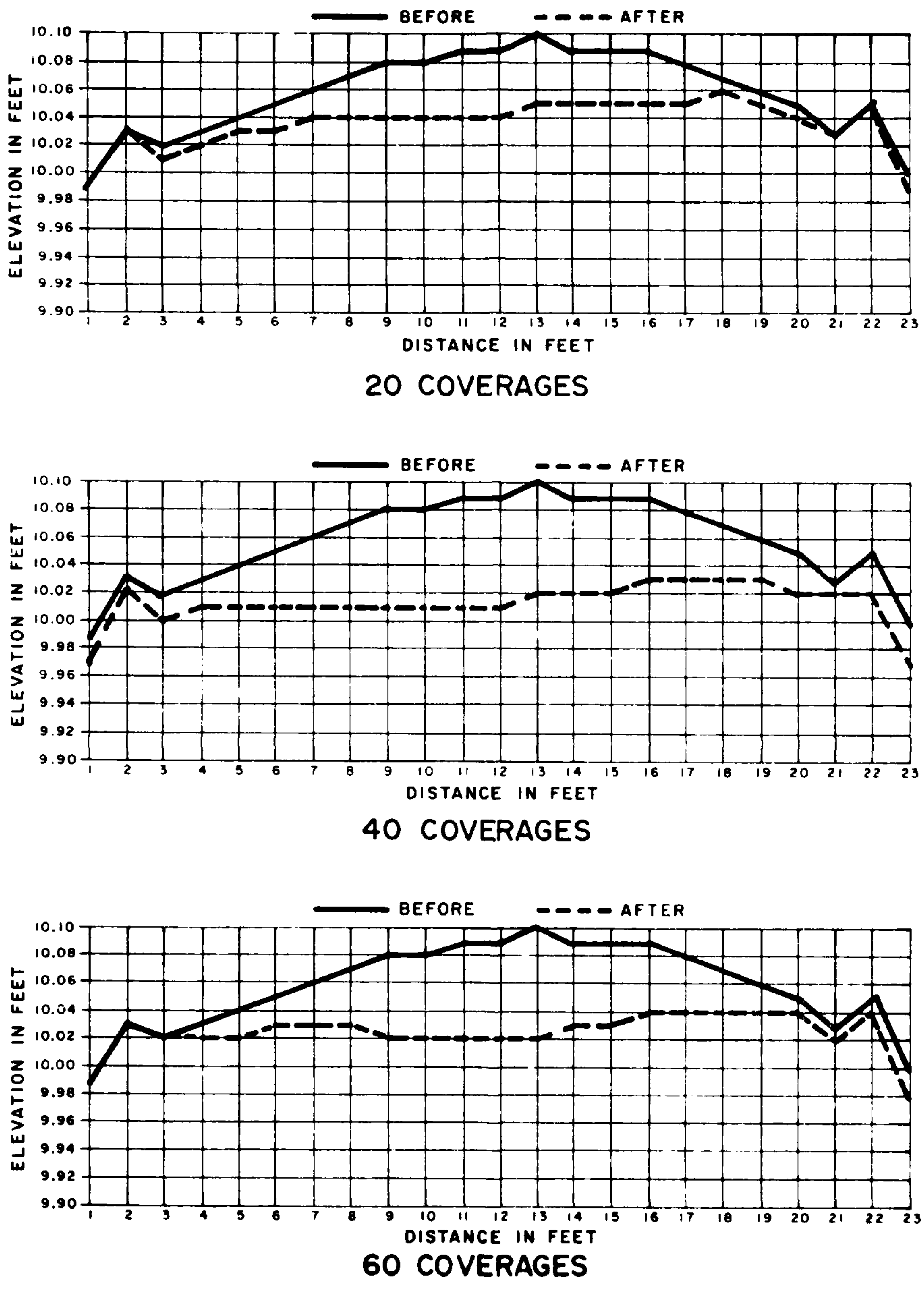



Figure 79. Coverages on Modified Side Panel System, F-4 Aircraft, Base Line B-B

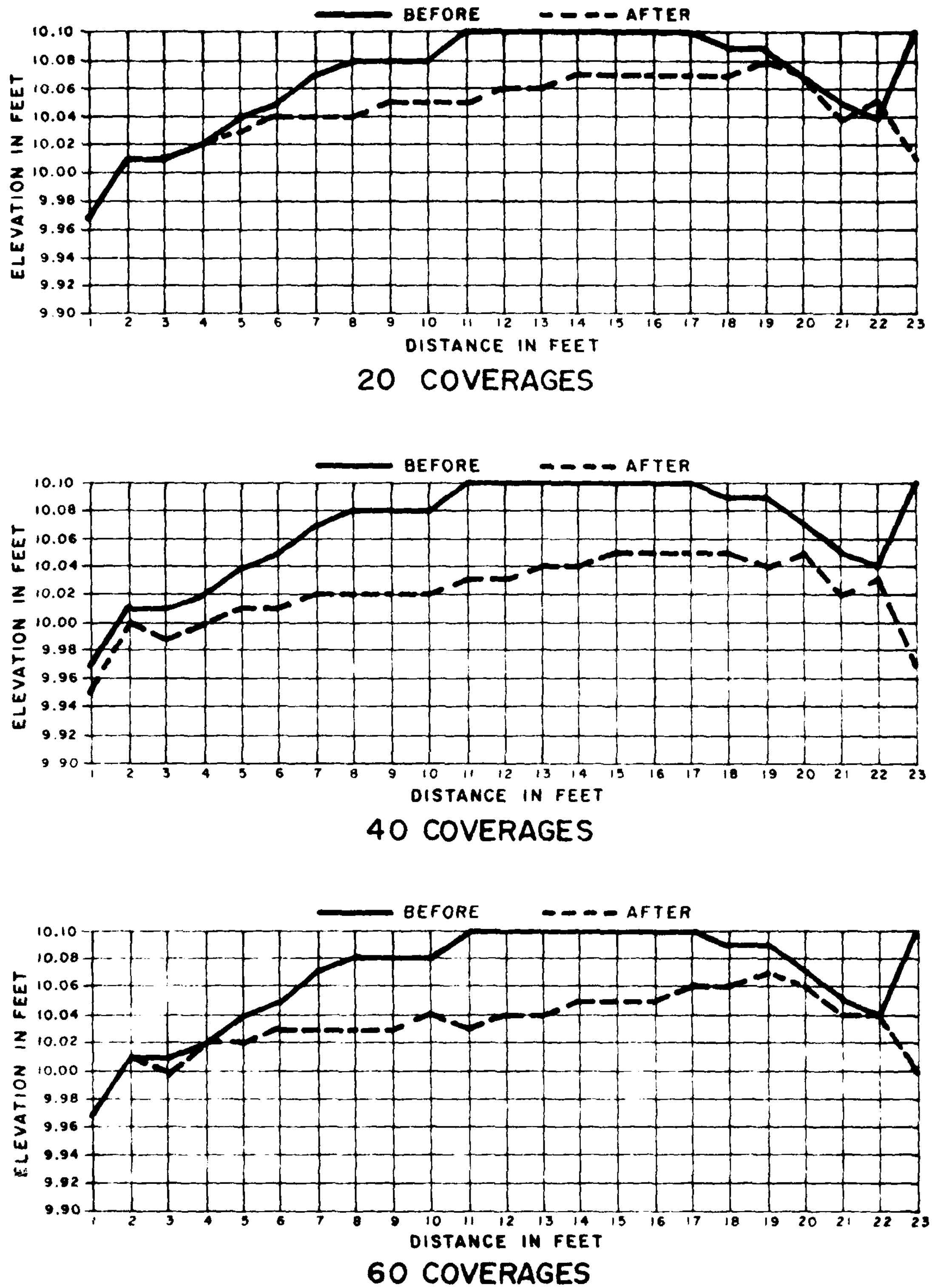
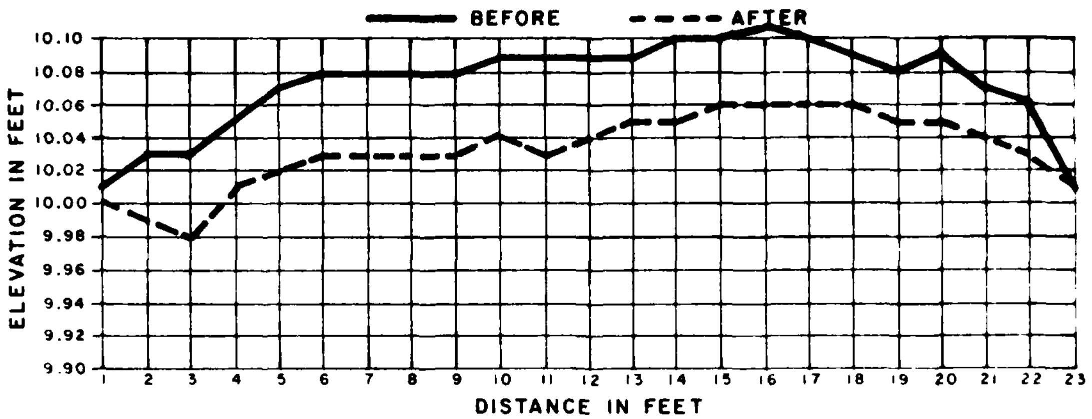
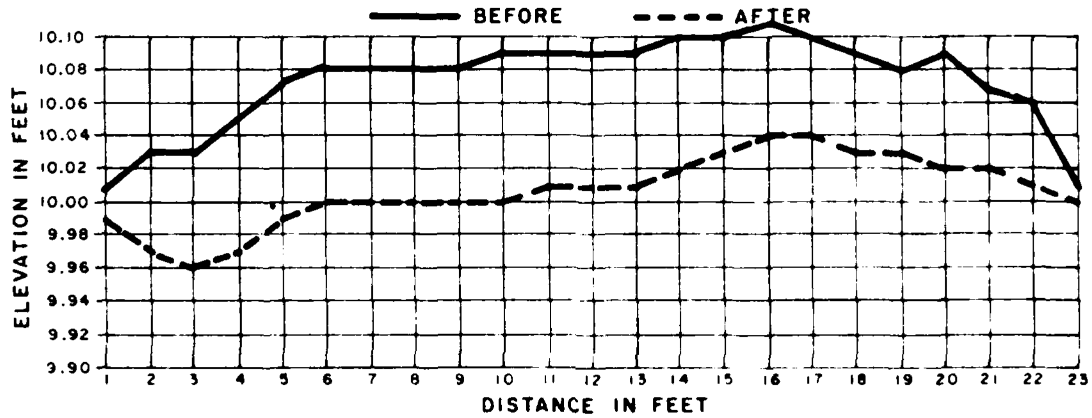


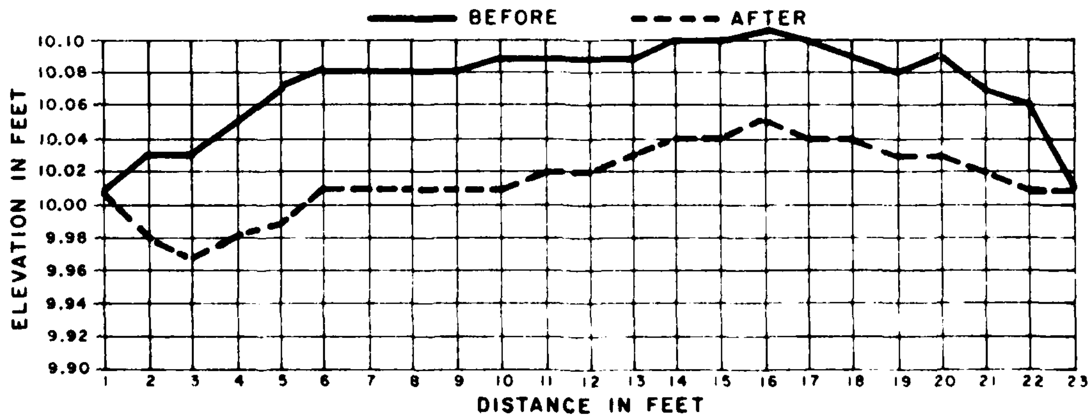

Figure 80. Coverages on Modified Side Panel System, F-4 Aircraft, Base Line C-C




20 COVERAGES

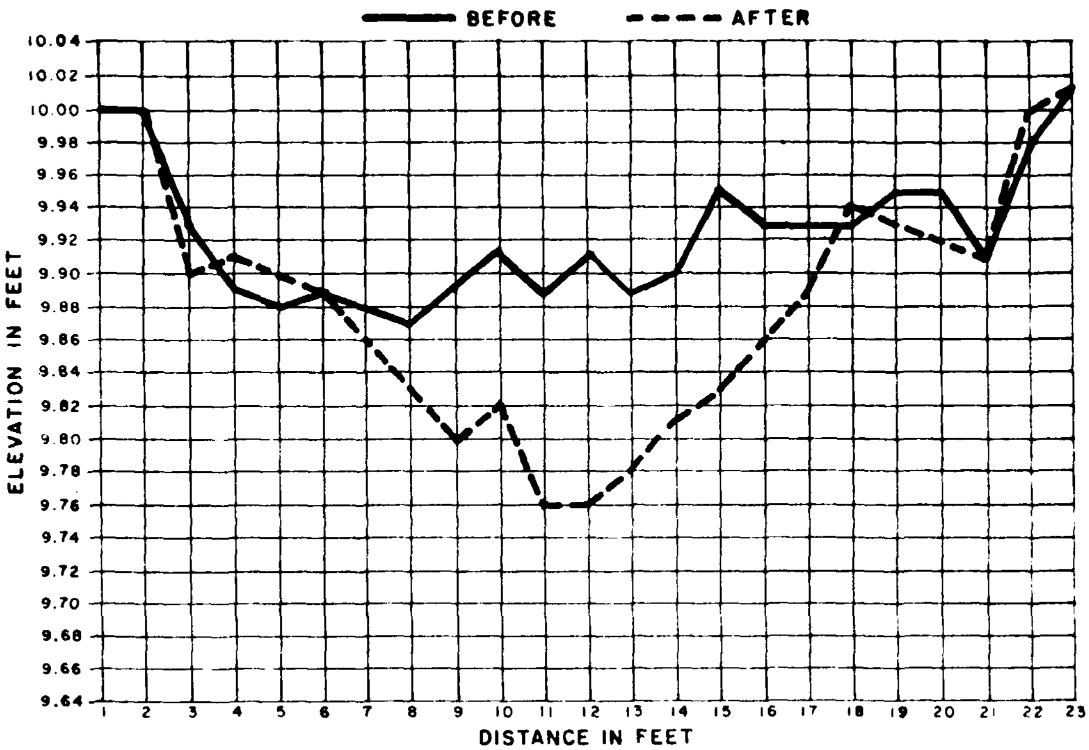



40 COVERAGES

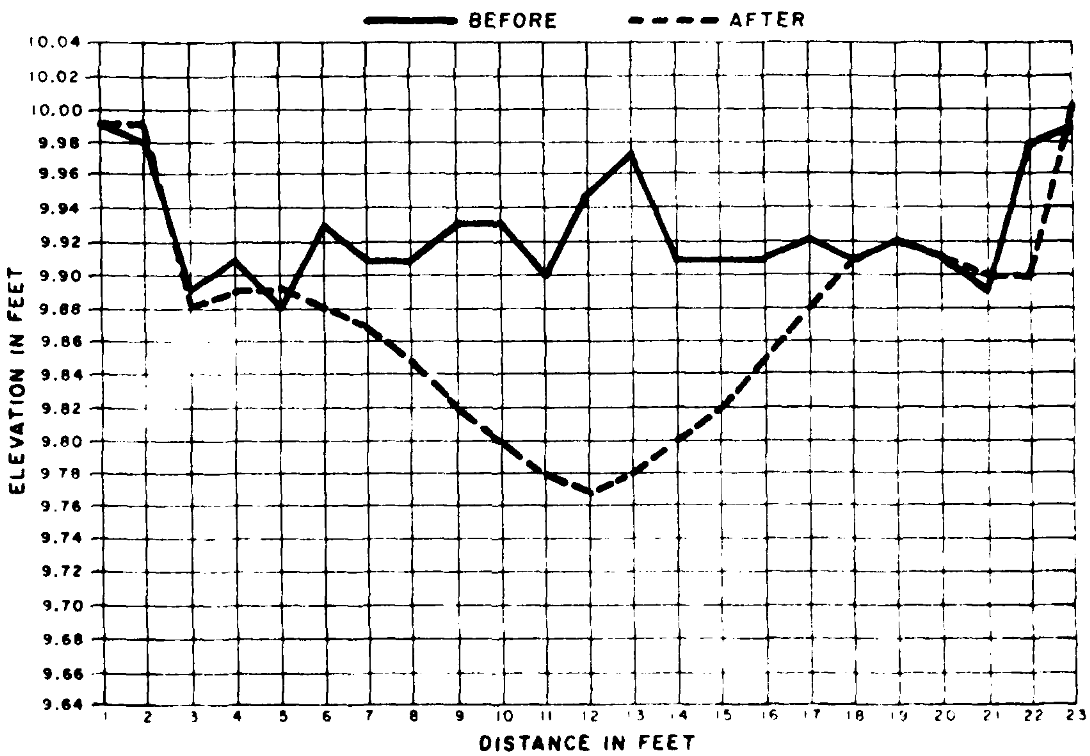



60 COVERAGES

Figure 81. Coverages on Modified Side Panel System, F-4 Aircraft, Base Line D-D

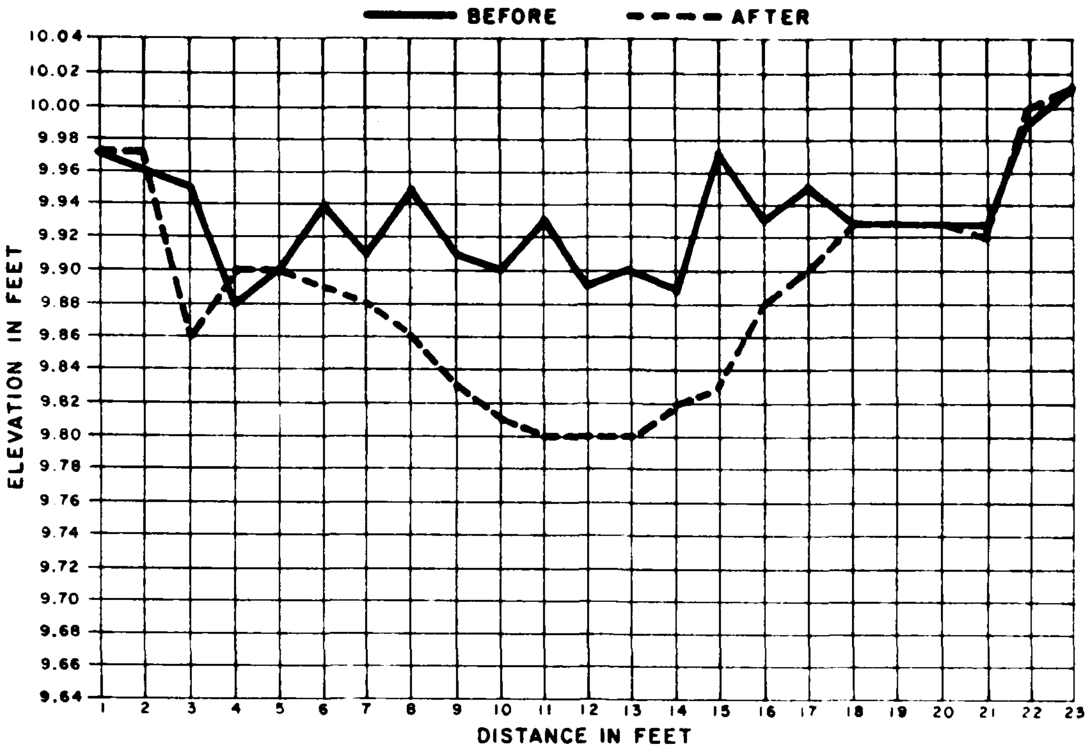



## BASE LINE A-A

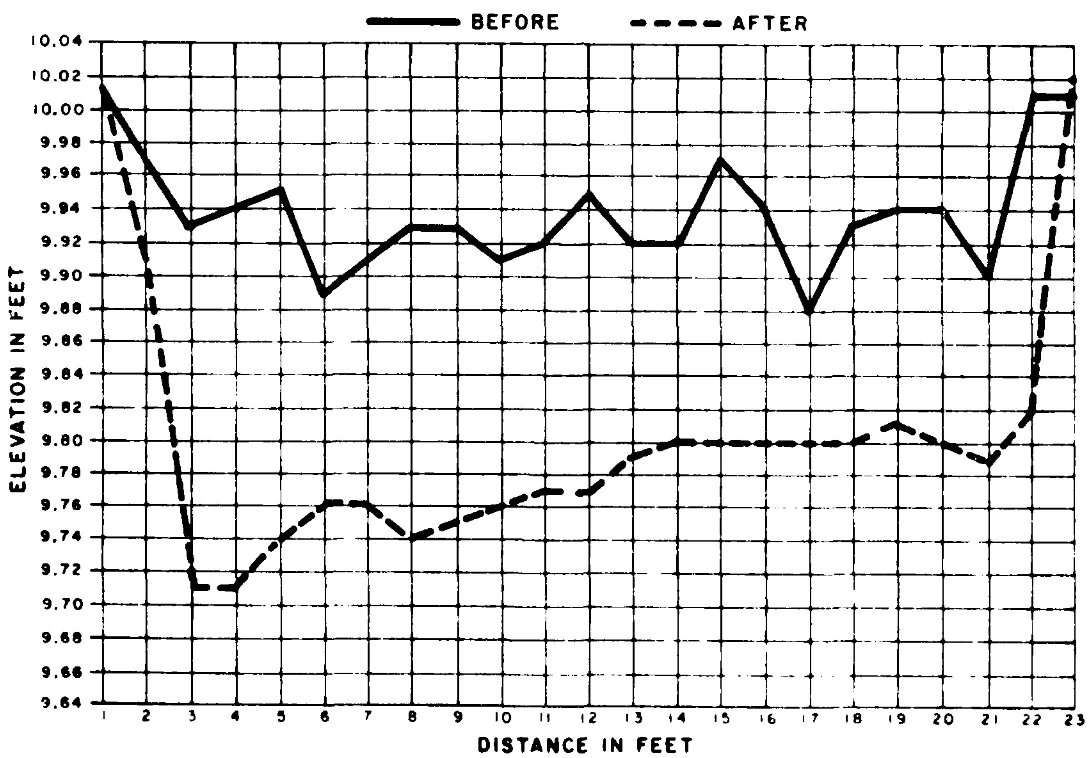



## BASE LINE B-B

Figure 82. Coverages on Modified Side Panel System, 60 Cov. F-4, Base Lines A-A and B-B




**BASE LINE C-C**




**BASE LINE D-D**

Figure 83. Base Course - Modified Side Rail, 60 Cov. F-4, Base Lines C-C and D-D

Figure 84. Test 4 (Modified Side Panel)-
Leveling Base Course

Figure 85. Test 4 (Modified Side Panel)-
Installing AM-2 Mat

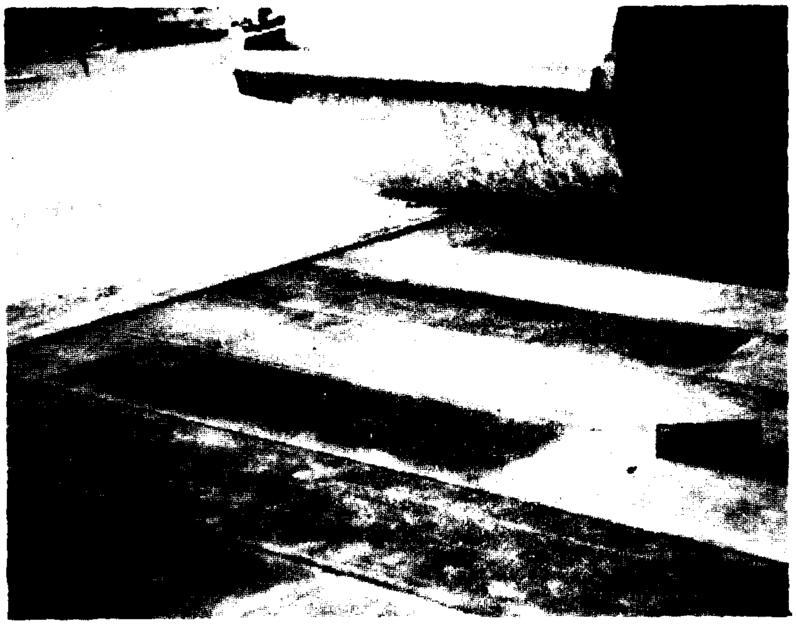


Figure 86. Test 4 (Modified Side Panel)-
Installing Locking Angle


Figure 87. Test 4 (Modified Side Panel)-
40 Coverages of F-4


Figure 88. Test 4 (Modified Side Panel)-
60 Coverages of F-4

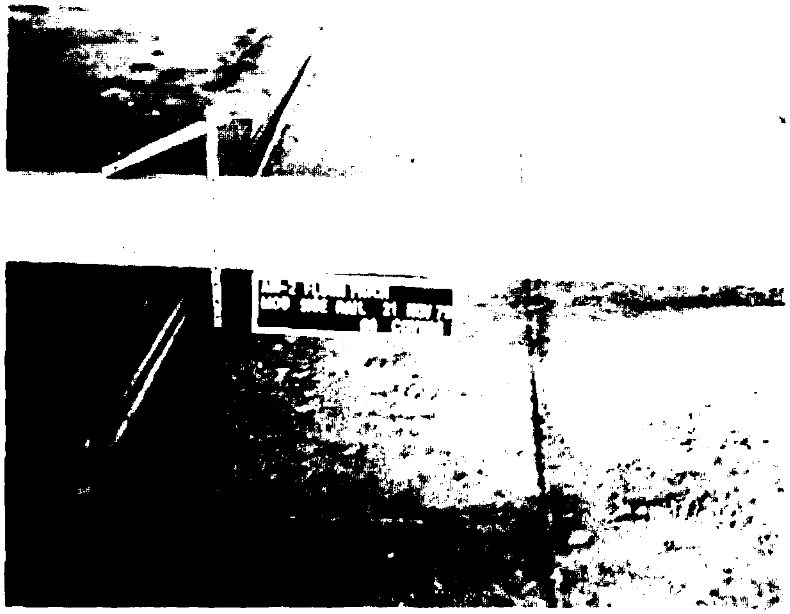


Figure 89. Test 4 (Modified Side Panel)-
60 Coverages of F-4

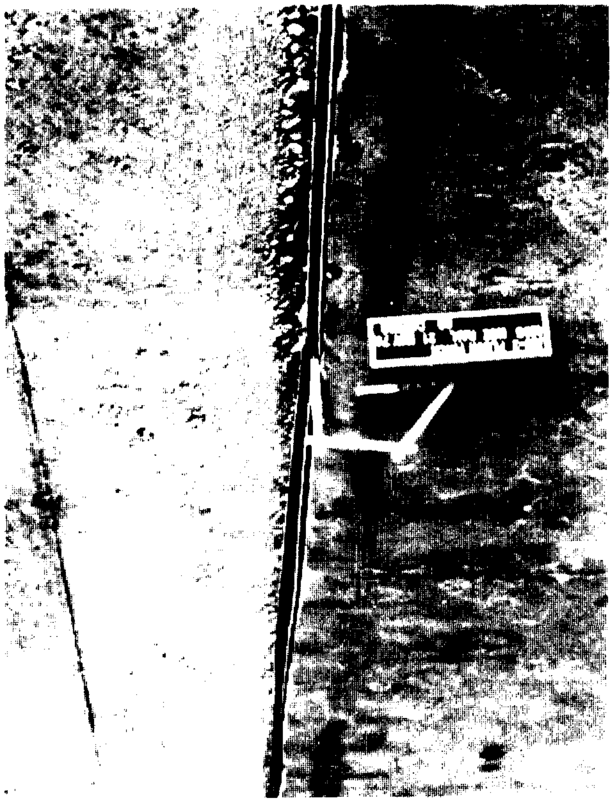


Figure 90. Test 4 (Modified Side Panel)-Deflection of Locking Assembly After 60 Coverages

Figure 91. Test 4 (Modified Side Panel)-Base Course After Testing

## SECTION IV

## CONCLUSIONS

The prototype patches were tested under considerably different conditions than originally designed. The repair system was designed to withstand a minimum of 300 passes of F-4 and 20 passes of C-141 aircraft. The patches were tested with 150 coverages (1440 passes) of the F-4 and 20 coverages of the C-141 or to failure. In addition, a 70,000-pound pull test was included to simulate braking action of the C-141. All of the prototypes met the original trafficking criteria. The side panel system was the only patch on which all planned trafficking was completed without repairing the patch. The 70,000-pound pull test was not completed on this patch due to fastener problems; however, 50,000 pounds was reached before the anchor failed.

It was assumed that a method of rapidly cutting concrete to the specified lateral and vertical tolerance was available. To date, such a method has not been found. Installation of all prototypes was a slow, tedious process. In all cases, considerable time was expended in preparing the crushed limestone at an elevation of 1-1/2 inches below the pavement surface. Actual placement of the mat surface was time consuming because of tolerances and close fittings in the anchoring system. Craters cannot be repaired within the specified time limits using the procedures described in this report.

The sides of the crater used for these tests were portland cement concrete. Thus, the explosively driven nails for the side panels were driven into portland cement concrete. In reality, the surface of most of the runways that may require repairing will be asphaltic concrete. The problems of nails working loose in the portland cement concrete would be severely compounded in asphaltic pavements. The side panel system would not perform satisfactorily in asphaltic concrete surfaces.

The systems tested did not all fail the specified traffic criteria. Problems, however, were encountered. Due to these problems (excessive repair time, special material requirements, complexity of crater preparation and mat assembly/installation, lack of rapid, accurate concrete cutting procedures) and the envisioned problems with asphalt runways, it is concluded that the flush AM-2 patch system is not presently feasible for use in rapid runway repair.

# SECTION V

## RECOMMENDATIONS

It is recommended that further investigation of the flush AM-2 patch system for use in rapid runway repair not be considered unless substantial progress is made in three areas:

1. Rapid and accurate cutting of portland cement concrete and asphalt-covered portland cement concrete.

2. Rapid and accurate leveling of crushed stone 1-1/2 inches below the surrounding surface.

3. Repair kits that are much faster to install.

## INITIAL DISTRIBUTION

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| HQ USAFE/DEMY | 2 |
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| HQ AFLC/DEE | 1 |
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