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NORTH FIELD '87 RAPID RUNWAY REPAIR TEST REPORT VOLUME I

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FINAL REPORT

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The North Field 87 Rapid Runway Repair Test, conducted ~~24 August through 4 September 1987~~ at North Field SC, was a concurrent Developmental Test and Evaluation (DT&E) and Initial Operational Test and Evaluation (IOT&E) of four Rapid Runway Repair Systems.

The DT&E portion of the test consisted of a Folded Fiberglass Mat Test and an Upheaval Measurement Test. The Folded Fiberglass Mat Test evaluated the performance of a folded fiberglass mat under aircraft trafficking. Two explosively formed craters were repaired with polyester folded fiberglass mats and trafficked with a maximum of 110 combined F-15 and F-16 aircraft passes. One mat was instrumented to record mat and anchor bolt loads during aircraft trafficking. Instrumentation results are reported in Volume II. Mat anchoring, hinge orientation, and mat reaction to jet blast were also examined. The upheaval measurement test evaluated three methods of determining upheaval. The standard stringline, modified stringline, and Dipstick pavement profiler were evaluated for speed and accuracy. (continued)

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The IOT&E tests, including the Hand-Mixed Polymer Spall Repair Test and the Minimum Operating Strip Marking Test, were conducted by the United States Air Force Tactical Air Warfare Center. IOT&E results are reported by USAFTAWC in Rapid Runway Repair (RRR) Subsystems for MOS Marking and Hand-Mixed Polymer Spall Repair (TAC Project 87C-068T), dated November 1987. Reliability and maintainability results from thesetests, as well as training results, are documented in this report.

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EXECUTIVE SUMMARY

The North Field 87 Rapid Runway Repair (RRR) Test was conducted 23 August through 4 September 1987 at North Auxiliary Field, North, South Carolina, a Military Airlift Command (MAC) training field operated by Charleston AFB.

The overall test was a combined effort of the Air Force Engineering and Services Center (AFESC), responsible agency for Development Test and Evaluation (DT&E); and the USAF Tactical Air Warfare Center (USAFTAWC), responsible agency for Initial Operational Test and Evaluation (IOT&E). The DT&E and IOT&E were independent tests, conducted concurrently for economy of test resources.

A. PURPOSE

The North Field 87 Test consisted of DT&E of the Folded Fiberglass Mat (FFGM) Crater Repair System and the Upheaval Measurement System, and IOT&E of the Minimum Operating Strip (MOS) Marking and Hand-Mixed Polymer Spall Repair Systems. The FFGM Test was conducted to evaluate the performance of two polyester folded fiberglass mats over a crushed stone crater repair. The Upheaval Measurement Test was conducted to compare the capabilities of the Dipstick and the standard and modified stringline and to evaluate their performance based on speed and accuracy.

IOT&E was conducted to evaluate the operational effectiveness and suitability of the MOS Marking and Spall Repair Systems. Results are reported by USAFTAWC in <u>Rapid Runway Repair (RRR) Subsystems for MOS Marking and Hand-Mixed Polymer Spall Repair, IOT&E Final Report</u> (TAC Project 87C-068T), November 1987.

B. TEST DESCRIPTION

Two explosively formed craters, with repair diameters of 45 and 48 feet, were repaired with crushed stone according to procedures established in <u>HQ AFESC RRR Interim Guidance</u>, 1984. The repairs were not timed.

One mat was instrumented to record mat and anchor bolt loads during aircraft trafficking. (Mat instrumentation results are reported separately in Volume II.) The instrumented mat, oriented with hinges parallel to the runway centerline, was anchored using 5/8-inch diameter anchor bolts and 4-inch diameter bushings, along with sixteen 1 1/4-inch diameter instrumented anchor bolts and 4-inch diameter bushings. The second mat, oriented with its hinges angled 4 degrees from the runway centerline, was fabricated with slotted anchor holes and was anchored using 3/4-inch diameter anchor bolts and 5-inch diameter bushings. Each mat was subjected to a range of trafficking, including taxi, takeoff, and touch-and-go operations, and a 30-second sustained engine run-up at 80 percent military power with the aircraft 50 feet from the mat.

The Upheaval Measurement Test originally was planned to evaluate three methods of determining crater upheaval: a standard stringline, consisting of a stringline pulled taut between two wooden guideposts; a modified stringline, consisting of a cable pulled taut between two metal stands; and a Dipstick pavement profiler (an electronic leveler). Because of an equipment problem with the modified stringline, only the Dipstick and standard stringline were tested at North Field. However, the test objectives for the modified stringline subsequently were completed at Det 2, Field 4, Eglin AFB, FL, in October 1987.

The Upheaval Measurement Test was conducted in conjunction with the crater repair. An accurate baseline upheaval boundary was established using rod-and-level measurements, then the upheaval was measured with each candidate device. Results from candidate devices were compared to the results from the baseline survey.

C. TEST RESULTS

Results from each test are presented by test objective.

1. FFGM Test

a. Objective 1: Evaluate the performance of a crushed stone repair covered with a commercially produced, hinged, fiberglass mat.

Crater 1 supported 108 aircraft trafficking passes, while Crater 2 sustained 110. Each repair remained within established surface roughness limits and did not require maintenance necessitating mat removal. There was no loss of anchors, no foreign object damage (FOD) generated, and no permanent mat deformation.

A tear in Mat 2, exposing mat delamination, was observed after the 69th pass. The area was repaired with the mat in place, and trafficking continued. An inspection of the mat problem revealed that the delaminated area was not thoroughly saturated with resin during manufacturing.

b. Objective 2: Compare anchor bolt loads and mat strains to those predicted by mat analysis.

A survivable mat instrumentation system was developed and implemented, with 39 of the original 48 instrumentation channels operating at the end of the test. However, excessive signal noise and tape recorder failures hampered data collection and limited mat strain gauge data. Maximum measured east-west horizontal anchor bolt loads for different F-15 aircraft ground operations from 30 selected events were recorded as follows:

1.	Taxi with hard braking	4,300 pounds
2.	Take off with afterburner	3,870 pounds
3.	Touch and go without afterburner	1,400 pounds
4.	Air blast 80-percent engine run-up	2,650 pounds (1 to 2-second duration)

Volume II of the test report details the mat instrumentation effort.

c. Objective 3: Compare the rutting performance of a crater repair with mat hinges parallel to the MOS centerline to that of a mat skewed 3 to 4 degrees off the MOS centerline.

Both repairs remained within surface roughness limits. There was no significant difference in rutting between the two repairs.

d. Objective 4: Evaluate anchor bushings' ability to remain tight, and compare the performance of standard and modified bushings.

The standard bushings on Mat 1 did not require tightening until Pass 61, when a maximum of 13 bushings (2 anchor and 11 joining) required tightening. Nine modified bushings on Mat 2, however, required tightening after Pass 13. For Mat 2, the number of loose bushings ranged from two to nine for all but one measurement interval. Angled bolt holes and improper seating of the bushings are suspected causes of the loosening.

e. Objective 5: Measure bow wave amplitudes, and compare the amplitude of bow wave on the standard mats versus the slotted and skewed mats.

The bow wave phenomenon, seen in earlier mat tests with larger aircraft, was not evident at North Field. Bow waves on the mats were not observed by repair monitors, nor were they indicated on high-speed film.

f. Objective 6: Appraise the adequacy of the mat anchoring system during loadcart and aircraft trafficking.

Under all conditions, both anchoring systems worked well. No bolts or bushings pulled out or broke free. The mats remained securely anchored to the pavement.

g. Objective 7: Appraise the mat's structural integrity and the anchoring system's adequacy during exposure to jet blast from engine run-ups by F-15 and F-16 aircraft.

During this test, only the F-15 was used because it represented the worst-case aircraft available for the test. Each mat was exposed to engine run-up at 80 percent military power, with the aircraft located 50 feet from the trailing edge. Approximately 10 seconds of exposure time was recorded for Mat 1 and 30 seconds for Mat 2. No effects were observed on either mat during the 80-percent run-ups. Each mat remained intact and firmly anchored.

2. Upheaval Measurement Devices Test

a. Objective 1: Determine the absolute accuracy of the standard stringline, the modified stringline, and the Dipstick upheaval measurement methods.

None of the devices was consistently able to measure upheaval to within the test criteria. Although the devices remained within the vertical accuracy criteria (3/4 inch), horizontal accuracies were off by as much as 8 feet.

b. Objective 2: Identify each method's repeatability.

A statistical analysis of initial measurements for the Dipstick and of intermediate measurements for the standard and modified stringlines shows that none of the devices gave repeatable results.

c. Objective 3: Determine the absolute measurement time, and compare each of the three tested method's measurement times.

Both the standard and modified stringlines met the 10-minute initial measurement time criterion, as well as the 15-minute intermediate measurement time criterion.

The Dipstick met the 10-minute criterion, when only accumulated profiling time is reported. Total operational time, including equipment setup and changing profile lanes, was not included because onsite instruction was given between measurements. Intermediate times were not taken for the Dipstick.

D. CONCLUSIONS AND RECOMMENDATIONS

1. FFGM Test

a. Conclusions

Overall, the FFGM Repair System exceeded minimum performance requirements. Each repair sustained more than 100 aircraft trafficking passes, remained within surface roughness tolerance limits, and did not require maintenance necessitating mat removal. The commercially manufactured, hinged fiberglass mats performed well. Mat 1 did not exhibit permanent deformation (tears, rips, etc.,) or delamination. Mat 2 also performed well, with the exception of a 2- to 3-foot tear (which was easily repaired) and minor delamination.

Hinge orientation had no significant effect on repair performance.

In general, the anchoring system held the mats solidly throughout the test, and no anchor bolt damage was reported. However, each type of bushing loosened often, with the conventional bushings holding longer than the modified bushings. The modified bushings also performed below the acceptable test criterion of 30 passes before requiring tightening.

b. Recommendations

(1) Additional testing should be conducted on both hinge orientation and the mat anchoring system.

(2) The effects cf hinge orientation on rutting should be examined in a more controlled environment.

(3) Further tests should be conducted to determine, under controlled conditions, the effects of angled bolt holes on bushing tightness. If warranted, use of a drill guide should be investigated.

2. Upheaval Measurement Test

a. Conclusions

Although none of the measurement devices consistently met the criterion for horizontal accuracy, all but four elevation measurements were within the 3/4-inch vertical upheaval tolerance. Test results show that none of the three devices gave repeatable results. Both stringlines met the 10-minute initial and 15-minute intermediate measurement criteria. For the Dipstick, the reported time for each profile, plus additional setup time, indicated that it would exceed the time criterion.

b. Recommendations

(1) Revise the procedures for the modified stringline to initially measure upheaval in a line parallel to traffic, rather than in a triangular pattern around the crater.

(2) Concentrate on future development and testing of the modified stringline, with emphasis on improved accuracy.

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PREFACE

This report was prepared by the BDM Corporation, 7915 Jones Branch Drive, McLean, Virginia 22101, under Contract F08635-84-C-0185, for the Air Force Engineering and Services Center, Rapid Runway Repair Program Office, Tyndall Air Force Base, Florida.

The performance period for this effort was 24 August to 4 September 1987. The AFESC/YER test director was Mr. Perry Dukes.

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This report has been reviewed and is approved for publication.

Perry E. Dukes

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Project Engineer

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SECTION I

INTRODUCTION

A. PURPOSE

As part of the U. S. Air Force's continuing program to develop systems and procedures for Rapid Runway Repair in a postattack environment, the Air Force Engineering and Services Center (RRR AFESC) and the USAF Tactical Air Warfare Center (USAFTAWC) jointly conducted the North Field '87 Rapid Runway Repair Test. The test was held at North Auxiliary Field, North, South Carolina, between 24 August and 4 September 1987.

The overall test purpose was the concurrent Development Test and Evaluation (DT&E) and Initial Operational Test and Evaluation (IOT&E) of several RRR subsystems. Four RRR systems were tested: (1) Folded Fiberglass Mat Crater Repair, (2) Crater Upheaval Measurement, (3) Hand-Mixed Polymer Spall Repair, and (4) Minimum Operating Strip (MOS) Marking. AFESC conducted DT&E of the Folded Fiberglass Mat (FFGM) Crater Repair System and of three methods for measuring crater upheaval. USAFTAWC conducted IOT&E of the Hand-Mixed Polymer Spall Repair System and the MOS Marking System.

B. BACKGROUND

1. Folded Fiberglass Mat Crater Repair

The FFGM crater repair consists of a crushed stone base course covered with a FFGM anchored to undamaged runway pavement with anchor bolts. Initial testing of the fiberglass mat repair system with F-4 aircraft was conducted in 1983 at North Field. The fiberglass mat concept was proven at the Air Base Survivability Capability Demonstration (SALTY DEMO) at Spangdahlem Air Base, Germany, in 1985. During the demonstration, 50- by 60-foot rigid polyurethane mats were installed over the repairs and were trafficked by operational fighter aircraft, including F-4s, F-15s, and A-10s. At RAF Wethersfield, England, folded mats, consisting of polyurethane panels connected with a flexible hinge material to allow the mat to be folded for easier packaging and transportation, were installed and were tested by C-5 and C-141 aircraft trafficking.

After the Wethersfield Test, numerous developmental tests were conducted at Tyndall AFB, Florida, to improve the folded mat system. The tests included examining hinge orientation and the performance of the anchoring system. The mats were trafficked with a loadcart.

The Crater Repair Test at North Field '87 was conducted to examine the performance of the folded mat system under fighter aircraft traffic. The dynamics of aircraft traffic were required to examine bow wave and other phenomena observed during trafficking in previous tests. One mat was instrumented to determine the dynamic loads experienced by the mats during trafficking.

2. Upheaval Measurement

Since 1985, AFESC has been investigating methods of determining crater upheaval that are rapid, yet more accurate than the stringline method now employed (RRR Interim Guidance, September 1984). Two alternative methods of upheaval measurement were proposed: the Dipstick, which is a pavement profiler, and a modified stringline that reduces cable sag. After extensive testing at Tyndall AFB, testing of these alternatives, along with the stringline method now used, was planned for North Field to determine the fastest and most accurate method.

3. Hand-Mixed Polymer Spall Repair

Hand-mixed polymer spall repair was demonstrated initially during SALTY DEMO. The hand-mixed polymer spall repair method, employing PERCOL™-S-100 polymer resins, was tested along with the Silikal repair method. The hand-mixed polymer method was faster and less labor-intensive.

AFESC continued developing the polymer spall repair system; environmentally safe polymer resins manufactured by ARNCO and Ashland were tested during the summer of 1987. AFESC selected the Ashland polymer resins on the basis of performance during these tests.

The current spall repair method is a two-resin system. Each resin is stored in separate 55-gallon drums. The component resins, one of which contains a catalyst, are dispensed into plastic buckets, mixed together in a third bucket, then poured into aggregate-filled spalls.

Part of the spall repair test at North Field was a formal IOT&E of the spall repair system. To evaluate the operational effectiveness and suitability before a procurement decision, AFESC personnel assessed the reliability and maintainability of the system.

4. MOS Marking

The MOS Marking System consists of a commercially available highway paint striping machine, runway edge and distance-to-go markers, and associated support vehicles. The system, in its early developmental stage, was deployed at SALTY DEMO. The current system is a result of subsequent development and improvements, in both hardware and procedures, by AFESC.

The MOS Marking Test at North Field, as a formal IOT&E of the MOS Marking System, included an evaluation of the MOS marking procedures and an evaluation, by pilots, of the deployed MOS markings during aircraft operations. AFESC personnel also evaluated the reliability and maintainability of system components.

C. TEST OVERVIEW

DT&E and IOT&E were conducted independently; however, planning and financial and logistics support for all tests were combined for economy. AFESC provided major test funding, equipment, and materials for DT&E and

IOT&E. USAFTAWC provided aircraft and aircraft support. In addition, the Military Airlift Command (MAC) provided the North Field test site, and the Tactical Air Command (TAC), through Shaw AFB, SC, provided Prime Base Engineer Emergency Force (BEEF) personnel as the test team. Finally, the test was supported by various organizations, including 3246 TW, Eglin AFB, FL; 823 CES HR, Hurlburt Field, FL; 437 CES, Charleston AFB, SC; 363 TFW, Shaw AFB, SC; and 240 CCS from McEntire ANGB, SC.

A total of 234 spalls and two explosively formed craters were repaired on the North Field 09/27 runway. Crater upheaval was measured as part of the crater repair. Twelve 50- by 5000-foot MOSs were marked under various conditions, with seven of the 12 MOSs expanded to 90 by 7400 feet. Pilots in F-15 and F-16 aircraft flew low approaches against the marked MOSs and trafficked the repaired craters and spalls with taxi, takeoff, and touch-and-go operations.

In addition to the data collected for the four major tests, reliability and maintainability (R&M) data were collected. R&M data were collected primarily on the paint machine, but also on edge and distance-to-go markers, the Spall Repair System dispensing hardware, and the upheaval measurement devices. Data were collected to satisfy IOT&E test objectives and for use in DT&E and system logistics planning.

Since the craters were explosively formed, data, including initial debris thickness and area, were recorded for future debris clearance studies.

D. TEST SITE

The test was conducted at North Auxiliary Field, North, SC (Figure 1), a MAC training field operated by Charleston AFB. North Field is comprised of a 500- by 10,000-foot main runway, one east/west 150- by 5000-foot runway (Runway 09/27) with a 3000-foot overrun, a north/south (N/S) taxiway, and a northeast/southwest (NE/SW) taxiway.

Figure 2 shows the location of major test and support sites. All test events were conducted on the 09/27 runway and overrun (Figure 3). This runway consists of 150 by 5000 feet of portland cement concrete (PCC) pavement with a 75- by 3000-foot overrun at the western end intersecting with the main runway. The overrun was covered with a thin asphalt overlay. The concrete section of Runway 09/27 is approximately 6 inches thick.

The test craters were located 1150 and 1550 feet from the runway threshold at the eastern end of Runway 09/27 and approximately 62.5 feet from the runway's northern edge. One hundred seventy spalls were formed using jackhammers and the excavator pavement breaker. The spalls were grouped into four areas. Area 1 (43 spalls), Area 2 (34 spalls), and Area 4 (30 spalls) were located on the southern portion of the runway. Areas 1 and 4 covered a 50- by 37.5-foot runway section, and Area 2 covered a 75- by 37.5-foot runway section. Area 3, with 63 spalls covering a 210- by 62.5-foot runway portion, was located between the test craters, so repaired spalls were exposed to aircraft trafficking.

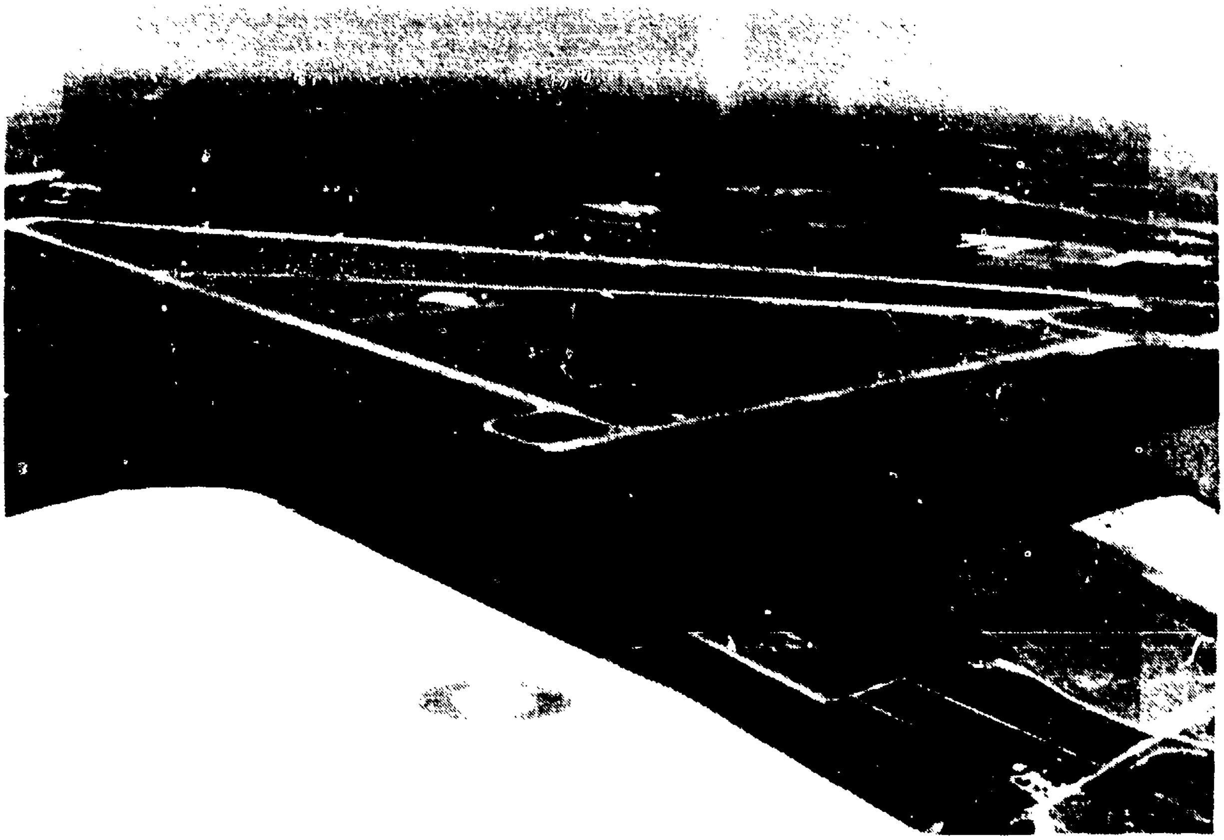

Figure 1. North Field, SC

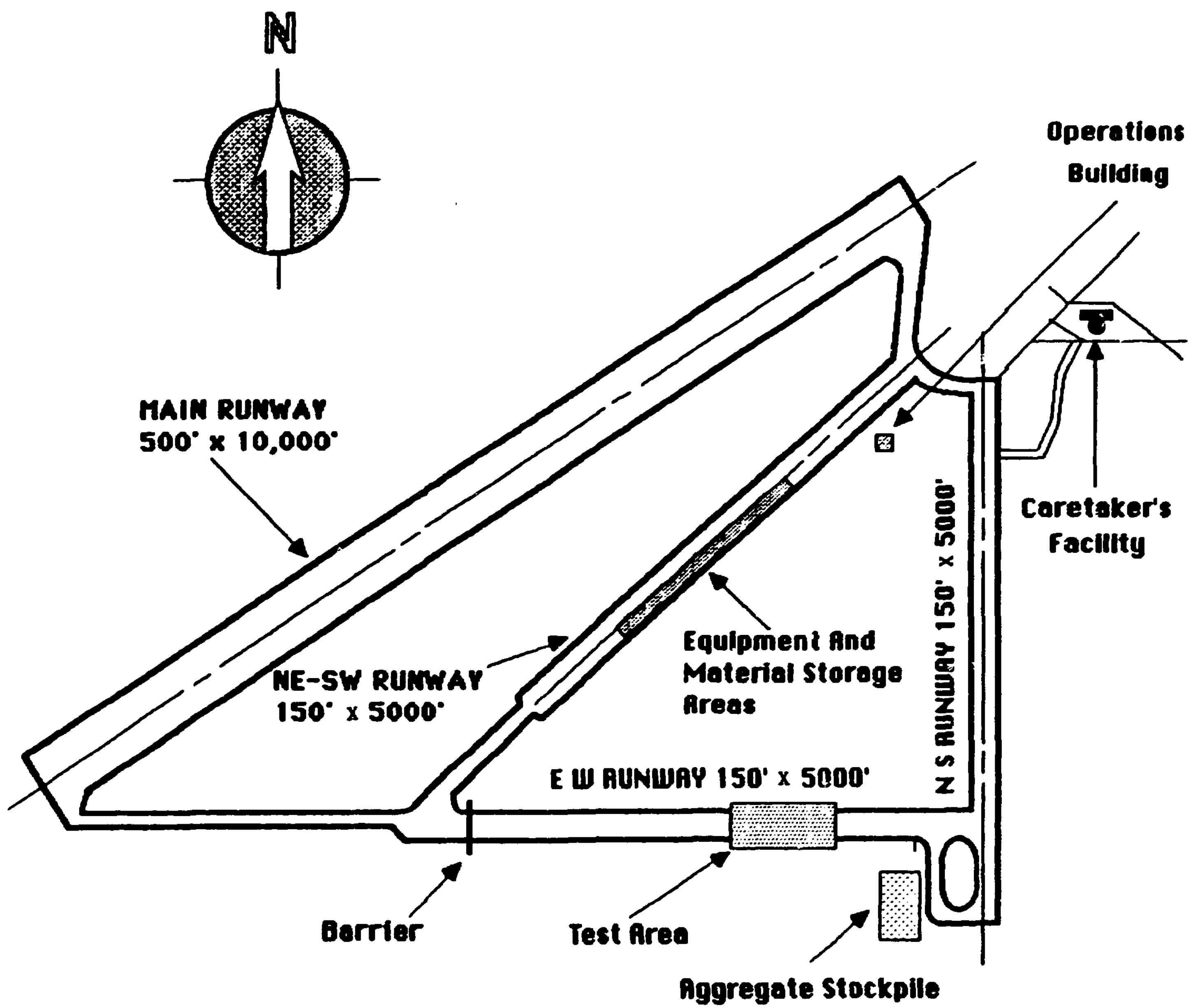

Figure 2. Test and Support Locations at North Field

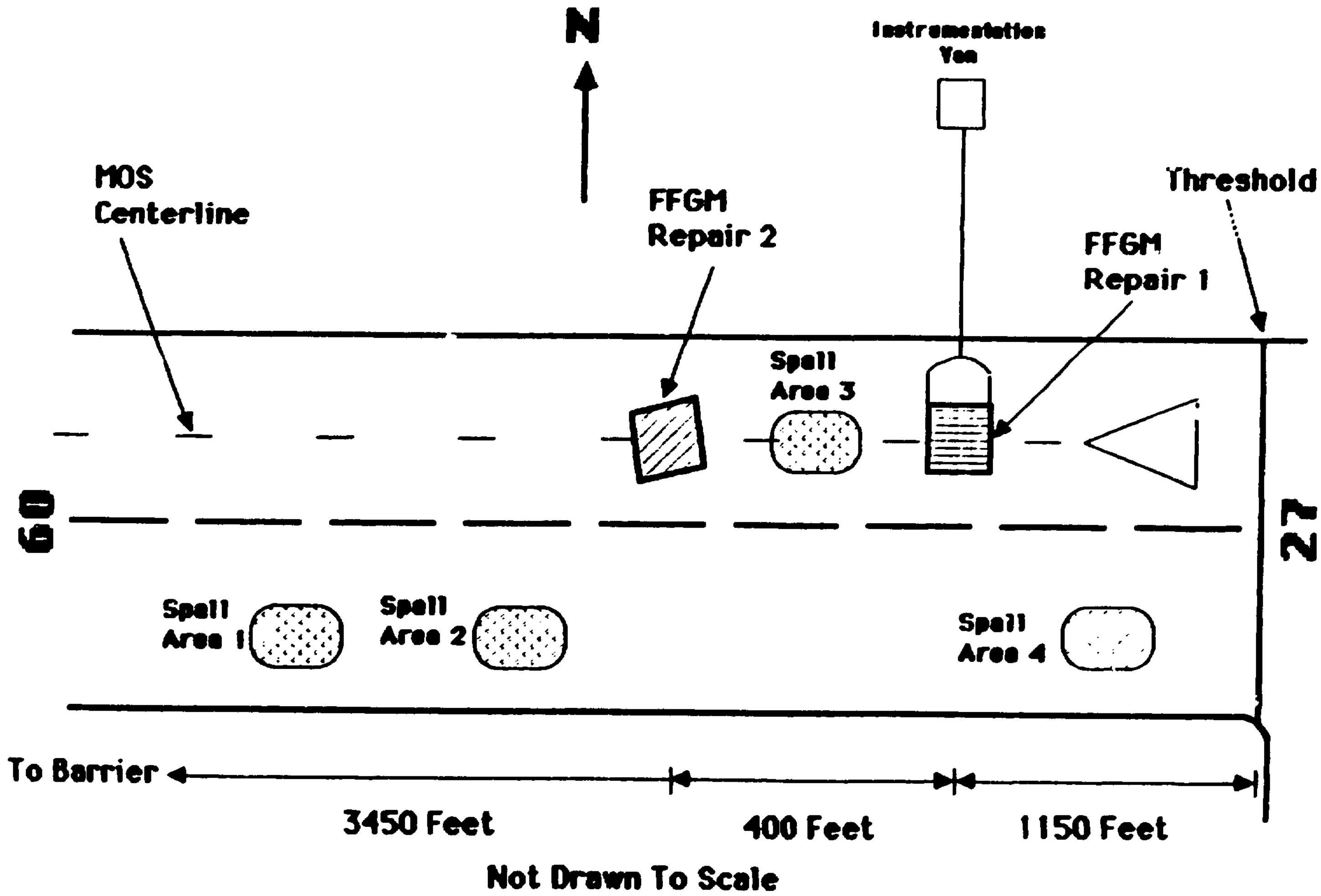

Figure 3. Test Site, Runway 09/27

Equipment and material were stored on the NE/SW taxiway. During the repair, equipment was staged in the grass, south of the repair site. Paint, polymer, and solvent, as well as storage drums for paint and polymer wastes, were stored in a designated hazardous materials area. The area, located on a paved section of the taxiway, was surrounded by a soil berm of 8 to 12 inches. Metal containers and drums were grounded, in accordance with Air Force Ground Safety Regulations.

For aircraft operations, the 363 TFW from Shaw AFB, SC, provided major maintenance and fuel support for the USAFTAWC-provided F-15 and F-16 aircraft. At North Field, an aircraft maintenance and refueling area was established on the N/S taxiway. F-15 and F-16 maintenance crews were available onsite during aircraft tests. The 823 CESHR installed an expeditionary BAK-12 barrier approximately 3000 feet west of the last crater. The barrier was tested with an 80-knot engagement by an F-15 aircraft before high-speed test events began. Fire and crash rescue support was provided by North Auxiliary Field. A "hot brakes" area was designated at the intersection of the NE/SW taxiway and Runway 09/27 for aircraft experiencing excessively high tire or brake temperatures during the scheduled operations.

Aircraft operations at North Field were controlled from a portable tower located on the north side of the runway about 4000 feet from the threshold. All landings and some takeoffs took place on the main runway.

E. REPORT SCOPE

This report is limited to the results of the DT&E tests and reliability and maintainability (R&M) investigations conducted by AFESC. Significant highlights of the Spall Repair Test and the MOS Marking Test are reported in the R&M section, but a detailed analysis of the IOT&E results are reported by USAFTAWC in Rapid Runway Repair (RRR) Subsystems MOS Marking and Hand-Mixed Polymer Spall Repair, (TAC Project 87C-068T) IOT&E Final Report, November 1987.

Because of the enormity of effort involved in the mat instrumentation portion of the FFGM Test, only highlights are reported. Details concerning the development, installation, and results of the instrumentation, as well as an analysis of results, are presented in Volume II of this report.

SECTION II

CRATER REPAIR TEST

The purpose of the Crater Repair Test was to evaluate the overall performance of the Folded Fiberglass Mat Crater Repair. Each test objective is related directly to the performance and response of the repairs to loadcart and aircraft traffic. Care was taken to construct the repairs using the materials and dimensions specified in the fielded procedures. There was no attempt to evaluate or use a particular equipment set or personnel mix, or to time the repair process.

A. TEST OBJECTIVES AND PASS/FAIL CRITERIA

Seven objectives were planned for the Crater Repair Test, as follows:

1. Evaluate the performance of a crushed stone repair covered with a commercially produced, hinged, fiberglass mat.

Pass/Fail Criteria:

a. Support 100 aircraft passes, within surface roughness limits, and not require maintenance necessitating mat removal.

b. Sustain trafficking and jet blast without:

(1) Loss of anchors

(2) Permanent mat deformation

(3) Mat fragmentation or delamination

(4) Producing foreign object damage (FOD)

2. Compare bolt loads and mat strains to those predicted by mat analysis.

Pass/Fail Criteria

a. Obtain relevant anchor bolt loads and mat strains for 10 traffic events.

b. Quantitative and qualitative correlation of test data with the appropriate analytical model (finite-element analysis).

3. Compare the resistance to rutting of a crater repair with mat hinges parallel to the MOS centerline to that of a mat skewed 3 to 4 degrees off the MOS centerline.

Pass/Fail Criterion

After 100 passes, the repair should not develop ruts which exceed surface roughness limits.

4. Evaluate the anchor bushings' ability to remain tight, and compare the performance of standard and modified bushings.

Pass/Fail Criteria

a. All bushings should remain tight for a minimum of 30 aircraft passes.

b. Modified bushings should remain tight longer than the standard bushings.

5. Measure bow wave amplitudes, and compare the amplitude of bow waves on the standard mats versus the slotted and skewed mat.

Pass/Fail Criteria

a. Bow waves on slotted mats should be smaller than those on standard mats.

b. Bow waves should not damage either mat system.

6. Appraise the anchoring system's adequacy during loadcart and aircraft trafficking.

Pass/Fail Criterion

Each anchor must keep the mat secured to the ground.

7. Appraise each mat's structural integrity and the anchoring system's adequacy during exposure to jet blast from 30-second engine run-ups by F-15 and F-16 aircraft.

Pass/Fail Criteria

a. Mats should not sustain damage which would prevent their continued use.

b. Each anchor must keep the mat secured to the ground.

B. TEST DESCRIPTION

1. Preparation

Two test craters were formed on 23 August at locations shown in Figure 3. Craters were formed by members of the 823 CESHR. Two 24-inch diameter boreholes, 6 feet deep for Crater 1 and 5 feet deep for Crater 2, were drilled with a line truck auger. Explosives, consisting of ammonium nitrate fuel oil (ANFO) and TNT, were placed in each hole. The hole was then stemmed with clay and sand. The net explosive weight of the charge forming Crater 1 was 44 pounds; the charge forming Crater 2 was 66 pounds.

Following the explosions, Crater 1 measured 5 feet deep with an apparent diameter of 25 feet. Crater 2 measured 6.6 feet deep with an apparent diameter of 26 feet. On the pavement surrounding each crater, debris from the explosion was measured beyond 70 feet east and west of the crater rim. When the debris surrounding the crater was removed, both radial and concentric cracks in the concrete pavement were visible. On Crater 1, four major radial cracks extended out approximately 15 feet. Cracks extended outward, at about 5-foot intervals, east and west of the crater. On Crater 2, approximately six 6- to 12-foot radial cracks extended beyond the crater. Other cracks conforming to the general shape of the crater formed an apparent single ring around the crater, approximately 6 feet from the crater edge. Figures 4 and 5 illustrate the observed pavement cracks.

2. Repair Description

A pretest surface roughness analysis was conducted to determine upheaval and sag limits for each repair. Computer simulations, using the results of a runway survey and a test limit of 80 percent design limit load for aircraft components, were run for F-15 and F-16 aircraft. The gross weights used in modeling were 42,500 and 24,700 pounds, respectively. Test criteria were established for both constant-speed taxi and braking operations. The simulation results, found in Table 1, illustrate the maximum allowable limits for safe aircraft operation. Results show that although a flush repair was the goal, a maximum of 3 inches of upheaval would be acceptable.

Each crater was repaired by AFESC/RDCO personnel and members of the Prime BEEF team. The general sequence of crater repair is shown in Figures 6 through 13. In conjunction with the crater repair, members of the Prime BEEF team also conducted portions of the Upheaval Measurement Test (see Section III).

a. Crater 1 Repair

Crater 1 repair began on 24 August. After removing debris from around the crater lip and from the surrounding pavement (particularly north and south of the crater), the repair was rolled with the vibrating drum of a Ray-Go 10-ton roller to partially compress the upheaved areas. This activity was neither a crater repair procedure nor objective, but was performed to take advantage of collecting data on an explosively formed crater. Previous AFESC tests (the Joint Upheaval Measurement and Planer Tests in July 1987) had indicated that the upheaved pavement could be significantly reduced with the roller. Profiles taken at North Field before and after rolling indicate that the height of the upheaval changed by a maximum of 1.92 inches on the western rim of the crater and an average of only 0.6 inch, yielding an average change in diameter of 6 feet.

Equipment operators broke out the upheaval pavement using a 2 1/2 yd^3 Case W24C front-end loader (FEL) and a RRR excavator. When the

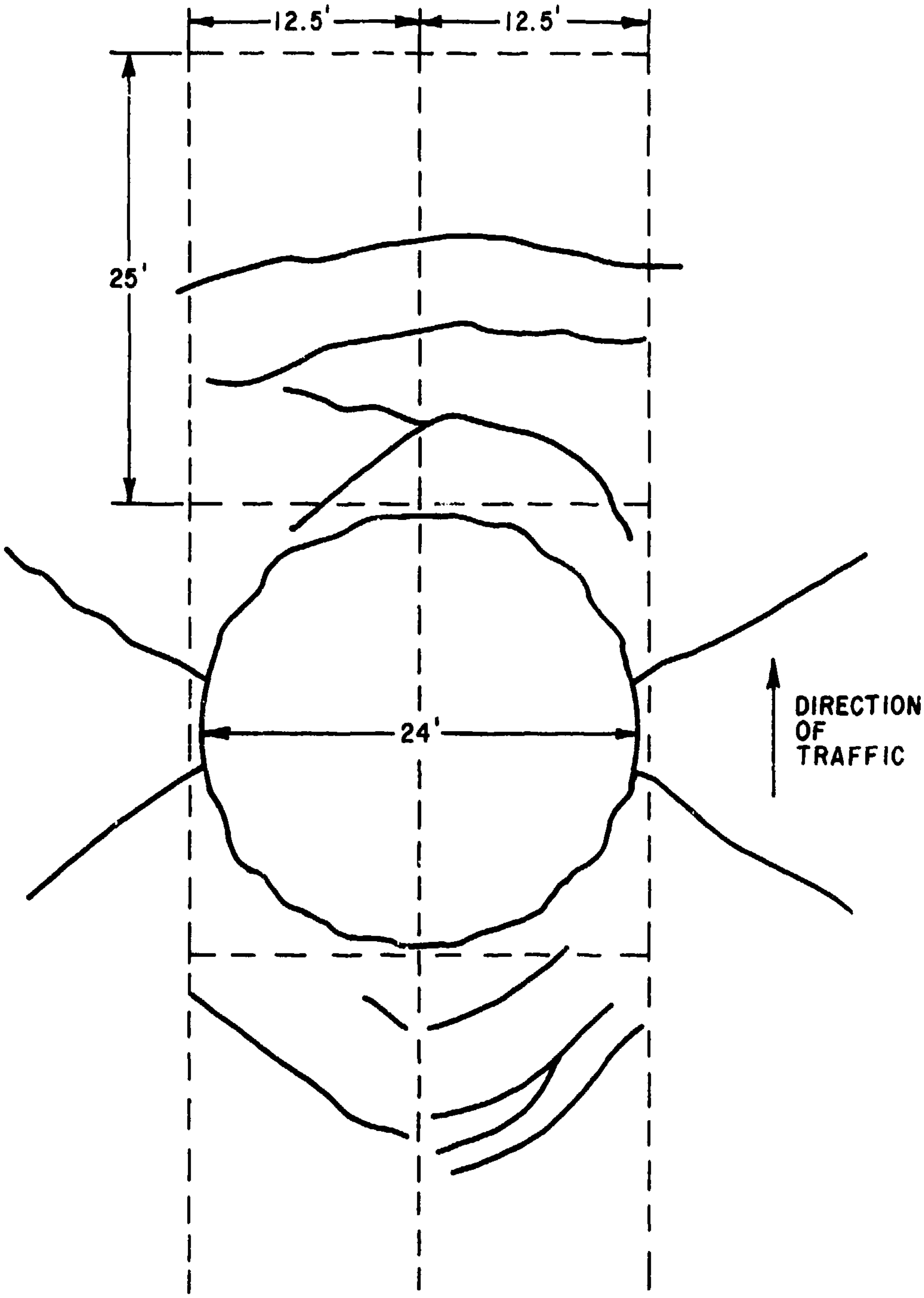

Figure 4. Cracking Pattern in Runway Slabs Surrounding Crater 1

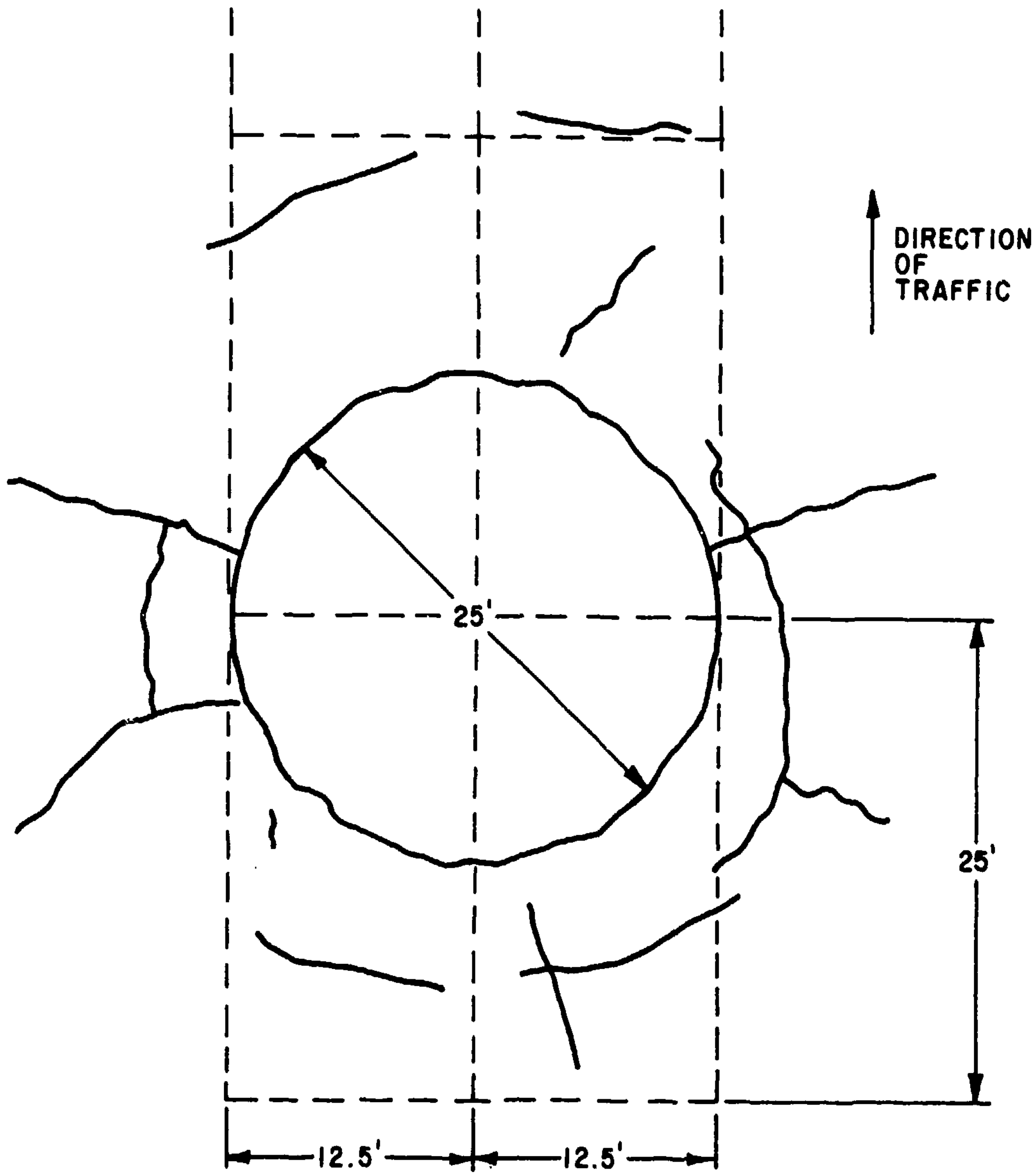

Figure 5. Cracking Pattern in Runway Slabs Surrounding Crater 2

TABLE 1. SURFACE ROUGHNESS LIMITS

	CONSTANT-SPEED TAXI		BRAKING	
	MAXIMUM ALLOWABLE UPHEAVAL* (INCHES)	MAXIMUM ALLOWABLE SAG** (INCHES)	MAXIMUM ALLOWABLE UPHEAVAL (INCHES)	MAXIMUM ALLOWABLE SAG (INCHES)
F-15 (42,500-pound gross weight)	3.0	2.5	3.0	1.5
F-16 (24,700-pound gross weight)	4.5	4.5	3.0	3.0

* Maximum projection above the original undamaged pavement surface.

** Maximum depression below an "imaginary repair surface," determined by stretching a string across a repair from the undamaged pavement on one side, over the upheaved crater lip on both sides, to the undamaged pavement on the opposite side.

Figure 6. Crater Before Repair

Figure 7. RRR Excavator Breaking Back Upheaval

Figure 8. FEL Leveling Debris Backfill

Figure 9. Rough Leveling Crushed Stone with FEL

Figure 10. Leveling Repair with Grader

Figure 11. Compacting Fill with 10-Ton Vibratory Roller

Figure 12. Towing Mat Over Repair

Figure 13. Anchoring the Folded Fiberglass Mat

upheaval was removed, the final repair diameter, measured at the crater centerline in the direction of traffic, was 48 feet.

The crater was filled with debris backfill to less than 2 feet below the pavement surface. The debris backfill was leveled with the excavator bucket and FEL before crushed stone was added. The stone was leveled with a John Deere 670A grader, compacted with four coverages of the vibratory roller, screeded again with the grader, and compacted only with four final roller coverages. Some additional crushed stone was hand-placed and compacted, especially around the pavement edges. The average thickness of crushed stone was 21.6 inches. Water occasionally was sprayed on the stockpile and the repair to control the moisture content of the crushed stone. Although not part of the repair procedure, this activity was necessary because of hot weather and the time required to complete the repair and to install the instrumentation.

Before the test, Law Engineering Inc., Columbia, SC, determined the optimum moisture content and maximum dry density of the crushed stone to be 6.5 percent and 136.3 lb/ft^3, respectively, in accordance with ASTM 1557A (modified Proctor). On 24 August, Law Engineering technicians determined the moisture content of the crushed stone in the stockpile to be 4.7 and 4.2 percent, after which the stockpile was sprayed with water. This procedure raised the moisture content to 7.6 percent. A moisture content of 7.3 percent was recorded on 25 August.

After Crater 1 was compacted, a Law Engineering technician measured in-place density using the sand-cone method (ASTM 1556). The density measured was 97.9 percent of maximum (ASTM D1557) at a moisture content 2.1 percent of optimum.

Figure 14 illustrates the final repair profile taken before mat installation. The figure shows that the repair is within surface roughness limits, with the crushed stone extending a maximum of 1.6 inches above the pavement.

The repair was covered with a 54- by 60-foot, hinged, polyester mat. The mat, manufactured by Molded Fiber Glass Company, Union City, PA, consisted of two 30- by 54-foot mat sections and a joining section. Each mat section contained nine 6-foot wide panels separated by hinge material, composed of fiberglass impregnated with Re-Pneu foam tire fill. At each end of the panel, 2 1/4-inch diameter anchor holes were spaced 36 inches on center. Before shipment to North Field, an anchor hole was added between existing holes in each panel, reducing anchor hole spacing to 18 inches on Crater 1. Mat sections arrived folded. Before crater repair began, the mats were unfolded and joined together with 24-inch wide, two-ply fiberglass joining panels and were secured with 5/8-inch diameter bolts and joining bushings.

Mat 1 was instrumented onsite with strain gauges to determine mat loads during trafficking (see Volume II). After the strain gauges were installed, the mat was pulled over the crater surface, but was not permanently anchored because of additional instrumentation work. The mat was removed from

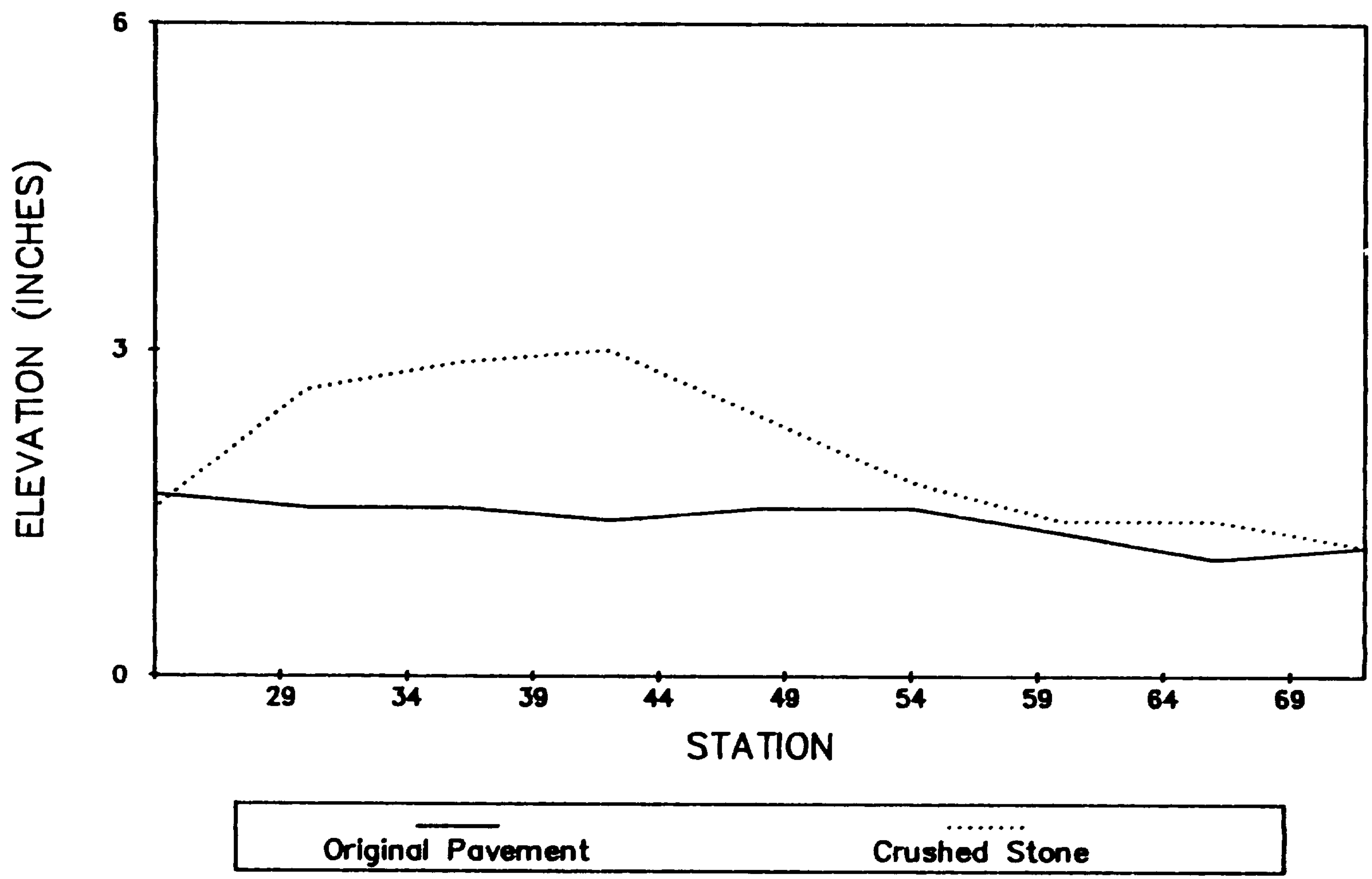

Figure 14. Repair 1, Final Centerline Profile of Crushed-Stone Surface

the repair periodically to allow installation of cable channels and cables, then replaced to prevent moisture loss from the crushed stone. While the mat was removed, the repair was covered with plastic sheets.

On 28 August, the repair was proofrolled with an F-15 loadcart, applying an estimated 25,600 pounds, with a tire pressure of 265 psi.* Proofrolling consisted of applying a single trafficking pass over the entire repair. The mat was in place over the repair, but was not anchored because the instrumentation was not completely installed. To avoid unnecessary damage to the installed mat sensors, proofrolling was conducted across the runway, perpendicular to the normal traffic direction.

Final mat-anchoring took place on 30 August. The mat was oriented with hinges parallel to the runway centerline and anchored to the pavement using 5/8-inch diameter Wej-It anchor bolts and standard anchor bushings. Sixteen of the anchor bolts were instrumented and were secured by a polymer plug (described below).

Initially, bushings were tightened using the "T"-handle wrench (also called the bushing tool) in the RRR mat kit. Before trafficking, all anchor and joining bushings were torqued to 65 foot-pounds. For easy identification during the test, the installed bushings were painted white and numbered.

Twenty strain gauges and 16 instrumented anchor bolts were installed, as shown in Figure 15.

The instrumented bolts were anchored to the pavement by polymer plugs. Using a coring drill, a 3-inch diameter hole was bored 8 inches in the pavement. A 4-inch diameter countersink hole was bored 2 inches in the pavement to prevent the installed bolt from contacting the pavement when deflected under side loads, and to provide clearance for wires leading from the bolt. After the bolt was positioned in the hole and the gauges properly aligned, a polymer resin mixture (Ashland Resins 65-088 and B65-032, and Ashland Catalyst 65-018) was poured in the hole. Figure 16 shows a cross section of an installed anchor bolt.

The mat and bolt strain gauges were connected to the data recording equipment through the main instrumentation cable. The cable ran from the mat to the instrumentation van, located approximately 200 feet north of Repair 1. The van housed the analog tape recorders and conditioning amplifiers.

Before the test, instrumented bolts and mat gauges were calibrated for vertical and horizontal loads. Detailed installation and calibration procedures are found in Volume II.

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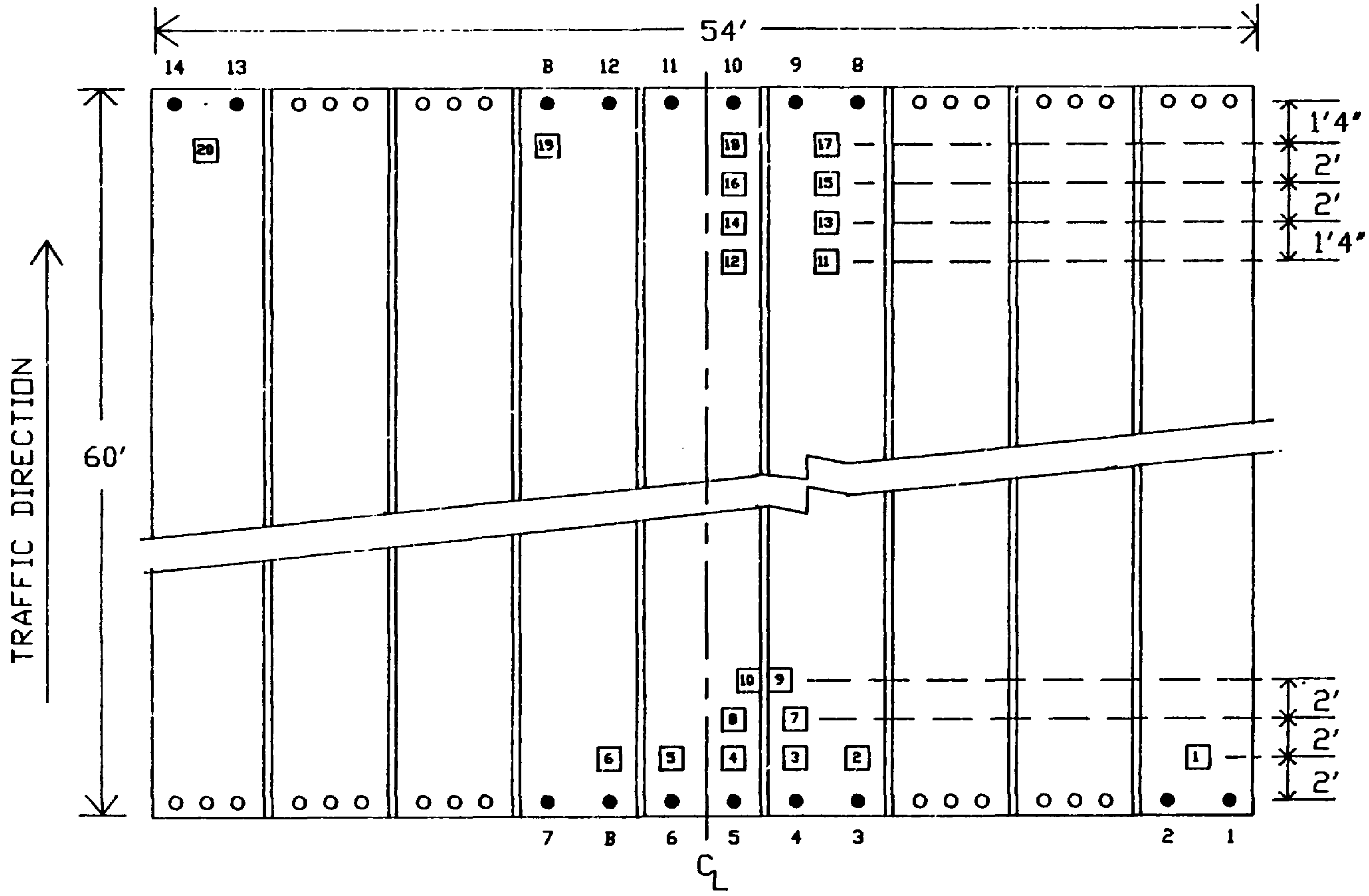
* The load on the test wheel was approximated by estimating the weight of the vehicle itself, estimating the weights of the lead pigs, measuring the distance from the lead weights to the front of the vehicles, and assuming the moments about the front wheels.



7● = Instrumented Bolt 7
$\boxed{6}$ = Strain Gauge 6
B● = Backup Instrumented Bolt

Figure 15. Location of Mat Gauges and Instrumented Anchor Bolts on Mat 1

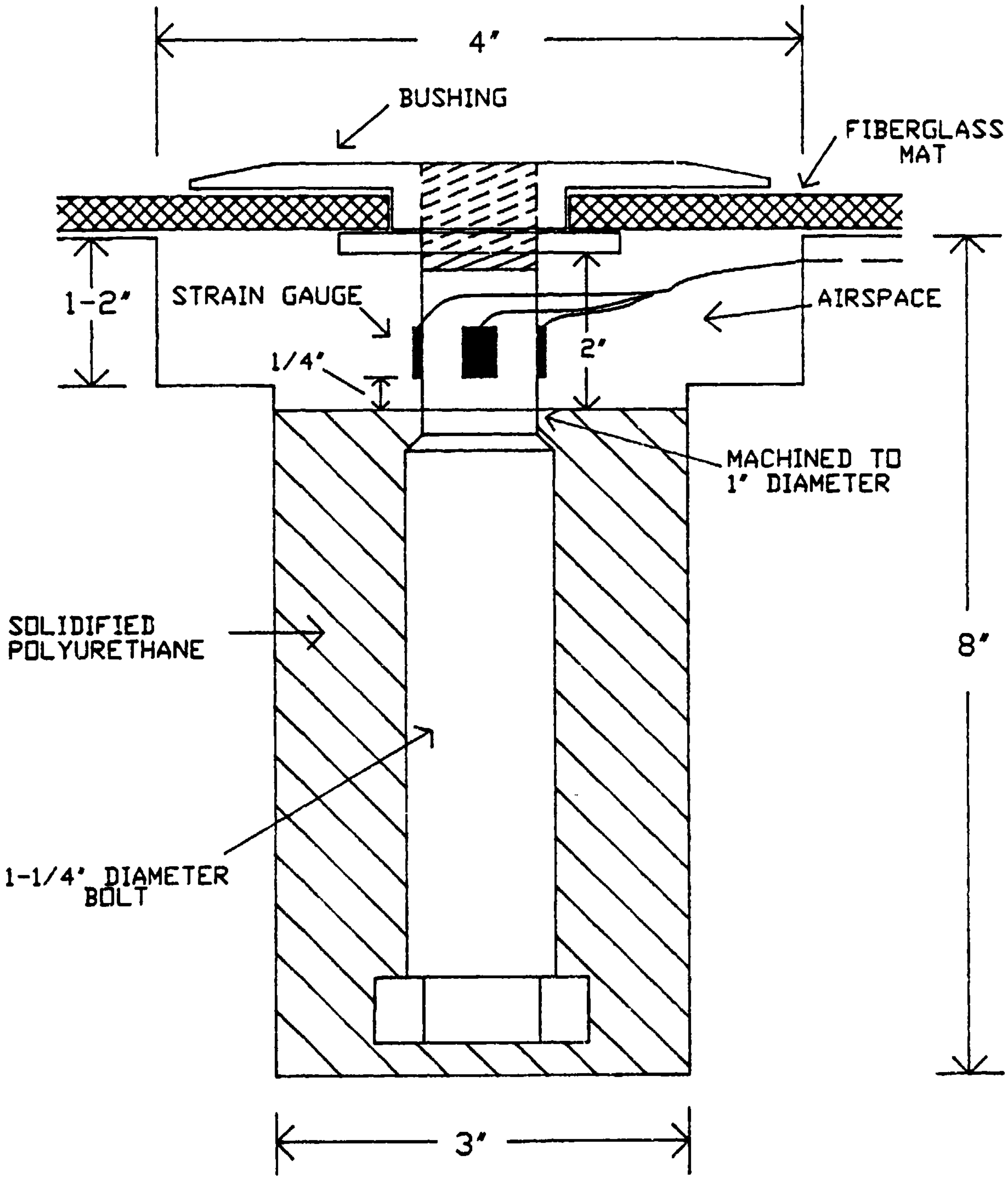


Figure 16. Installed Instrumented Anchor Bolt

b. Crater Repair 2

The Crater 2 repair began on 25 August. The repair method was the same as that used for Crater 1. The upheaved pavement surrounding Crater 2 was not rolled before removal, as was done for Crater 1. After upheaval removal, the final repair diameter of Crater 2 measured 45 feet at the centerline in the direction of traffic.

The crater was backfilled with debris to less than 2 feet below the pavement surface. The repair crews used the FEL to level debris before adding the layer of crushed stone. Stone was added to an average depth of 21.6 inches, screeded with the grader, compacted with four coverages of the 10-ton vibratory roller, screeded again, then compacted with four final coverages of the roller. As with Crater 1, water was added occasionally during the repair. The dry density, from two samples measured by the sand cone method, was 97.6 and 101.8 percent of maximum (ASTM 1556).

Figure 17 illustrates the final repair profile taken before mat installation. As in Crater 1, the repair conformed to the pretest surface roughness limits, with the crushed stone extending a maximum of 2.5 inches above the pavement.

The repair was covered with a hinged, polyester mat, similar to the one covering Repair 1. The hinges were composed of fiberglass, impregnated with a polymer elastomer (ITP-8000-2). The anchor holes in the second mat were 3- by 6 1/2-inch slots, rather than the conventional circular holes. The slots, formed in the mat panels at Tyndall AFB before shipment to North Field, were designed to allow the mat to dissipate the energy from bow waves, through limited movement. Bolt spacing was the same as on Mat 1. At North Field, the mat sections were unfolded and joined together using 5/8-inch diameter bolts, joining bushings, and joining panels (See Appendix G, Test Plan). The mat had sustained damage to one end panel during packaging at Tyndall AFB, necessitating panel removal and resulting in a mat 60 feet long by 48 feet wide.

The mat was positioned over Repair 2 at an angle of 4 degrees to the MOS centerline. With this alignment, hinges would not be trafficked along their entire length, potentially reducing rutting. The mat was angled by first aligning the mat with the hinges parallel to the centerline of the MOS. The corner of the mat was marked with spray paint. Chains were attached to the northwest corner and, using a FEL, the mat was pulled slightly westward. The tow chains then were attached to the mat's southwest corner, and the mat was adjusted by pulling it southward. After angling, the centerline hinge at the east (threshold) end was 1.5 feet north of its original alignment position. The centerline hinge at the west end of the mat was 2 feet, 7 inches south of its original position.

The mat was anchored using 3/4-inch diameter Wej-It anchor bolts and modified anchor bushings, designed for use with the slotted mat. Bushings initially were tightened using the spanner wrench in the RRR mat kit. During the anchoring process, test personnel discovered that the anchor bolts were too long, and the upper ends of the bolts would jam against the bushing

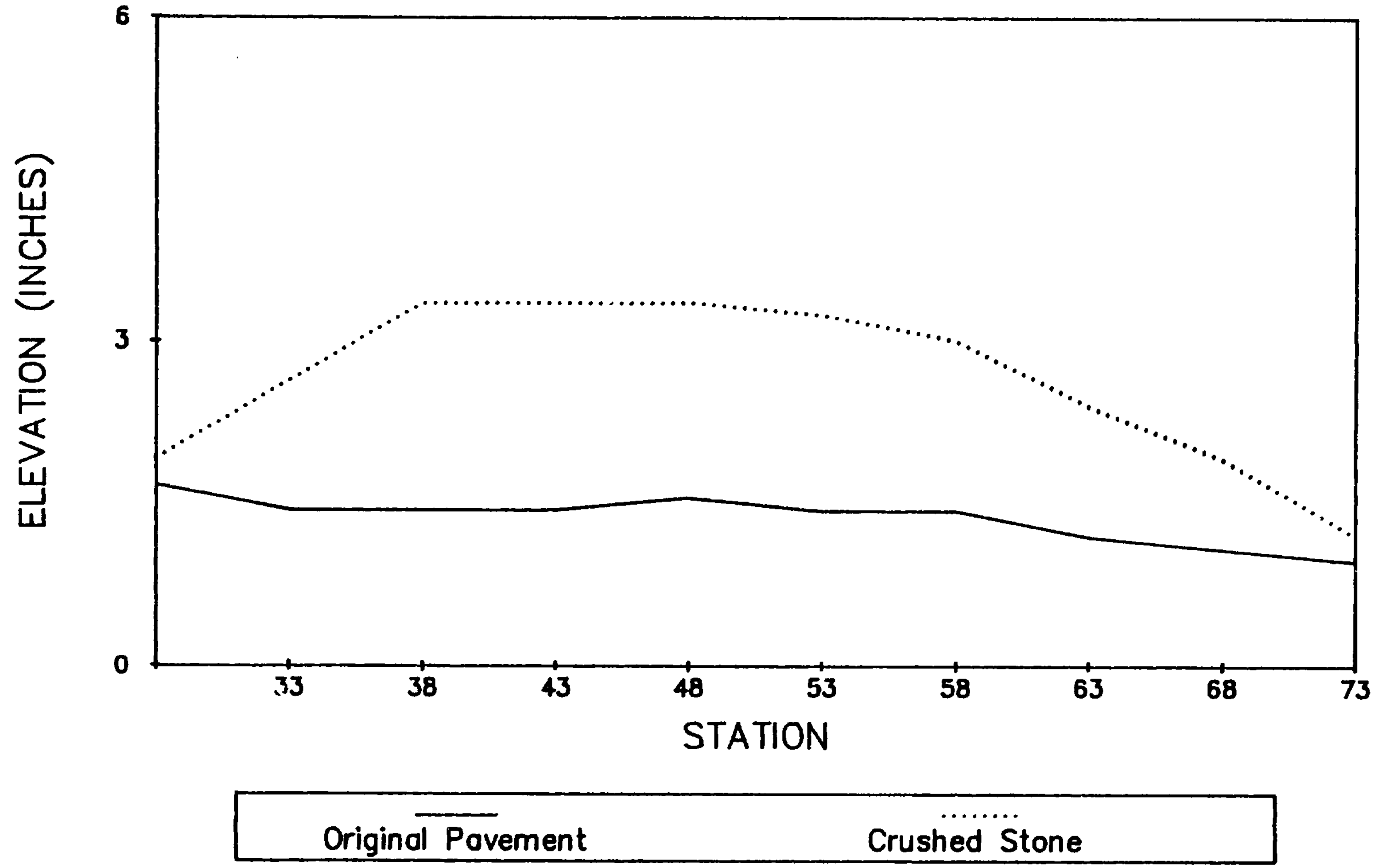


Figure 17. Repair 2, Final Centerline Profile of Crushed-Stone Surface

tool before the anchor wings were extended. The bolts were shortened by 1/2 inch at a local machine shop, then installed as planned.

One complete coverage of the F-15 loadcart, was applied on 28 August in the traffic direction. Each bushing was torqued to 65 foot pounds after proofrolling.

3. Aircraft Trafficking

Between 31 August and 3 September, an F-15 and an F-16 aircraft, provided by USAFTAWC, Eglin AFB, FL, trafficked the repairs. The aircraft operations at North Field were conducted to satisfy IOT&E and DT&E test objectives concurrently. Pilots were to observe and evaluate MOS marking patterns during both low approaches and touch-and-go landings. In addition, low- and high-speed taxis, touch-and-go landings, and takeoffs from Runway 09/27 were planned to traffic both the repaired craters (DT&E) and the repaired spalls (IOT&E).

Rather than establishing a fixed number of test events conducted in a specific sequence, the aircraft operations at North Field were conducted according to the following routine:

a. Each day the aircraft arrived from Shaw AFB (about a 10-minute flight).

b. Pilots executed low approaches and touch-and-go landings until the aircraft's fuel load was reduced to the planned landing weight.

c. For full-stop landings, pilots landed on the main runway at North Field and conducted a series of taxi operations on the test area before proceeding to the refueling area.

d. While the aircraft were refueled and checked by maintenance crews, pilots serving as the Supervisor of Flying (SOF) and the Flight Safety Officer (FSO) switched roles with the pilots flying the F-15 and F-16 aircraft. The switch was necessary to provide additional pilot data points in the MOS marking evaluation.

e. The pilots conducted additional taxi operations before takeoff on either Runway 09/27 or the main runway.

f. The pilots conducted additional low approaches and touch-and-go landings until refueling was required.

g. The pilots landed on the main runway, taxied over the repairs, and returned to the refueling area.

h. The pilots again switched roles and took off (from either the test runway (09/27) or the main runway), and flew low approaches and touch-and-go landings until fuel considerations required the aircraft to return and land at Shaw AFB.

Monitoring the operational routine, rather than forcing events in a specific order, provided enough flexibility to recover from unanticipated delays caused by weather, aircraft mechanical problems, and other events.

To observe and evaluate the MOS pattern, pilots flew low approaches using a wide pattern. This was necessary, since 4 nautical miles was the threshold visibility criterion for each MOS pattern. During low approaches and touch-and-go operations in the wide pattern, pilots reported the Visual Acquisition Distance of the MOS.

For most touch-and-go landings, the aircraft flew a tighter pattern to increase the frequency of passes. On each touch-and-go, the pilot attempted to touch down before Repair 1, roll over each repair, then take off. Typically, the aircraft crossed the repairs at approximately 140 knots.

Taxi passes were made bidirectionally. Pilots returning to the refueling area were instructed to taxi over each repair. During scheduled taxi operations, low-speed taxi runs (less than 40 knots) were conducted eastward, and high-speed operations (up to 63 knots) were conducted westward. During extended taxi operations, aircraft tires and brakes were monitored by two members of 3246 TW using surface contact and optical pyrometers. The maximum recorded tire temperatures were 146°F for the F-15 and 141°F for the F-16. Brake temperatures peaked at approximately 560°F on both aircraft. At no time was aircraft trafficking stopped because of high brake or tire temperatures.

High-speed video and 16 mm high-speed film cameras, operated by 3246 TW Photography Lab personnel, were set up to record repair reaction to aircraft trafficking. Two 16 mm high-speed cameras were positioned on tripods approximately 200 feet from each repair, one focused on the mats' leading edge and the other on the trailing edge. Two high-speed video cameras were located near the instrumentation van, and each one was focused on a mat to provide a split-screen view on the monitor.

The first day of trafficking, 31 August, consisted primarily of low approaches and taxi operations, with four touch-and-go events. In addition to the test events, the aircraft were used to certify the BAK-12 barrier and to provide firefighters with egress training. Both the barrier engagement and the egress training were required before the test events started. Low ceilings and restricted visibility in the afternoon prevented the pilots and aircraft from returning to Shaw AFB. The test day ended with 14 completed aircraft passes on each repair.

On 1 September, the weather was again marginal. Operations began, concentrating on low- and high-speed taxi passes. The weather improved around noon, long enough to allow the aircraft to return to Shaw AFB. At the end of the day, the aircraft had completed 40 passes, including two takeoffs, over each repair.

On 2 September, aircraft operations began according to the scheduled routine. The pilots flew a series of low approaches and touch-and-go landings on Runway 27, and conducted several taxi passes and two takeoffs over the repairs. On the last operational set, after several low approaches and touch-and-goes, the F-15 struck a bird. Although the aircraft received only minor damage, operations were suspended for the day, and the aircraft returned to Shaw AFB for inspection. Repair 1 had received 73 cumulative passes and Repair 2, 71 passes.

On 3 September, operations continued until test goals were satisfied. The majority of events consisted of low approaches, touch-and-go landings, and some taxi passes. A jet blast test was conducted, in which an F-15 taxied over each repair, stopped approximately 50 feet west of the repair, and performed an 80-percent military power engine run-up which lasted, at most, 30 seconds. At the end of the test day, Repairs 1 and 2 had received 108 and 110 aircraft passes, respectively. Appendix D lists each North Field aircraft trafficking test event.

C. TEST RESULTS

1. Repair Performance

Table 2 is a breakdown of the number of aircraft passes traversing each repair. An aircraft pass was defined as a touch-and-go, taxi pass, or takeoff where one or more landing gear came in contact with the mat.

TABLE 2. AIRCRAFT TRAFFICKING PASSES

Operation	Repair 1	Repair 2
Taxi Events (Taxi with Braking)	48 (5)	48 (3)
Touch-and-Go Events	56	58
Takeoffs	4	4
Total Passes	108	110

Usually during touch-and-go landings, only the main landing gear of each aircraft touched the mat (Figure 18). Aircraft occasionally missed one or both mats completely. Only actual contact with the mat was counted as a pass for that repair. Several times, the aircraft touched down directly on Repair 1, rather than before it. On Repair 1, the gear trafficked Mat Panels 4, 5, and 6 almost exclusively. Figure 19 shows the marks on Mat 1.

Profiles were taken on the mat surface of Repair 1 before trafficking and after 14, 40, 73, and 108 aircraft passes. Profiles also were taken on the mat surface of Repair 2 before trafficking and after 14, 40, 71, and 110 aircraft passes. Additionally, profiles were taken on the crushed stone surfaces of Repairs 1 and 2 before and after all aircraft trafficking. Profile lines were established in the direction of aircraft traffic, as shown in Figure 20. Measurements were taken at 1-foot intervals over a distance of 100 feet along each profile line.

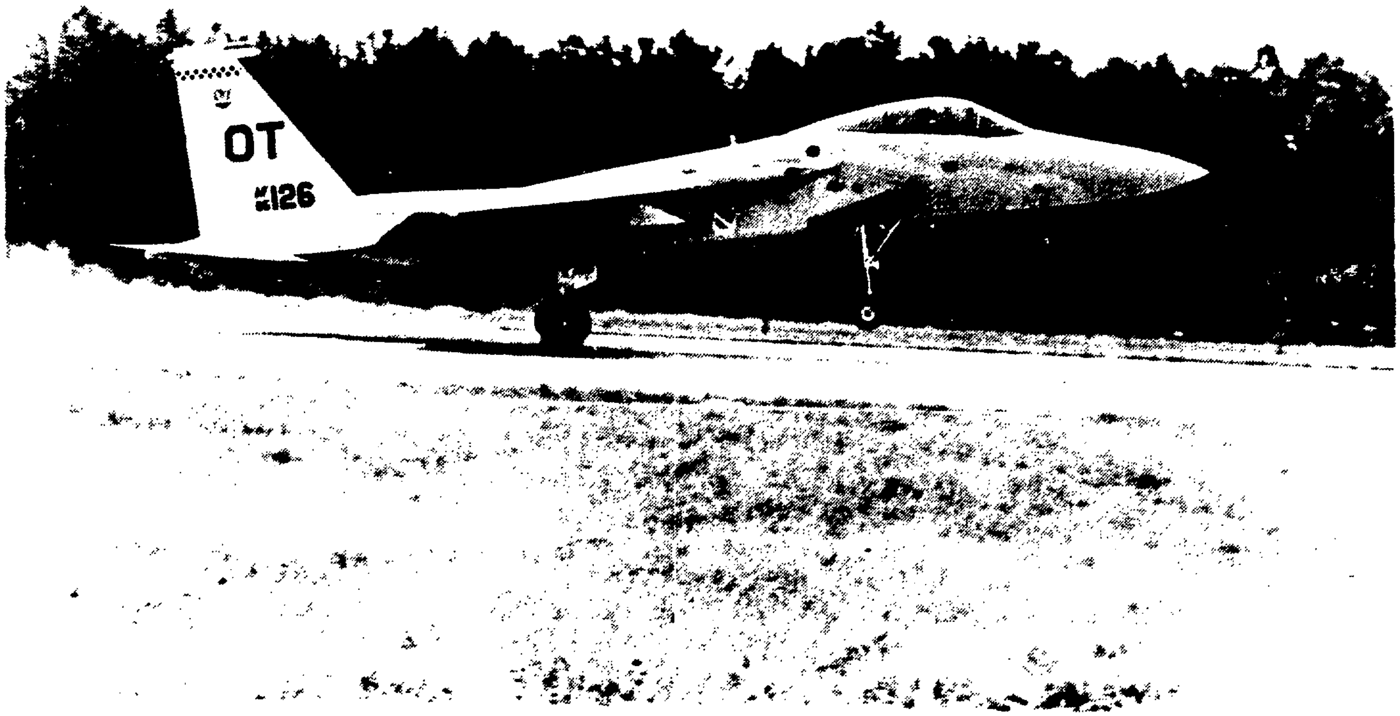


Figure 18. F-15 Touching Down on Mat 1

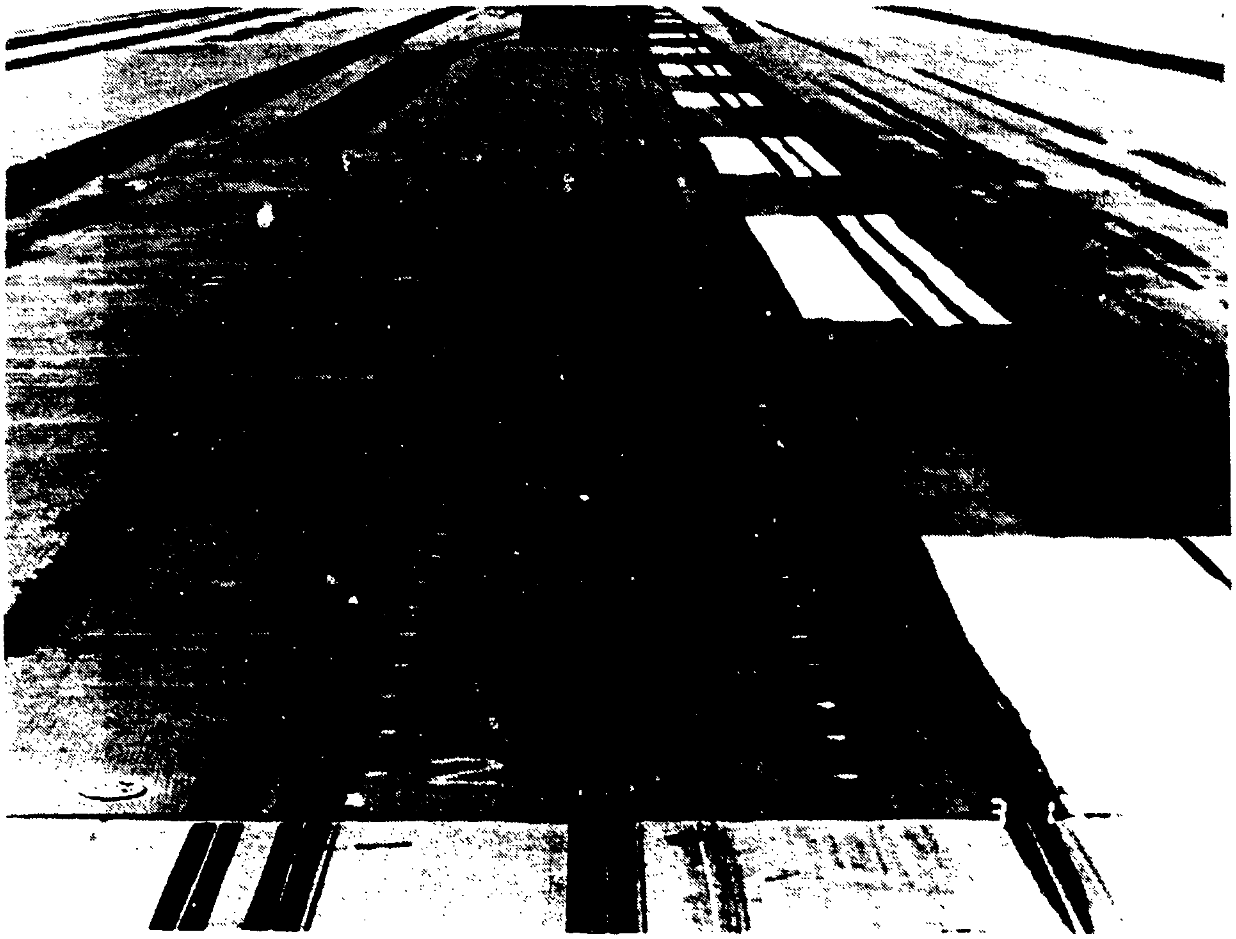


Figure 19. Tire Marks from Aircraft Operations, Mat 1

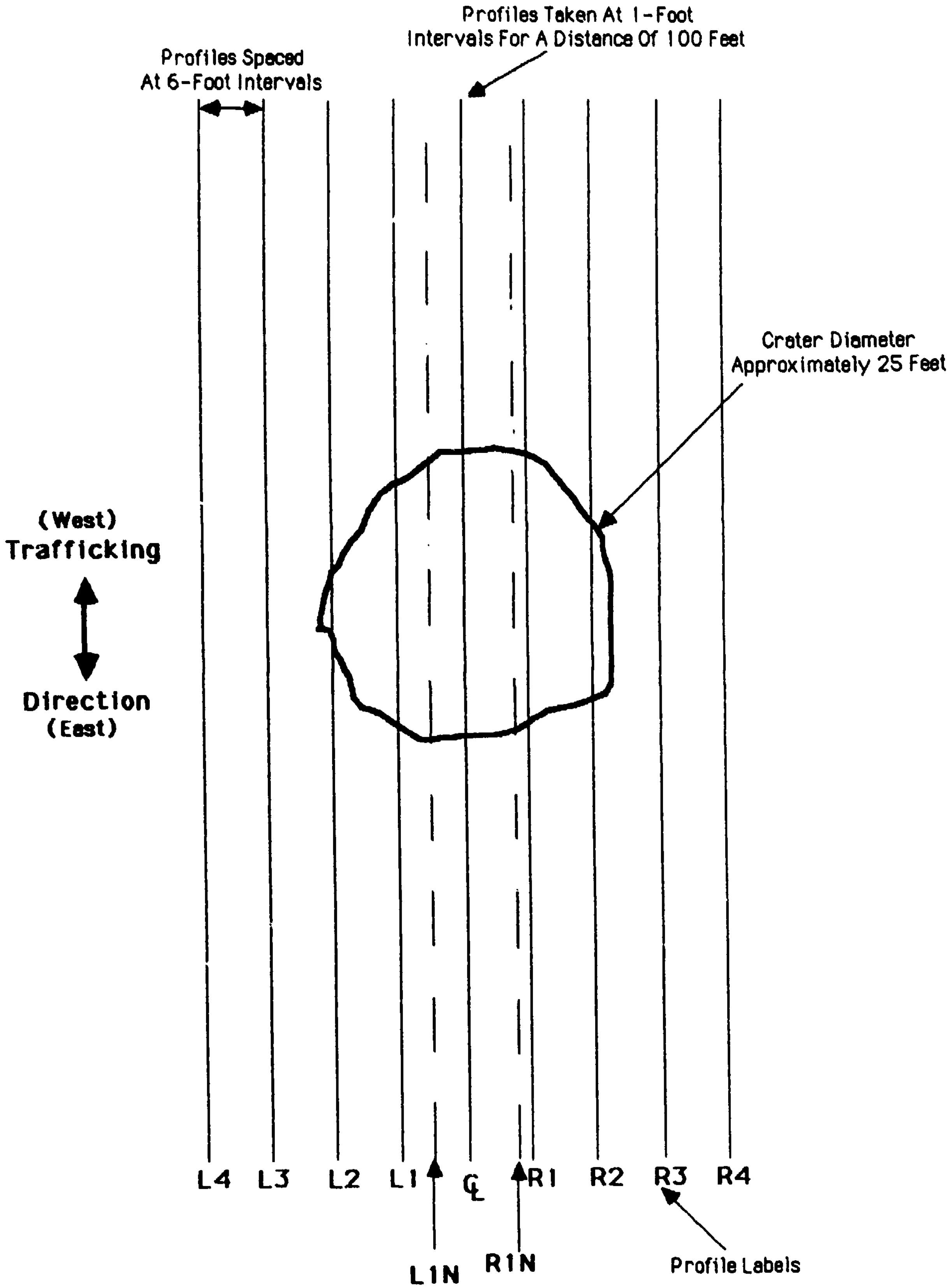


Figure 20. Repair Profile Line Locations

Both repair rutting and repair sag were determined from the profiles. Rutting or deformation is the vertical distance from a point on the finished repair surface to the same point on the final repair surface. Sag is the vertical distance from the highest point on the profile to the lowest point on the same profile.

Repair 1 rutted along two lines situated 9 feet apart. The lines were located 1 foot south of Line R1, and 2 feet north of Line L1. Similar rutting was observed on Repair 2 along lines 6 inches south of Line R1, and 3 feet north of Line L1. Profiles taken over areas of maximum rutting are annotated as "R1n" and "L1n." Note that Lines R1 and L1 are used as baselines for comparison with Lines R1n and L1n on each crater and provide only an estimate of the repair profile at lines R1n and L1n before traffic.

Table 3 lists the maximum deformation and sag recorded at each measurement interval. Figures 21 through 24 show the repair profile containing the maximum deformation values for Craters 1 and 2. The tables and figures illustrate that most rutting occurs within the first 40 to 50 passes, after which the repair stabilizes.

TABLE 3. MAXIMUM REPAIR DEFORMATION AND SAG

		NUMBER OF PASSES	DEFORMATIONS (INCHES)	LOCATION LINE	LOCATION STATION	SAG (INCHES)
REPAIR 1	MAT	14	1.44	L2	53	1.32
		40	2.04	L1N	48	2.16
		73	2.04	L1N	48	1.68
		108	2.16	L1N	48	2.40
	STONE	108	2.04	L1N	52	1.80
REPAIR 2	MAT	14	0.96	R2	65	1.68
		40	1.92	L1N	62	1.32
		71	1.92	L1N	62	1.32
		110	2.04	L1N	62	1.32
	STONE	110	1.32	L1N	53	1.00

Profiles also were taken on the crushed stone surfaces of Repairs 1 and 2 after the fiberglass mats were removed. The profiles on the crushed stone surfaces, illustrated in Figures 25 and 26, were taken along the same profile lines as profiles taken on the mat surfaces of Repairs 1 and 2, but at fewer stations.

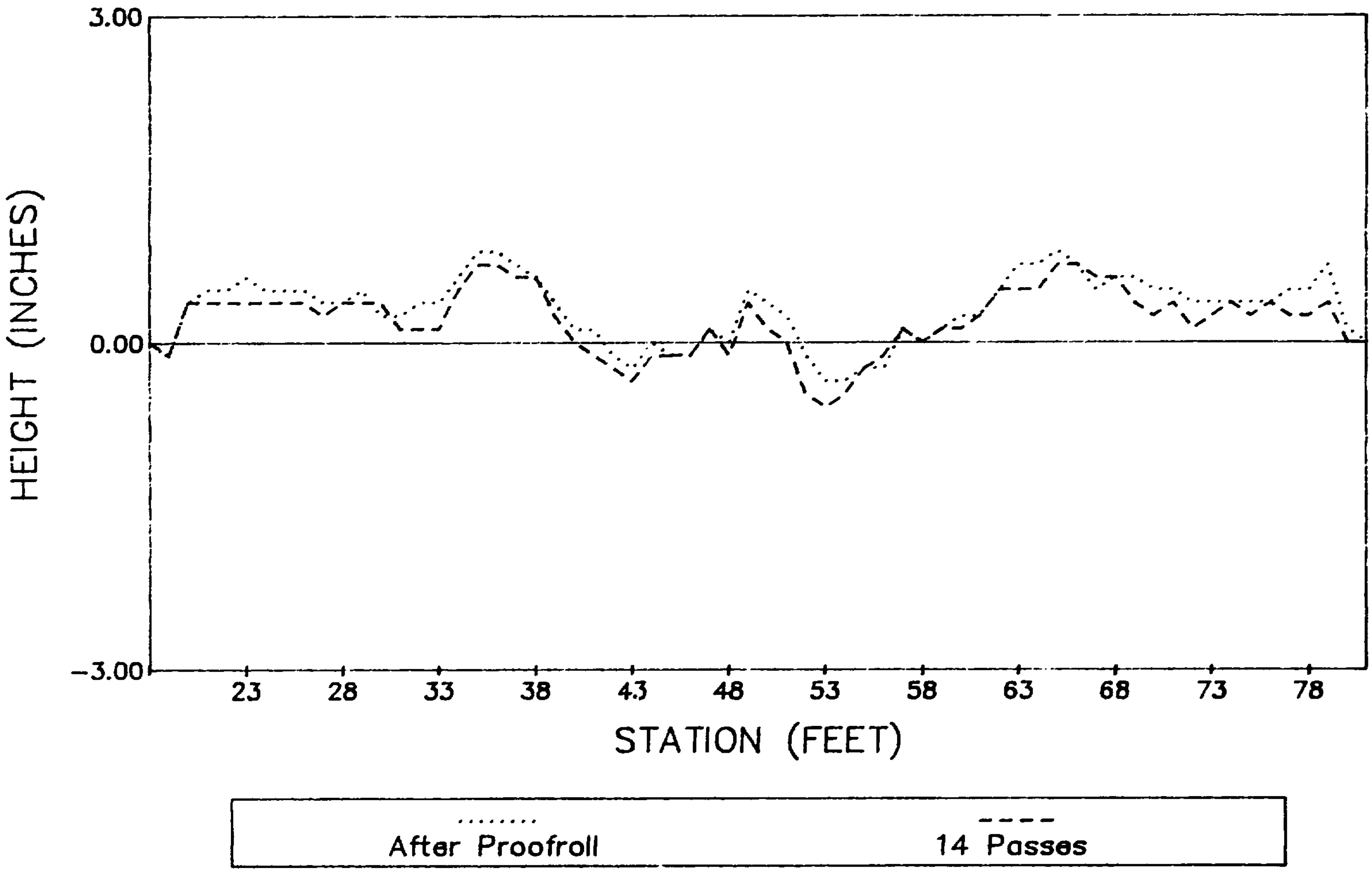


Figure 21. Maximum Deformation on Repair 1 After 14 Passes

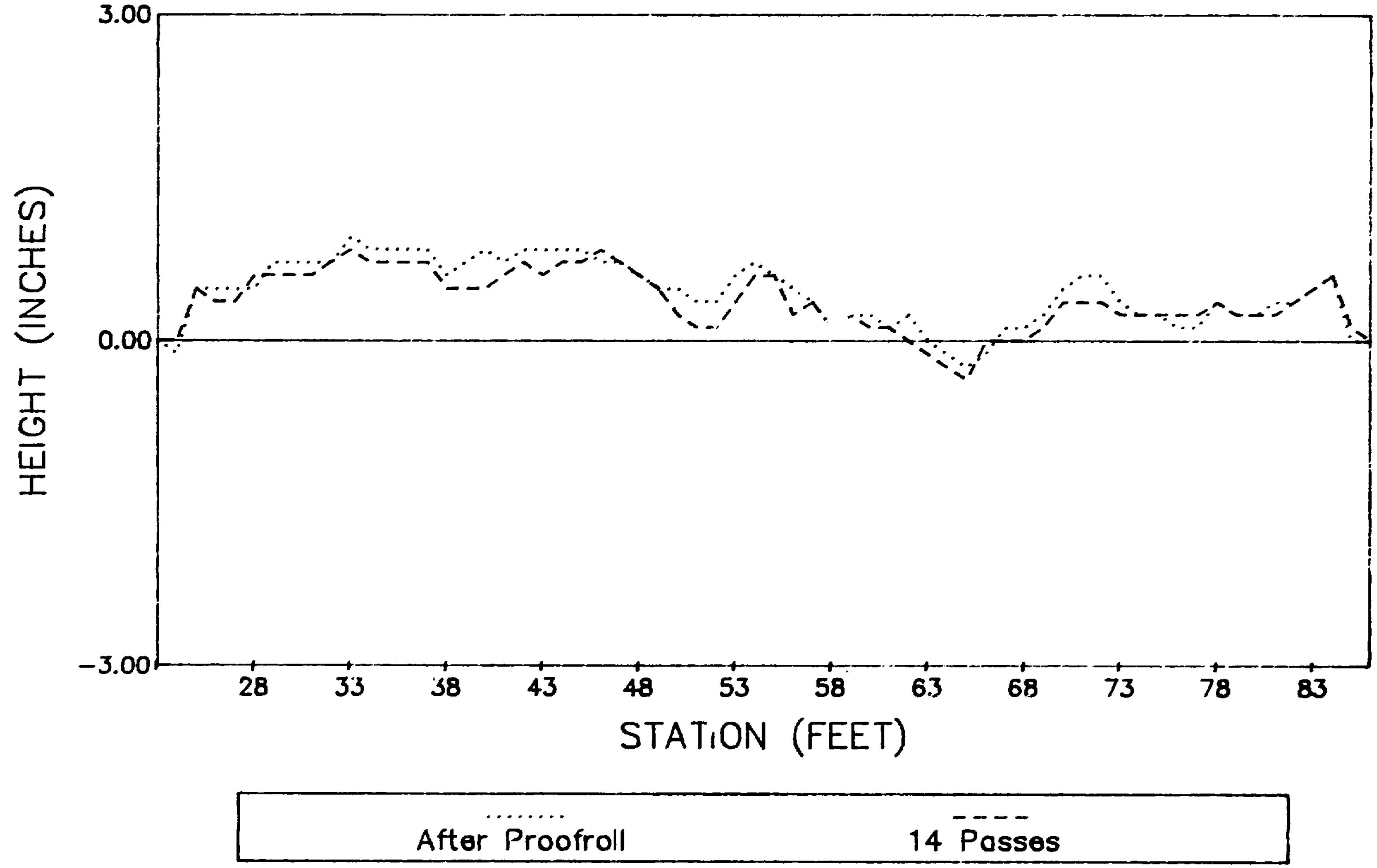


Figure 22. Maximum Deformation on Repair 2 After 14 Passes

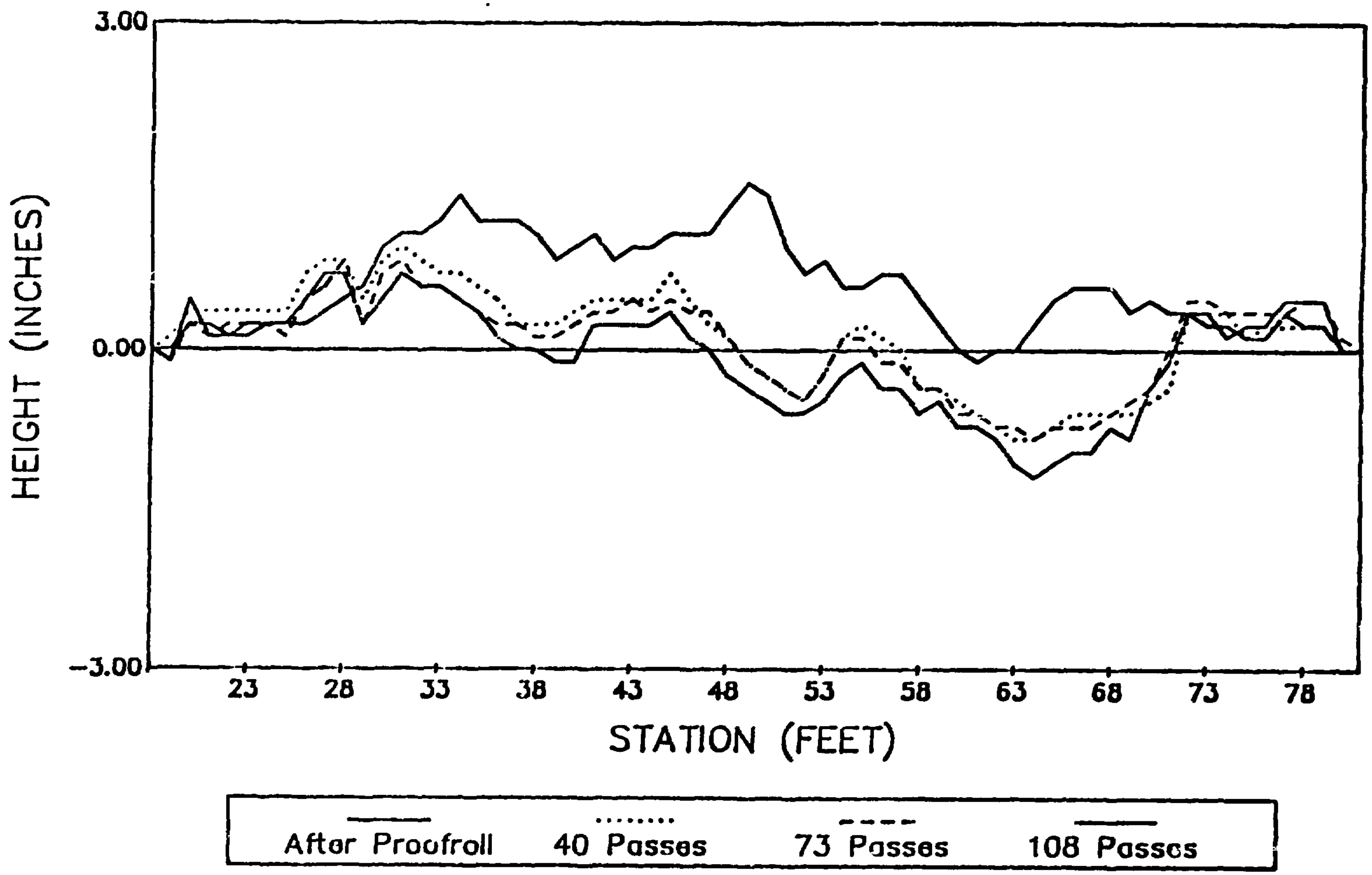


Figure 23. Maximum Repair Deformation of Repair 1
After 40, 73, and 108 Passes

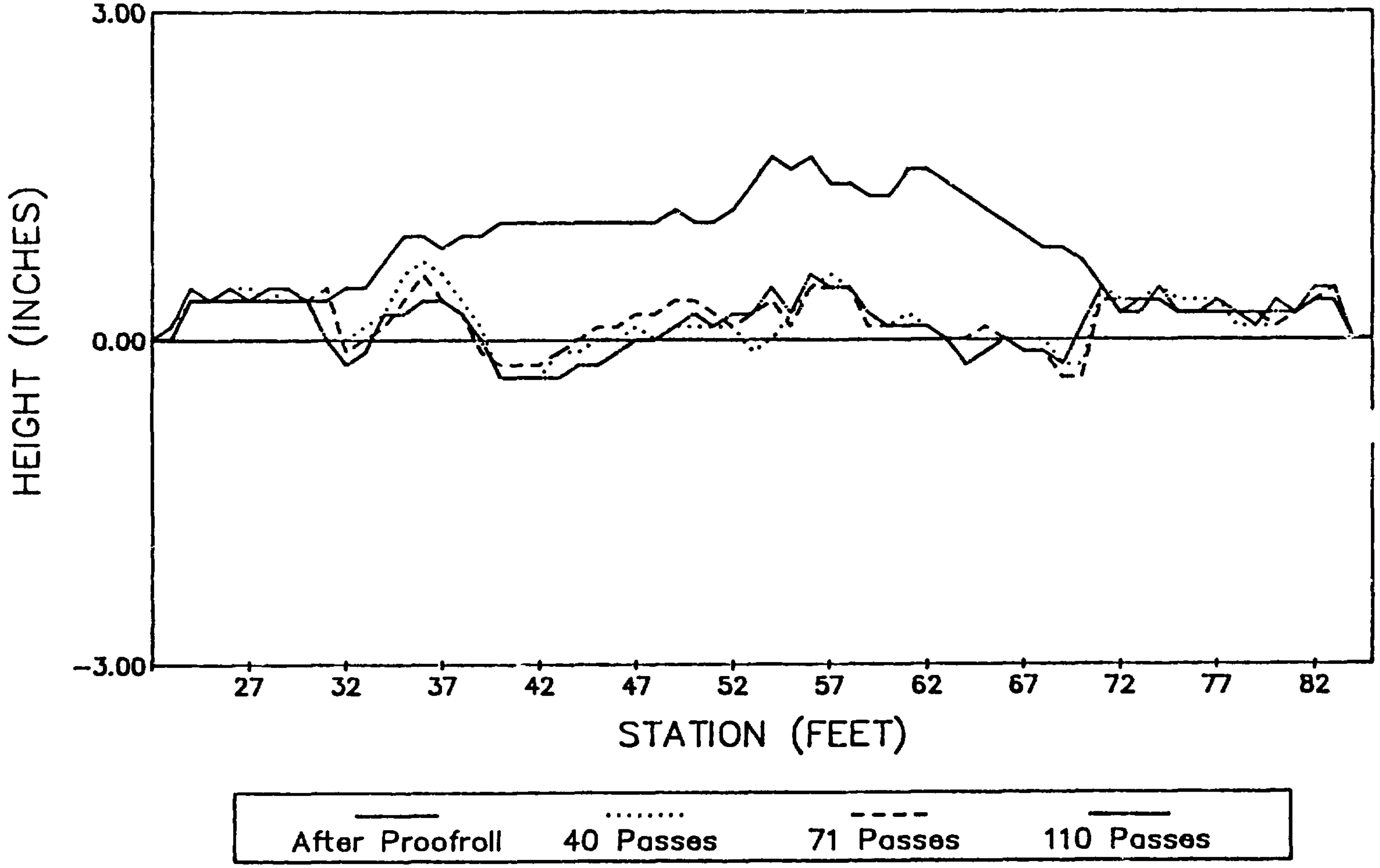


Figure 24. Maximum Repair Deformation of Repair 2
After 40, 71, and 110 Passes

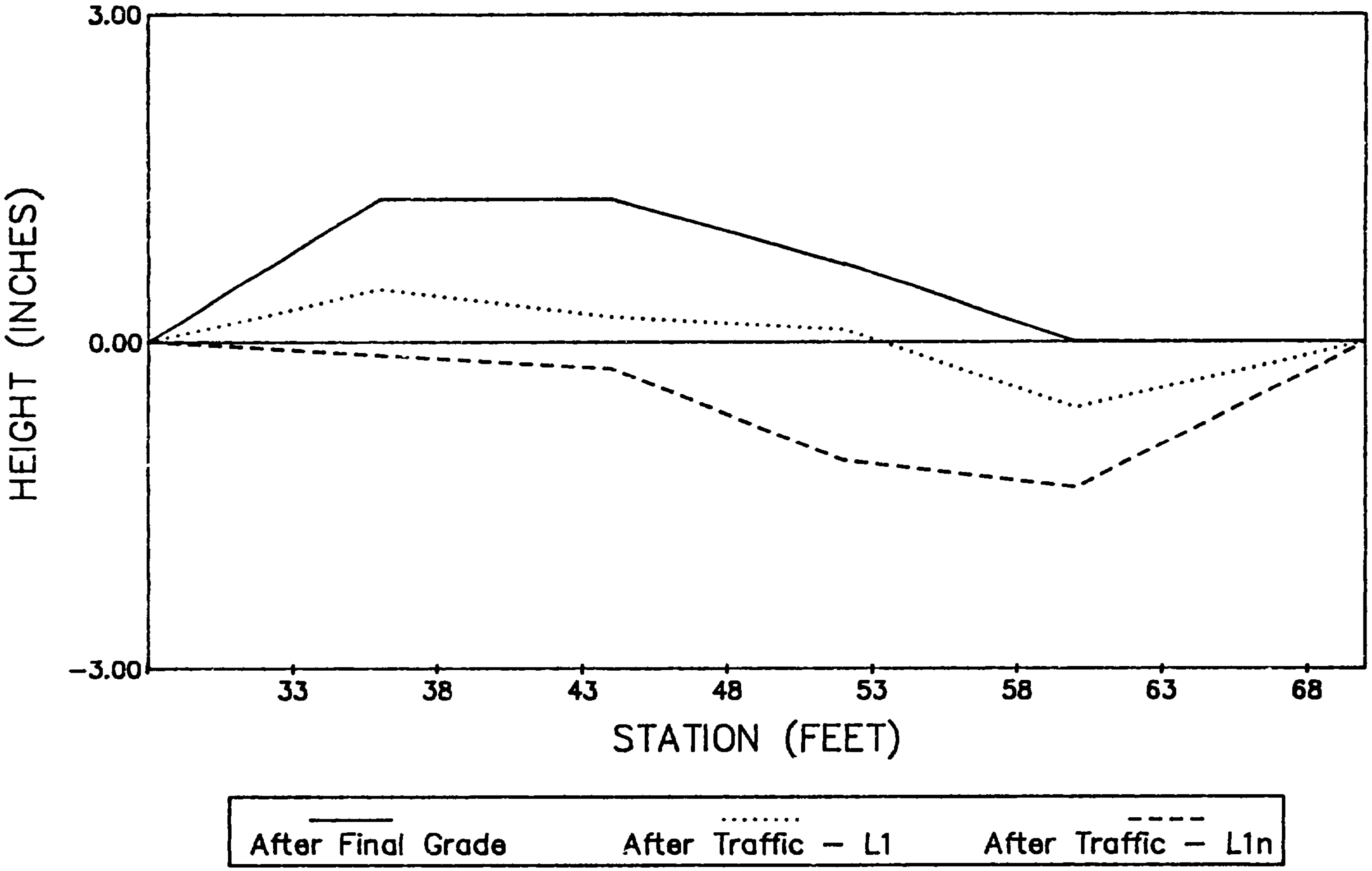


Figure 25. Maximum Repair Deformation of Repair 1, After 108 Passes (Measured on Crushed Stone Surface)

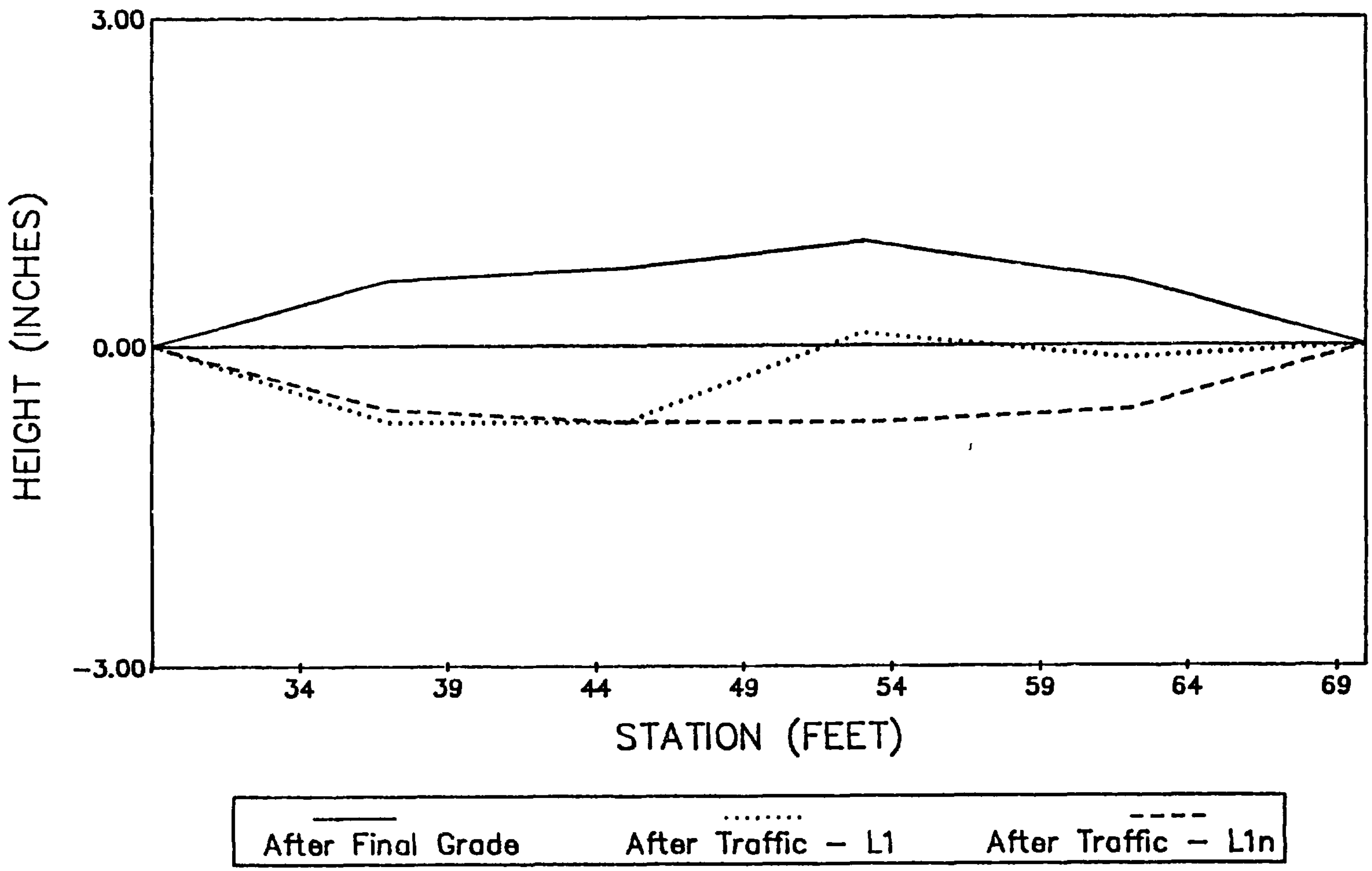


Figure 26. Maximum Repair Deformation of Repair 2, After 108 Passes (Measured on Crushed Stone Surface)

2. Mat Performance

No low waves were observed, either during aircraft trafficking or through post-trafficking analysis of high-speed videotape. After the test, careful review of each pass on 16 mm high-speed film also revealed no visible bow wave, but did uncover a slight "flutter" on the trailing edge of the mat. The "flutter" was noticeable during touch-and-go passes where the nose of the aircraft was elevated above the tail. Throughout trafficking, each mat remained securely anchored to the ground, and anchor bolts were not damaged.

Mat 1 withstood trafficking without damage. Excess Re-Pneu hinge material, however, became tacky and started to peel. Although some of this material did stick to the aircraft tires, its small quantity and soft consistency did not hinder the operation. A tear on Mat 2 was observed after Pass 69. The damage occurred on the mat's western section, near the joining panel, along the third hinge from the mat's southern edge. The damage consisted of a tear in the top ply of fiberglass in two directions. The tear measured approximately 5 feet along the hinge and approximately 2.5 feet across the fourth panel from the mat's south edge. The top ply had delaminated from the lower ply.

Inspection of the separated plies indicated that this area was not thoroughly saturated with resin during the manufacturing process. The white areas in Figure 27, a detailed view of the delaminated panel, illustrate bare fiberglass.

The mat was repaired in approximately 20 minutes, as follows:

a. First, existing joining bushings were removed to free the joining panel.

b. An 18-inch triangle of bare fiberglass was placed between the delaminated plies in Panel 4 (Figure 28). A 6- by 12-inch strip of bare fiberglass was placed between the mat and the joining panel. Finally, a 6-inch by 3-foot piece of fiberglass was placed under the upper ply of the torn hinge.

c. Two gallons of polyester resin (Owens-Corning) were poured on the bare fiberglass, and the ply was pressed down into place (Figure 29).

d. The bare fiberglass then was trimmed to remove rough edges (Figure 30).

e. Two holes were cut in the joining panel and in the underlying mat, one hole on each side of the tear, for placing joining bolts and bushings (Figure 31). Two 4-inch joining bushings were installed (Figure 32) to prevent jet blast from lifting the panels and further damaging the hinge and panel.

The resulting repair, shown in Figure 33, performed satisfactorily. Figure 34 shows the mat after 104 aircraft passes. Neat polymer, spilled during the repair, formed a thin, solid layer over a small area of the mat.

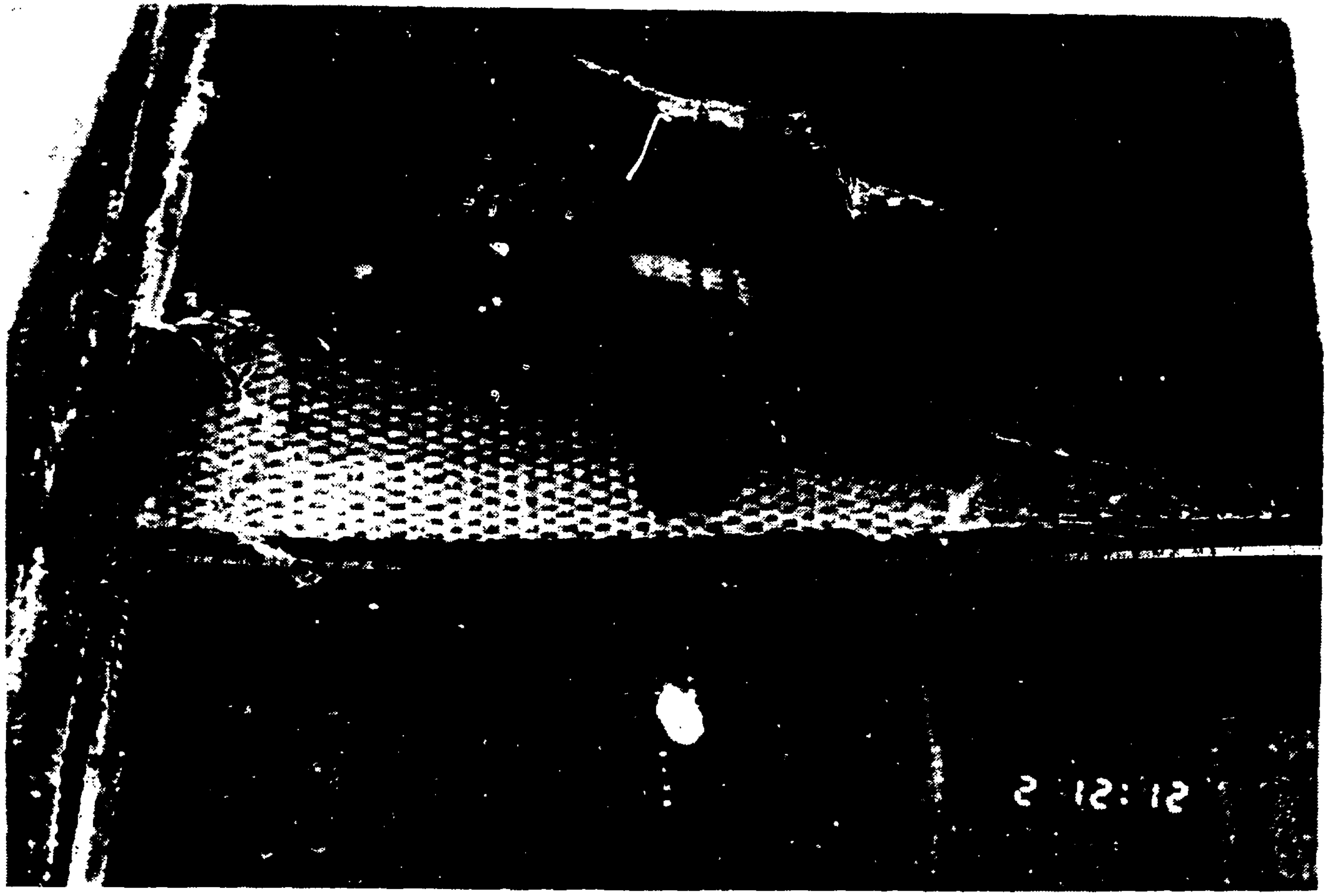


Figure 27. Closeup View of Mat Delamination

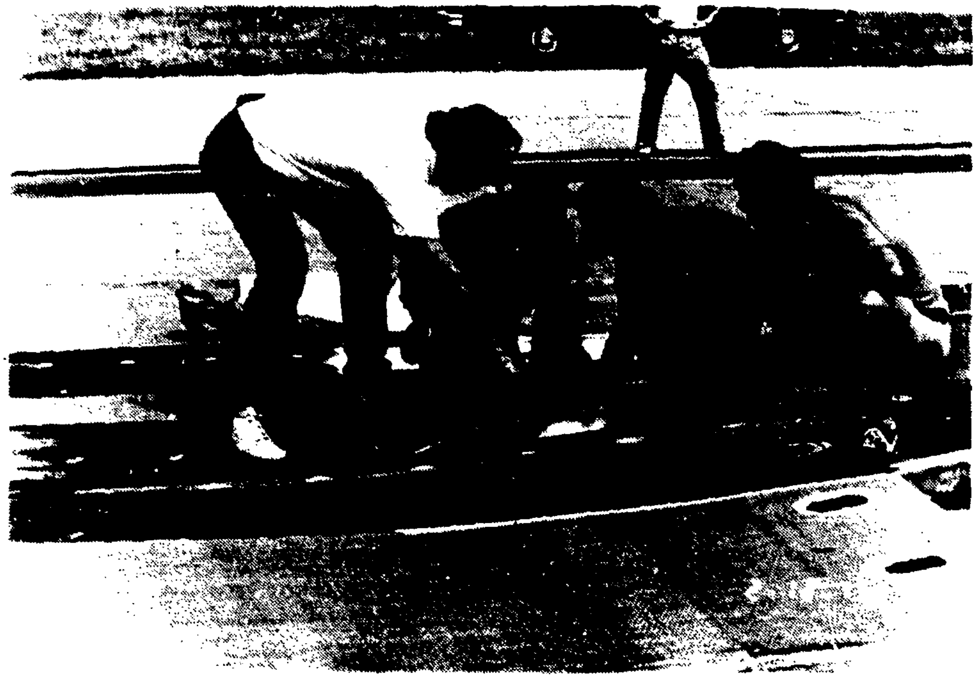


Figure 28. Adding Fiberglass to Tear

Figure 29. Adding Resin to Fiberglass Patch

Figure 30. Trimming Fiberglass

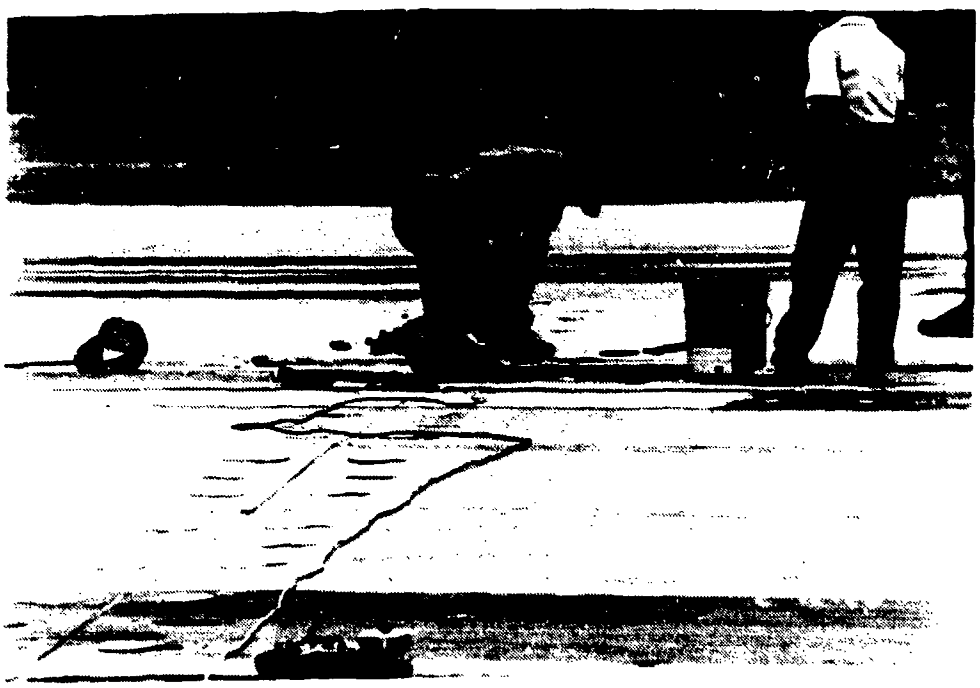


Figure 31. Drilling Holes for Additional Joining Bolts

Figure 32. Tightening Joining Bushings

Figure 33. Completed Mat Repair

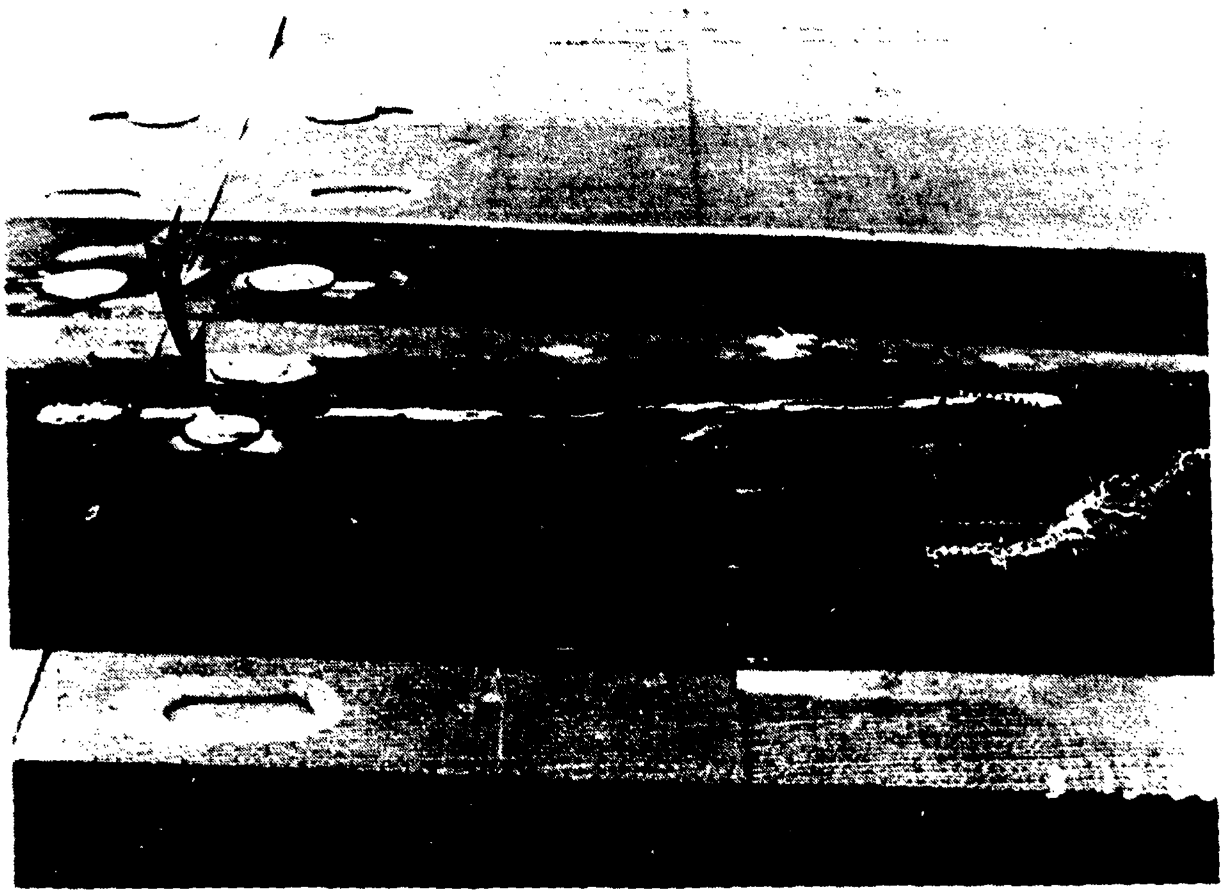


Figure 34. Repaired Mat Hinge After 104 Aircraft Passes

This layer shattered during subsequent trafficking. Apparently, the resin spilled on the painted surface of the mat (overpaint from the MOS marking test) and bonded to the paint rather than to the mat. Fragments of shattered resin were less than 1/4-inch thick and broke easily. Since the fragments were not judged to be an aircraft hazard, trafficking continued.

A minor tear, 13 inches long, developed along the hinge at the west edge of Mat 2, between the third and fourth panels from the mat's north side. However, the tear did not require repair.

3. Anchoring System Performance

Two types of concrete anchor bolts and bushings, plus a third type of bolt used for instrumentation, were installed during the test. Mat 1 was anchored with thirty 5/8-inch diameter, 5-inch long Wej-It anchor bolts with standard bushings and 16 instrumented bolts, described in Section 2. Mat 2 was anchored entirely with 3/4-inch diameter, 5-inch long anchor bolts and modified bushings.

Before trafficking, test personnel measured anchor bushing torque to determine the initial tightness achieved using the spanner wrench. Measurements were taken using a torque wrench with a memory feature (Utica Tool Company, Manufacturer Number D-A3250FM).

Table 4 shows anchor bushing locations, along with the measured initial anchor bushing torque, for each mat. For Mat 1, no activity occurred between initial installation and the time the measurements were recorded. For Mat 2, the paint machine had crossed the mat seven times, and the mat had been proofrolled between bushing installation and recorded measurements. As seen in Table 4, the tightness achieved on Mat 1 using the spanner wrench was, in most cases, less than the specified 35 foot-pounds. Bushings 6 through 23 on the west side of Mat 2 were originally tightened using the torque wrench instead of the spanner wrench. Zero values were recorded for these bushings to indicate that no initial torque measurement was taken. The larger bolts, used for Mat 2, also registered below the specified 60 to 65 foot-pounds. After bushing tightness was measured, the bushings were retightened to specified torques.

Test personnel checked bolts and bushings periodically during trafficking for failure (sheared or completely missing bolts or a mat torn from the bolt), damage (bent bolt, bent bushing, etc.,), or looseness. No bolt or bushing completely failed or was damaged; however, loose bushings were common throughout trafficking. Looseness was defined as movement under the examiner's foot when the examiner stepped on the bushing and rotated his foot. The location of each loose bushing was recorded, then the bushing was retightened to the specified torque.

Table 5 shows the number of loose bushings observed during periodic mat inspections. Tables 6 and 7 illustrate the number of times a given bushing was reported loose. Tables 6 and 7 also show the location of each bushing and mat panel.

TABLE 4. ANCHOR BOLT LOCATIONS AND INITIAL TORQUE MEASUREMENTS

	MAT 1				MAT 2			
MAT PANEL	EAST ANCHOR BUSHING NUMBER	INITIAL TORQUE (FT-LB)	WEST ANCHOR BUSHING NUMBER	INITIAL TORQUE (FT-LB)	EAST ANCHOR BUSHING NUMBER	INITIAL TORQUE (FT-LB)	WEST ANCHOR BUSHING NUMBER	INITIAL TORQUE (FT-LB)
1	1	35	1*	36	1	25	1	25
	2	10	2*	25	2	45	2	25
	3	15			3	50	3	35
2	4	15	3	20	4	50	4	32
	5	25	4	10	5	35	5	25
	6	20	5	10	6	40	6	20
3	7	20	6	0**	7	45	7	Bolt Loose
	8	20	7	0	8	50	8	15
	9	25	8	0	9	25	9	10
4	10*	10	9*	0	10	25	10	Bolt Loose
	11*	30	10*	0	11	30	11	20
					12	20	12	10
5	12*	20	11*	0	13	35	13	10
	13*	20	12*	0	14	35	14	28
					15	35	15	10
6	14*	5	13*	0	16	Bolt Stripped	16	20
	15*	25	14*	0	17	50	17	Bolt Loose
					18	35	18	35
7	16	10	15	0	19	35	19	10
	17	30	16	0	20	35	20	20
	18	25	17	0	21	35	21	40
8	19	20	18	0	22	50	22	25
	20	20	19	0	23	Not Recorded	23	20
	21	20	20	0	24	Not Recorded	24	20
9	22*	35	21	0				
	23*	45	22	0				
			23	0				

* ANCHORED WITH POLYMER FOR INSTRUMENTATION

** BUSHINGS NOT TIGHTENED WITH SPANNER WRENCH BEFORE MEASUREMENT RECORDED AS ZERO

TABLE 5. LOOSE BUSHINGS PER MAT INSPECTION

PASS NUMBER	NUMBER OF LOOSE BUSHINGS			
	MAT 1		MAT 2	
Repair 1/Repair 2	Anchor	Joining	Anchor	Joining
13 / 13	0	0	9	0
14 / 14	0	0	9	0
24 / 24	0	0	2	0
38 / 38	0	0	5	0
40 / 40	0	0	6	0
61* / 58*	2	11	7	0
71 / 69	0	3	0	2
73 / 71	0	0	3	1
102 / 104	0	3	9	2
SUMMARY				
Maximum Number of Loose Bushings at Any One Time	13		11	

* Occurred during the same trafficking event. Aircraft missed repair several times during touch-and-go operations.

TABLE 6. LOOSE BUSHINGS, MAT 1

MAT PANEL	EAST ANCHOR NUMBER	NUMBER OF TIMES LOOSE	EAST JOINING BUSHING NUMBER	NUMBER OF TIMES LOOSE	WEST JOINING BUSHING NUMBER	NUMBER OF TIMES LOOSE	WEST ANCHOR NUMBER	NUMBER OF TIMES LOOSE
1	1 2 3		1 2	1 1	1 2	1 1	1* 2*	
2	4 5 6		3 4	1 1	3 4	2 1	3 4 5	
3	7 8 9		5 6		5 6	1 1	6 7 8	 1
4	10* 11*		7 8		7 8	1 1	9* 10*	
5	12* 13*		9 10	 1	9 10		11* 12*	
6	14* 15*		11 12		11 12		13* 14*	
7	16 17 18		13 14	1	13 14	1	15 16 17	 1
8	19 20 21		15 16	 1	15 16	 1	18 19 20	
9	22* 23*		17 18	 1	17 18		21 22 23	

* ANCHORED WITH POLYMER FOR INSTRUMENTATION

TABLE 7. LOOSE BUSHINGS, MAT 2

PANEL	EAST ANCHOR NUMBER	NUMBER OF TIMES LOOSE	EAST JOINING BUSHING NUMBER	NUMBER OF TIMES LOOSE	WEST JOINING BUSHING NUMBER	NUMBER OF TIMES LOOSE	WEST ANCHOR NUMBER	NUMBER OF TIMES LOOSE
1	1	1	1		1		1	
	2	1	2		2		2	2
	3						3	
2	4		3		3		4	
	5		4		4		5	
	6						6	
3	7	1	5		5		7	
	8	4	6		6	1	8	
	9	4					9	2
4	10	2	7		7	2	10	2
	11		8	1	8	2	11	5
	12						12	3
5	13	1	9		9		13	4
	14	2	10		10		14	4
	15						15	2
6	16		11		11		16	3
	17		12		12		17	2
	18	1					18	1
7	19		13		13		19	1
	20		14		14		20	
	21	1					21	
8	22	1	15		15		22	
	23		16		16		23	
	24						24	

The first loose bushing on Mat 1 was discovered after Pass 61. The mat's leading edge (closest to the threshold) did not exhibit loose bolts; most loose bolts were found in the joining panel.

The bushings in Mat 2, however, required tightening after 13 aircraft passes (Table 5). Both anchor and joining bushings loosened, primarily near the mat's trafficking zone. Properly installed anchor bolts are perpendicular to the pavement, but many of the bolts were observed installed at an angle.

After the test, five installed anchor bolts were measured for straightness. A 4-inch diameter bushing was screwed onto each bolt. The distance between the lowest and the highest edge of the bushing was recorded, and the bolt angle was calculated. Measured distances ranged from 1/16 of an inch (1-degree angle) to 1/4 inch (4 degrees), with an average of slightly more than 5/32 inch (2.4 degrees).

4. Instrumentation Results

At the beginning of aircraft trafficking, 14 instrumented anchor bolts and 19 mat strain gauges were functional. After aircraft trafficking, all anchor bolts were functional, but only 10 mat gauges were operational. Further test results and analysis are presented in Volume II.

5. Repair Reaction to Jet Blast

The repaired craters experienced jet blast during touch-and-go (Figure 35) and takeoff operations and during the scheduled jet blast test at the conclusion of trafficking. During trafficking operations, afterburner blast was recorded five times on Repair 1, including one takeoff, and seven times on Repair 2. Pilots intentionally rotated over each repair. Neither mat showed visible or adverse reaction to the blast.

In the jet blast test, an F-15 taxied over each repair and stopped approximately 50 feet beyond the repair to simulate an operational engine run-up. (The F-16 was not used in this test.) The engine was run up to 80 percent military power for about 10 seconds on Mat 1 and 30 seconds on Mat 2. No effects were observed on either mat.

6. Pilot's Comments

The pilots commented that there were no noticable effects to the aircraft during taxiing or touch and goes. One pilot noticed a slight bounce as his aircraft crossed Repair 1; another said the repair was no more noticable than a rough seam on the runway. Several pilots felt the mats were difficult to see.

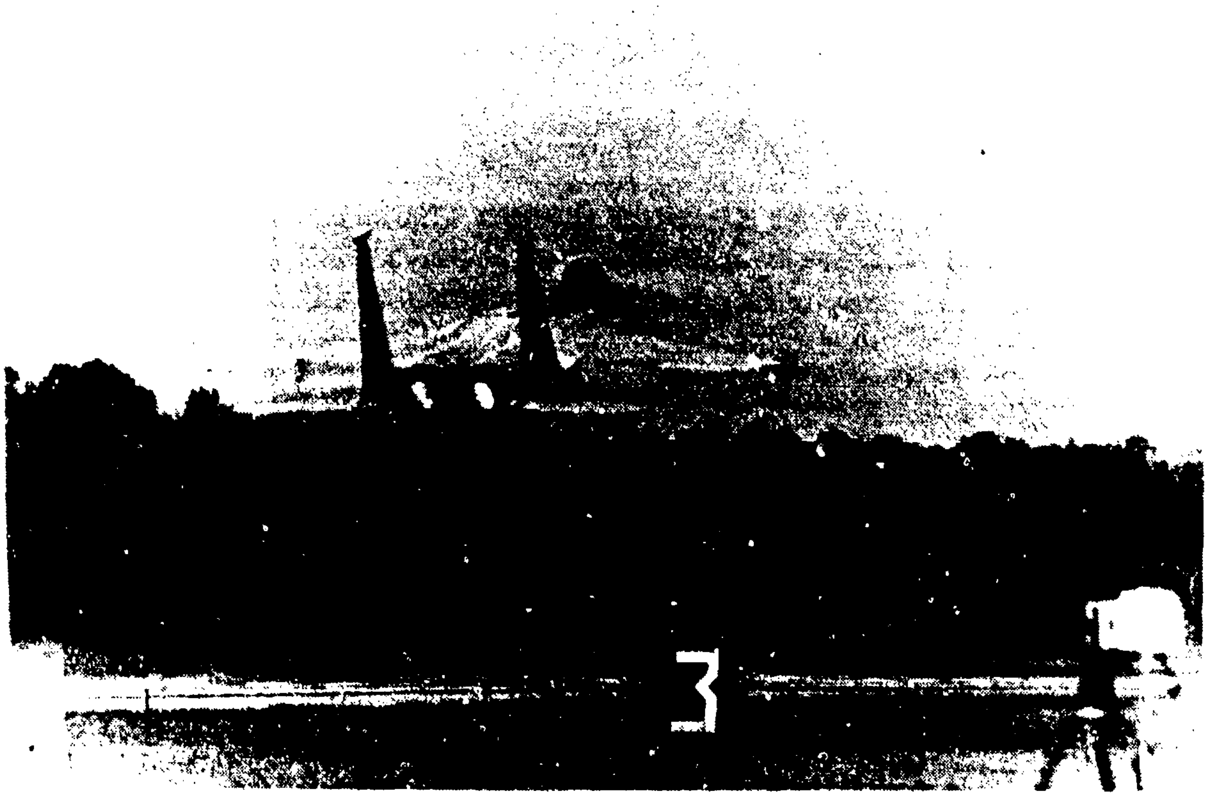


Figure 35. Afterburner Blast over Mat 2

D. CONCLUSIONS AND RECOMMENDATIONS

1. Objective 1

On both repairs, the FFGM Repair System exceeded the minimum performance requirements. Each repair sustained in excess of 100 aircraft passes, remained within surface roughness tolerance limitations, and did not require maintenance necessitating mat removal. Except for the minor tear and delamination on Mat 2, the commercially produced, hinged fiberglass mats performed well and did not exhibit permanent mat deformation (severe delamination, tears, etc.).

2. Objective 2

Data were collected successfully from the instrumented mat according to the criterion established in the test objectives. All bolt gauges in operation on the first day of trafficking were operational at trafficking completion, and 12 of the 20 mat gauges survived trafficking. The data and comparison with an analytical model are reported in Volume II.

3. Objective 3

Hinge orientation had no significant effect on repair performance. Hinge orientation effectiveness was to be evaluated based on rutting; however, neither repair exhibited significant rutting, and relative rutting was about equal.

4. Objectives 4 and 6

In general, the anchoring system held the mats solidly throughout all phases of trafficking and during the jet blast test. No anchors pulled free; tore the mat; or were bent, deformed, or sheared.

The bushings, however, loosened often. According to the test pass/fail criteria, the modified bushings performed below the acceptable criteria. The modified bushings were loose on the 13th pass, when the criteria specified 30 passes.

One suspected cause of the bushing loosening is the imprecise installation of bolts and bushings. As observed, bolt holes were not drilled perpendicular to the pavement. In many cases, this prevented the bushing from seating properly against the mat. Improper seating, in turn, may transfer torque from the movement of the mat to the bushing.

The modified bushing, on the other hand, was designed to seat against the pavement. However, many bushings were observed to seat against the mat. Late delivery of the bushings prevented proper tolerance checks and corrective action. For this reason, as well as the imprecise installation, conclusions cannot be drawn on the performance of the modified versus the standard bushing.

Finally, the mechanism of bolt loosening and its impact on mat system performance must be studied further.

5. Objective 5

Bow waves were not observed during the test or on high-speed film.

6. Objective 7

Both mats and the anchoring system performed well during the jet blast test and under afterburner blast during trafficking. Neither mat showed adverse reaction to jet blast.

SECTION III

UPHEAVAL MEASUREMENT TEST

Upheaved pavement is identified using a standard stringline device (see Figure 36). Procedures for using the stringline are given in Rapid Runway Repair Interim Guidance, September 1984 (Chapter 6, pages 26-32) and in the North Field Test Plan (Appendix G).

The purpose of the Upheaval Measurement Test was to conduct a side-by-side comparison of the three upheaval measurement devices. Air Force Prime BEEF teams, using each device, would identify the upheaved pavement around the two explosively formed craters. The relative accuracy of each device would be determined by comparing the results to results from a rod-and-level survey.

One major problem exists with the standard stringline. The string cannot be stretched more than 40 feet without excessive sag in the line. Excessive sag greatly reduces the accuracy and, hence, repeatability of upheaval measurements. Because the upheaval measurement on larger repairs may exceed the capability of the stringline, the possibility exists of measuring upheaved pavement from upheaved or damaged pavement.

Two potential devices for improving the identification of upheaved pavement around a bomb crater have been developed. The first is the modified stringline shown in Figure 37. The modified stringline is based on the same concept as the standard stringline, but uses 1/16-inch steel cable, tensioned with a hand-cranked winch. The additional strength allows more tension over a greater distance. By minimizing sag, the accuracy of the modified stringline should be superior to the standard stringline.

The second device is the Dipstick (see Figure 38), originally developed to measure the levelness of large concrete areas, such as floors in warehouses. The Dipstick is a battery-powered electronic device used to determine the relative slope between two points exactly 1 foot apart. Using the Dipstick, upheaved pavement can be identified along a specific profile line by an abrupt change in the pavement's slope. By measuring the slope along a series of profile lines across damaged pavement surrounding the crater, the upheaved pavement area can be identified.

A. TEST OBJECTIVES AND PASS/FAIL CRITERIA

1. Determine the absolute accuracy of the stringline, the modified stringline, and the Dipstick upheaval measurement methods.

Pass/Fail Criteria

a. Initial identification of the start of upheaval within 2 feet of the point determined by a rod-and-level survey.

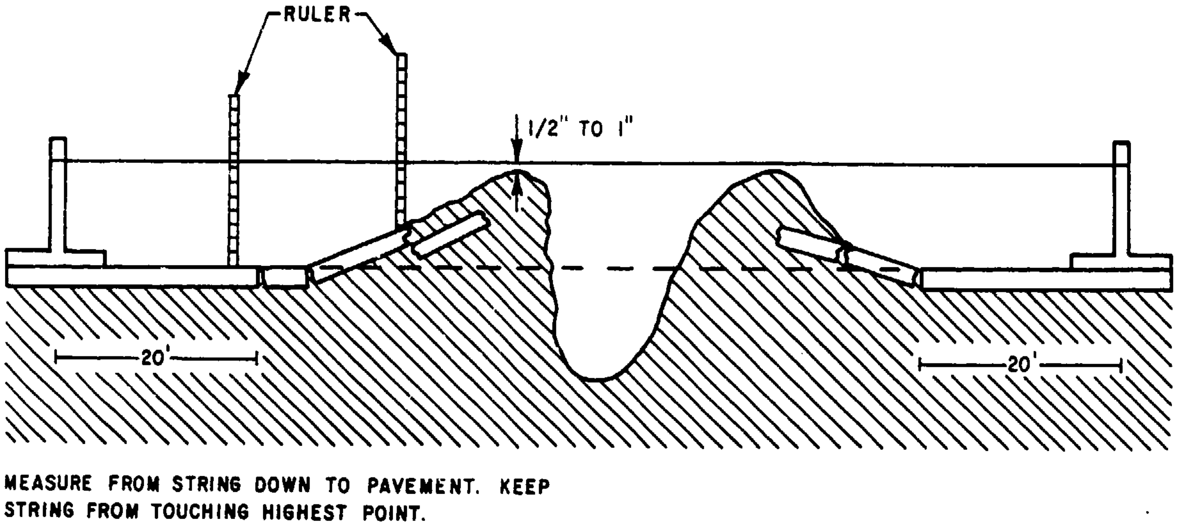


Figure 36. Standard Stringline

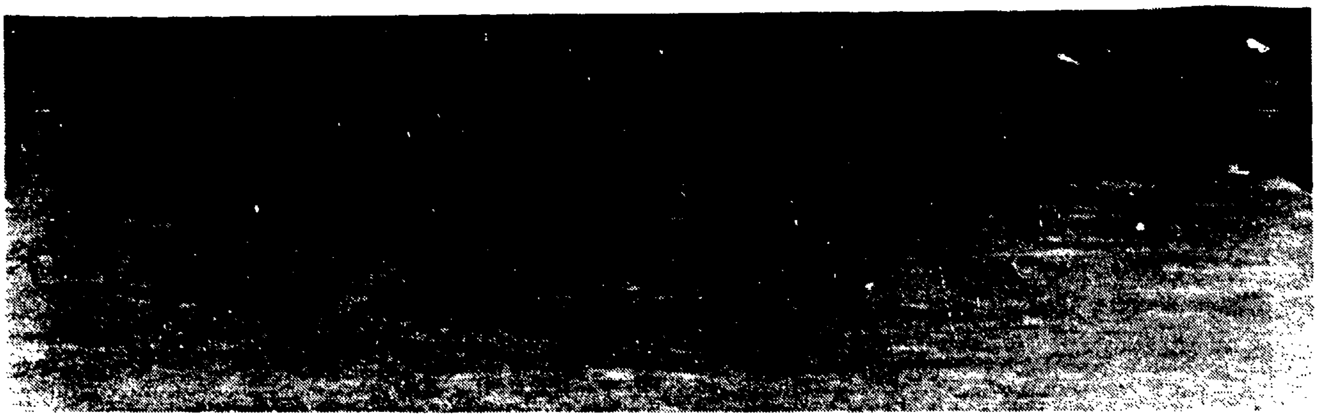


Figure 37. Modified Stringline

Figure 38. Upheaval Measurement Using the Dipstick Pavement Profiler

b. Intermediate measurement (measurement after upheaval has been removed): within ±3/4 inch vertical of rod-and-level survey.

2. Identify Each Method's Repeatability

Pass/Fail Criterion

Each team must identify all upheaval to be removed (for a flush repair).

3. Determine the absolute measurement time, and compare each of the three tested method's measurement times.

Pass/Fail Criteria

a. Initial measurement completed within 10 minutes of teams arriving at the crater.

b. Intermediate measurement completed within 15 minutes of teams arriving at the crater.

B. TEST DESCRIPTION

The Upheaval Measurement Test was conducted in conjunction with the crater repairs. Teams for each tested device were selected from Prime BEEF personnel from Shaw AFB. Two three-man teams were formed for the standard and modified stringline, and one, two-man team was formed for the Dipstick. Each team, except the team for the modified stringline, measured the upheaval on both craters.

During training, the 1/16-inch stainless steel cable of the modified stringline broke, and attempts to locate and replace the cable were unsuccessful. This permitted a side-by-side comparison between only the standard stringline and the Dipstick at North Field. To fulfill the objectives of the North Field Test, subsequent testing, comparing the standard and modified stringlines, was conducted at Field 4, Eglin AFB, Florida, in October 1987. Results from the Field 4 test are included in this section.

1. North Field Testing

a. Preparation

Each team received approximately 1 hour of classroom instruction on each device, followed by 1 to 2 hours of field training before actual testing. A detailed description of the upheaval training (classroom and field) conducted at North Field is found in Section V.

Before the start of upheaval measurement testing, a rod-and-level survey was conducted on the two explosively formed craters, in accordance with the profile configuration shown in Figure 20. This survey was the baseline from which the accuracy (horizontal and vertical) of each candidate device was determined.

b. Measurement Procedures

Measurement procedures followed those described in Rapid Runway Repair Interim Guidance (September 1984) for the standard stringline, and those given in the North Field Test Plan (Appendix G) for the Dipstick and modified stringline. In general, upheaval identification requires three measurements:

(1) Initial Measurement

Initial measurements are taken at the beginning of the crater repair process to quickly identify the upheaved pavement so breakout and removal can begin. Initial stringline measurements, both standard and modified, are taken in triangular fashion around the crater. The Dipstick measures initial upheaval in parallel profile lines in the direction of traffic. For the Dipstick, data recorded from the initial measurement are entered into a computer, which plots profiles of the pavement around the crater.

(2) Intermediate Measurement

Intermediate measurements are taken after the upheaved pavement has been removed. The intermediate measurement acts as a check to ensure all required upheaved pavement has been removed before completing the repair. Intermediate measurements for each device are taken parallel to the runway heading.

(3) Quality Control Measurement

This measurement is taken after the crater repair has been completed. The quality control measurement not only ensures the pavement around a repair meets surface roughness criteria (SRC), with respect to upheaval, but also that the surface of the repair itself meets SRC.

At North Field, only initial measurements were taken because of the constraints involved in repairing the craters in time for aircraft operations. Since two Dipstick operators were used, each operator obtained a set of initial measurements per crater. A single initial measurement was obtained for the stringline. All devices and corresponding measurements were evaluated for speed, accuracy, and repeatability.

2. Field 4, Eglin AFB Testing

Upheaval measurements, using both standard and modified stringlines, were taken at Field 4, Eglin AFB between 13 and 19 October 1987. A three-worker team from Field 4 measured upheaval on a single, explosively formed, 25-foot diameter crater.

Before upheaval measurement, the crater was surveyed according to the profile pattern established for the craters at North Field (Figure 20).

Also, the measurement team was trained in the modified stringline measurement method for 30 to 60 minutes.

At Field 4, both initial and intermediate upheaval measurements were recorded. The intermediate measurement procedures for the modified stringline were used for intermediate measurements taken with the standard stringline. This was done so there could be a direct comparison between results. With each stringline, three initial measurements and two intermediate measurements were recorded.

Also, the intermediate measurements were taken before the crater upheaval was removed. Several intermediate measurements could not be taken because the upheaved pavement interferred with the string.

C. TEST RESULTS

1. North Field Testing

a. Crater 1

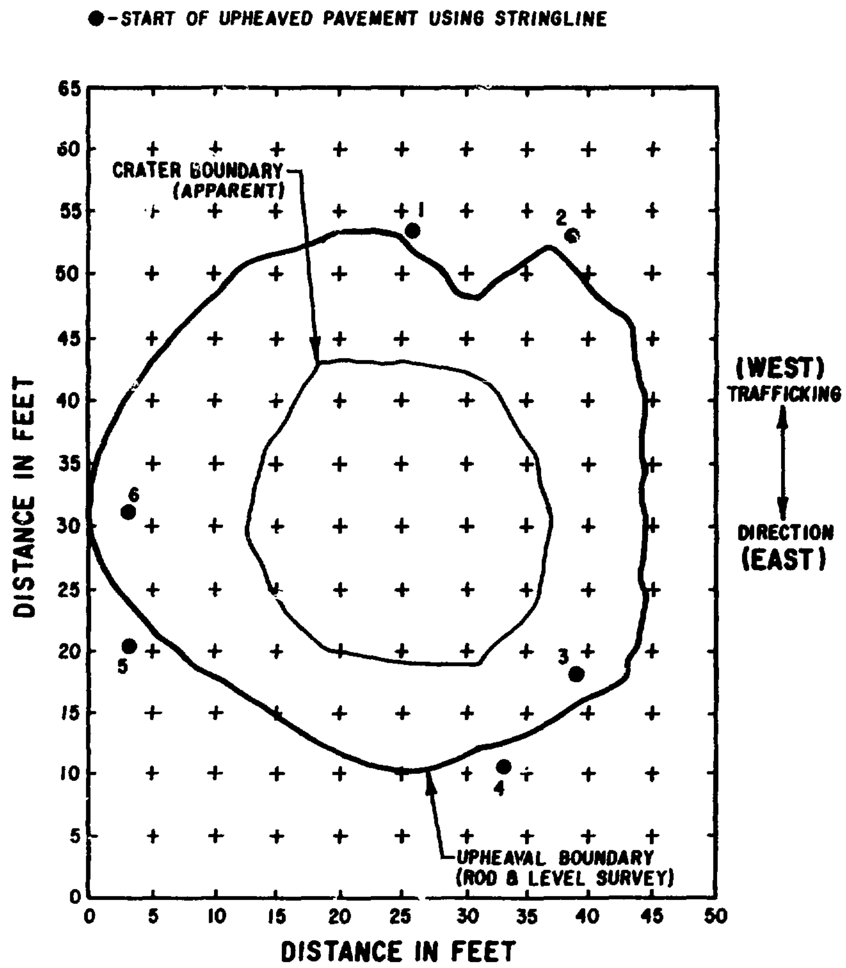
Initial measurement results for the standard stringline are shown in Figure 39. The location of the six measurement points are plotted in relationship to the crater and to the upheaval boundary determined by the rod-and-level survey. Figure 39 also shows the distance of each point from the upheaval boundary, the elevation difference from the closest rod-and-level elevation point, and the time to complete all indicated measurements.

Figure 40 shows the initial measurement results for the Dipstick. The upheaval points determined by each operator are plotted against the actual upheaval boundary. Because the Dipstick measures along profile lines, measurement points are referenced by profile line and location, either east or west of the crater. Corresponding elevation differences and measurement times also are reported.

Figures 39 and 40 show that both the standard stringline and the Dipstick measured upheaval boundary within the actual boundary determined by the rod-and-level survey. Of the six measurements taken, the stringline met the test accuracy criterion (± 2 feet from the actual upheaval boundary) 67 percent of the time. For the Dipstick, the first operator met the horizontal criterion 20 percent of the time, the second operator, 43 percent of the time. Although not part of the initial measurement criterion, all but one of the elevation measurements, including measurements taken inside the upheaval boundary, were within the 3/4-inch upheaval tolerance.

b. Crater 2

Initial measurement results for the standard stringline are given in Figure 41. Figure 42 shows the initial measurement results for the Dipstick. These figures again show that both the stringline and the Dipstick measured upheaval boundary within the boundary pavement area. This time, however, the stringline team and both Dipstick operators met the horizontal

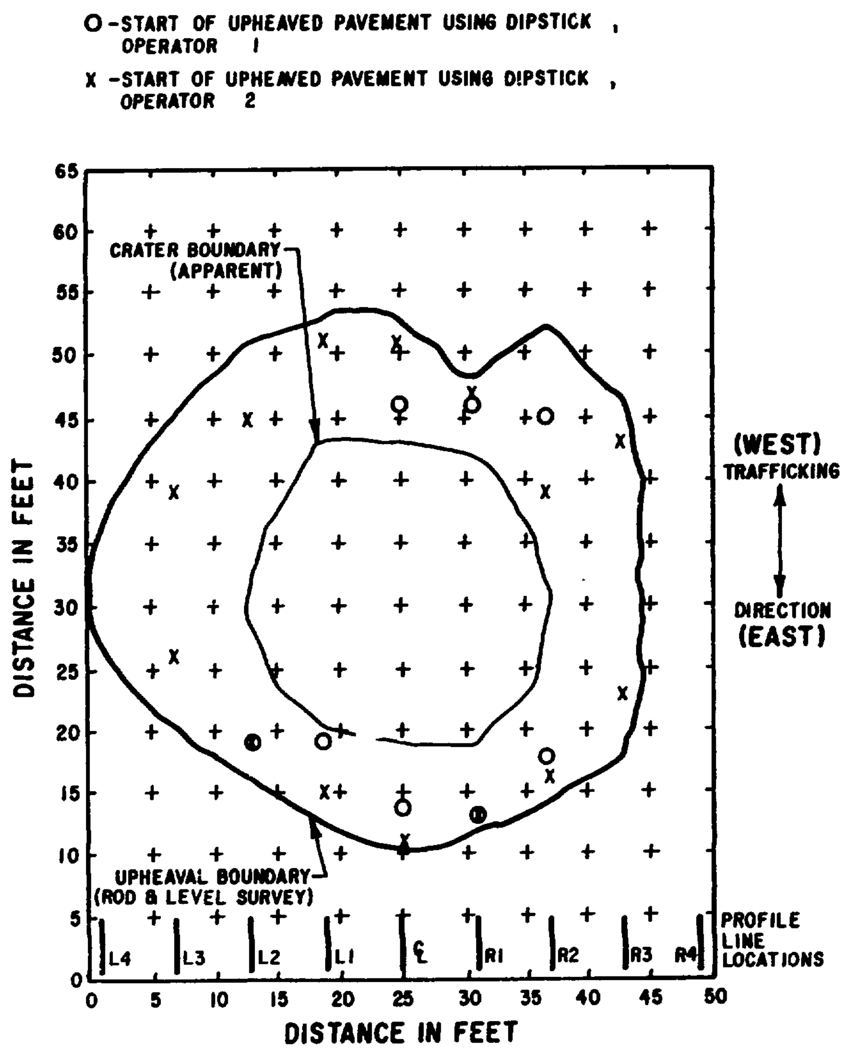


Marked Points	Distance From Upheaval Boundary (Feet)*	Elevation Difference (Inches)**
1	+1	-0.24
2	+2	-0.12
3	-2	-0.24
4	+2	+0.12
5	+3	-0.12
6	-4	+0.48

Measurement Time (min:sec) 5:26

* (-): Marked point within upheaved area
(+): Marked point outside upheaved area
** (-): Marked point lower than upheaval boundary
(+): Marked point higher than upheaval boundary

Figure 39. Crater 1 Stringline Initial Upheaval Measurement Results



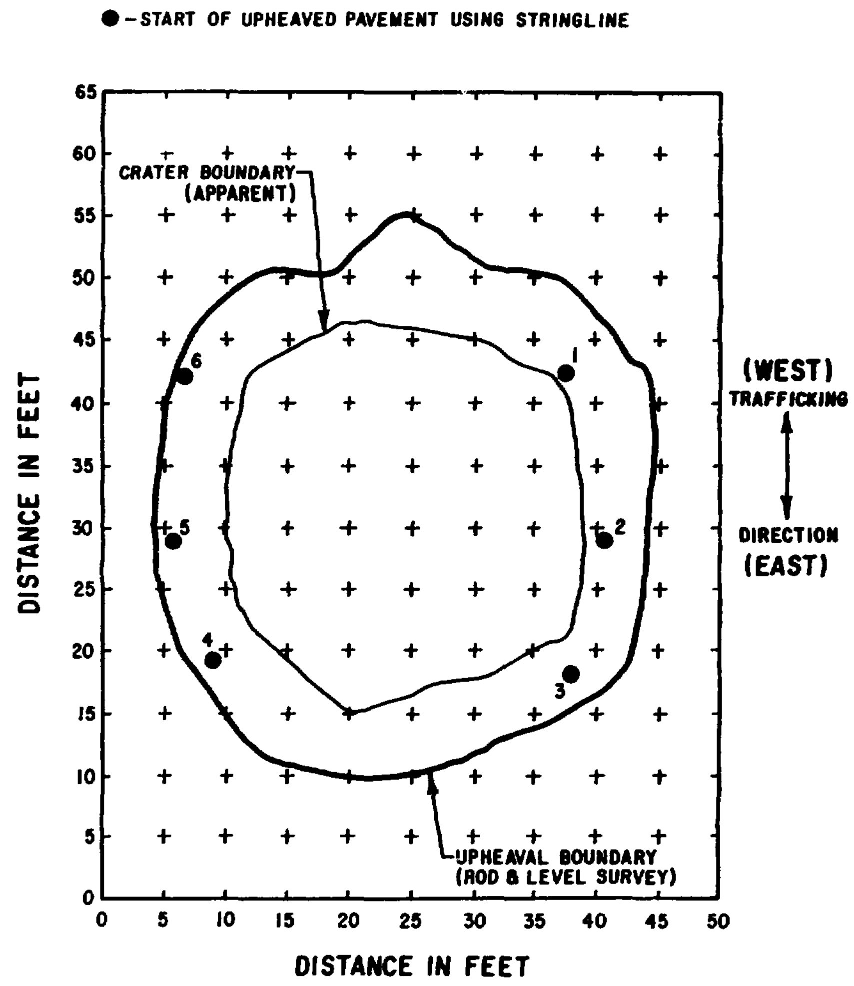
Profile Line	Distance From Upheaval Boundary (Feet)*			
	Operator 1		Operator 2	
	East	West	East	West
L4	----		----	
L3	----		-6	-6
L2	-4	N/A	-4	-6
L1	-4	N/A	-3	-2
CL	-4	-7	-1	-2
R1	-1	-2	-1	-1
R2	-4	-8	-2	-14
R3	----		-4	-4
R4	----		----	

Profile Line	Elevation Differences (Inches)**			
	Operator 1		Operator 2	
	East	West	East	West
L4	----		----	
L3	----		----	
L2	-0.12	N/A	+0.36	+0.48
L1	+0.12	N/A	-0.12	+0.48
CL	+0.24	+1.08	0	+0.12
R1	+0.12	+0.48	+0.12	+0.24
R2	+0.12	+0.36	+0.12	+1.20
R3	----		+0.24	+0.12
R4	----		----	
Measurement Time (min:sec)	9:53		10:46	

* (-): Marked point within upheaved area
(+): Marked point outside upheaved area

** (-): Marked point lower than upheaval boundary
(+): Marked point higher than upheaval boundary
N/A: Operator reported no upheaval

Figure 40. Crater 1 Dipstick Initial Upheaval Measurement Results



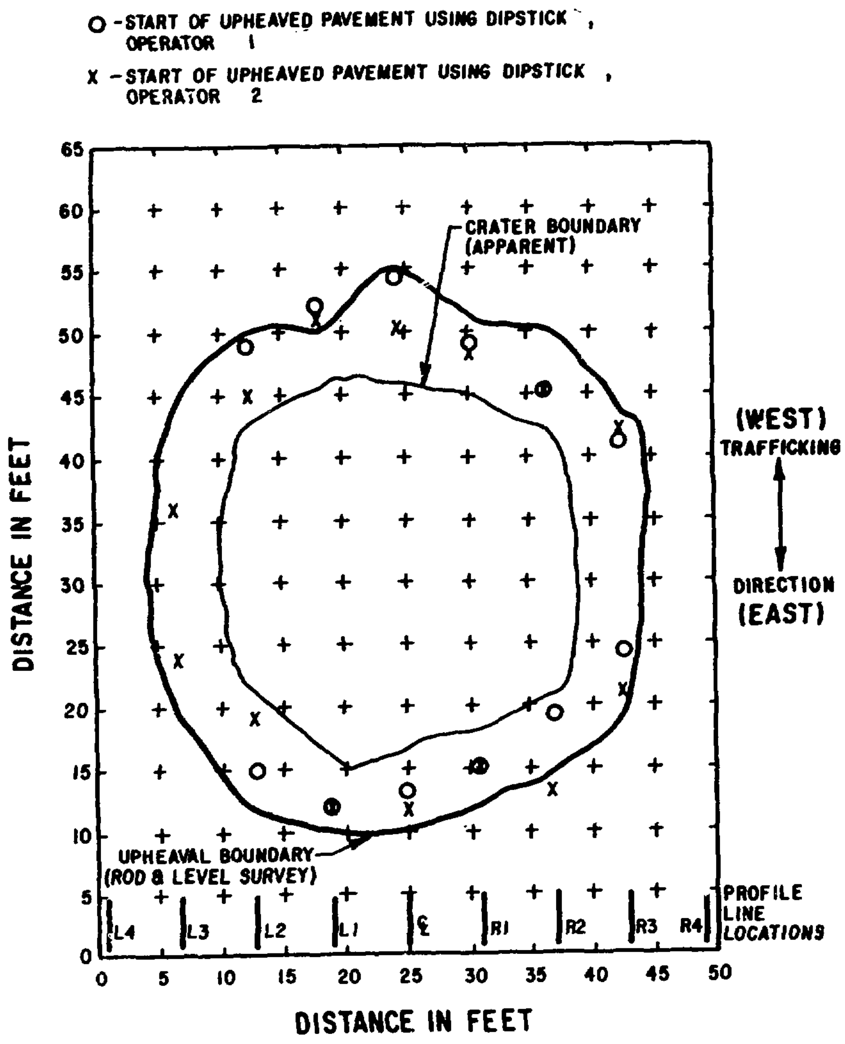
Marked Points	Distance From *Upheaval Boundary* (Feet)*	Elevation *Difference* (Inches)**
1	-5	+1.30
2	-3	+1.00
3	-3	+0.24
4	-2	+0.12
5	-2	+0.12
6	-1	0

Measurement Time (min:sec) 4:30

* (-): Marked point within upheaved area
(+): Marked point outside upheaved area

** (-): Marked point lower than upheaval boundary
(+): Marked point higher than upheaval boundary

Figure 41. Crater 2 Stringline Initial Upheaval Measurement Results



Profile Line	Distance From Upheaval Boundary (Feet)*			
	Operator 1		Operator 2	
	East	West	East	West
L4	----		----	
L3	----		-4	-8
L2	-3	-1	-7	-4
L1	-2	+2	-2	+1
CL	-3	-1	-2	-4
R1	-3	-2	-3	-3
R2	-5	-5	+1	-5
R3	-5	-2	-2	-1
R4	----		----	

Profile Line	Elevation Differences (Inches)**			
	Operator 1		Operator 2	
	East	West	East	West
L4	----		----	
L3	----		+0.60	+0.96
L2	+0.36	+0.12	+1.32	+0.60
L1	+0.12	-0.36	+0.12	-0.36
CL	+0.84	+0.12	+0.24	+0.60
R1	+0.36	+0.48	+0.36	+0.60
R2	+0.60	+0.72	-0.12	+0.72
R3	+0.24	+0.36	+0.12	+0.24
R4	----		----	
Measurement Time (min:sec)	9:26		9:09	

* (-): Marked point within upheaved area
(+): Marked point outside upheaved area
** (-): Marked point lower than upheaval boundary
(+): Marked point higher than upheaval boundary

Figure 42. Crater 2 Dipstick Initial Upheaval Measurement Results

all but three points, including those points within the upheaval boundary, were within the 3/4-inch vertical tolerance.

c. Summary

Results from Craters 1 and 2 at North Field indicate that the Dipstick and the standard stringline cannot, in many cases, identify upheaval to within the 2-foot horizontal accuracy criterion. However, most measured values were within acceptable vertical tolerance.

The stringline measurement time met the 10-minute measurement criterion. Caution, however, must be exercised in interpreting the Dipstick measurement time. The total time for the Dipstick operation is reported as the summation of the time to complete each profile line, rather than as an overall operational time. This was done because additional instruction were given to the operator between profile measurements. An overall event time was not taken.

2. Field 4, Eglin AFB Testing

Upheaval measurement testing was conducted at Field 4 on a single, explosively formed, 25-foot diameter crater during 13 to 19 October 1987. Before testing, a rod-and-level survey was conducted similar to that conducted at North Field. Three operators tested both the standard and modified stringlines.

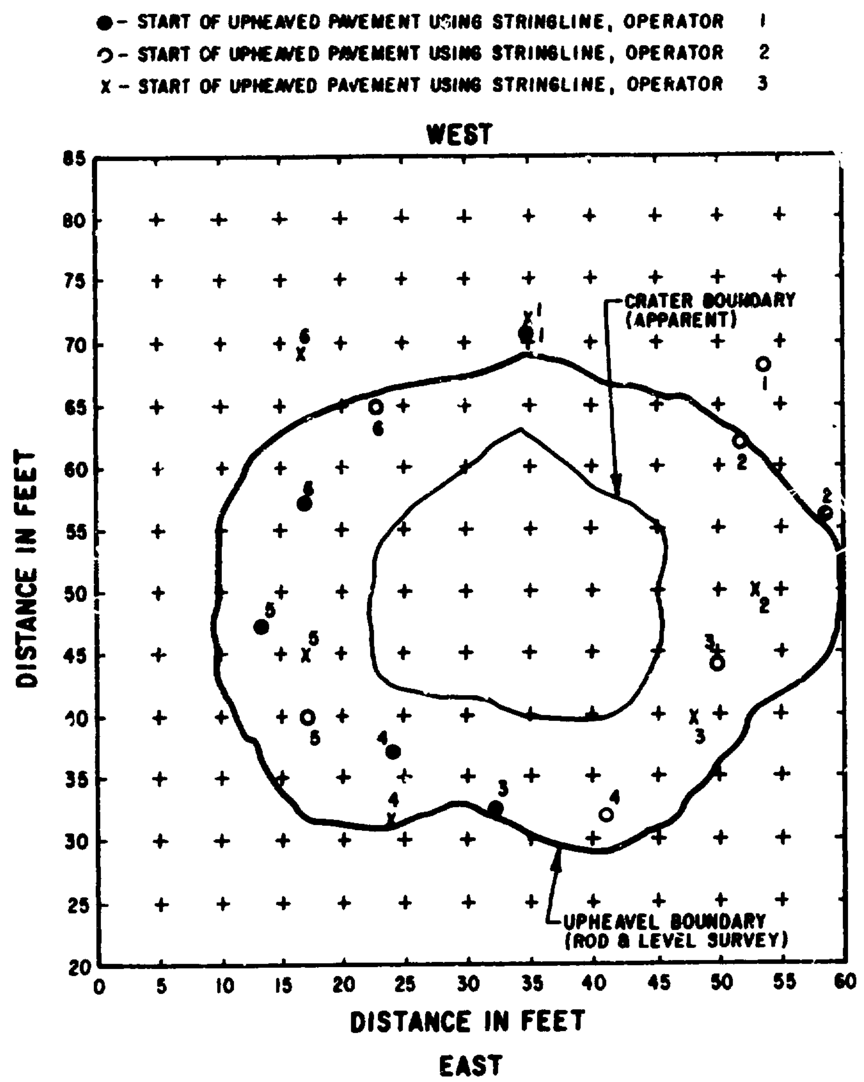
a. Initial Measurements

Initial measurement results for the standard stringline are given in Figure 43. Initial measurement results for the modified stringline appear in Figure 44. The upheaval boundary points measured by each of the three operators are plotted against the location of the upheaval boundary determined by rod-and-level survey. Deviations from the actual upheaval boundary, as well as elevation differences and measurement time, are recorded for each operator tested.

Figure 43 shows that most points measured using the standard stringline lie within the area of upheaved pavement. However, most points measured using the modified stringline lie outside the upheaval boundary. Two of the three stringline operators met the horizontal accuracy criterion 50 percent of the time, whereas the third operator only met the criterion once in six times. One modified stringline operator met the criterion 67 percent of the time; the other operators registered 50 and 17 percent.

b. Intermediate Measurements

Although intermediate measurements usually are taken after the upheaval is removed from the crater, at Field 4 the upheaval was left in place. Only the measurement procedures differed. Thus, for each stringline, measurements were taken with the strings stretched in the anticipated traffic direction over the repair, rather than in a triangular pattern around the crater.



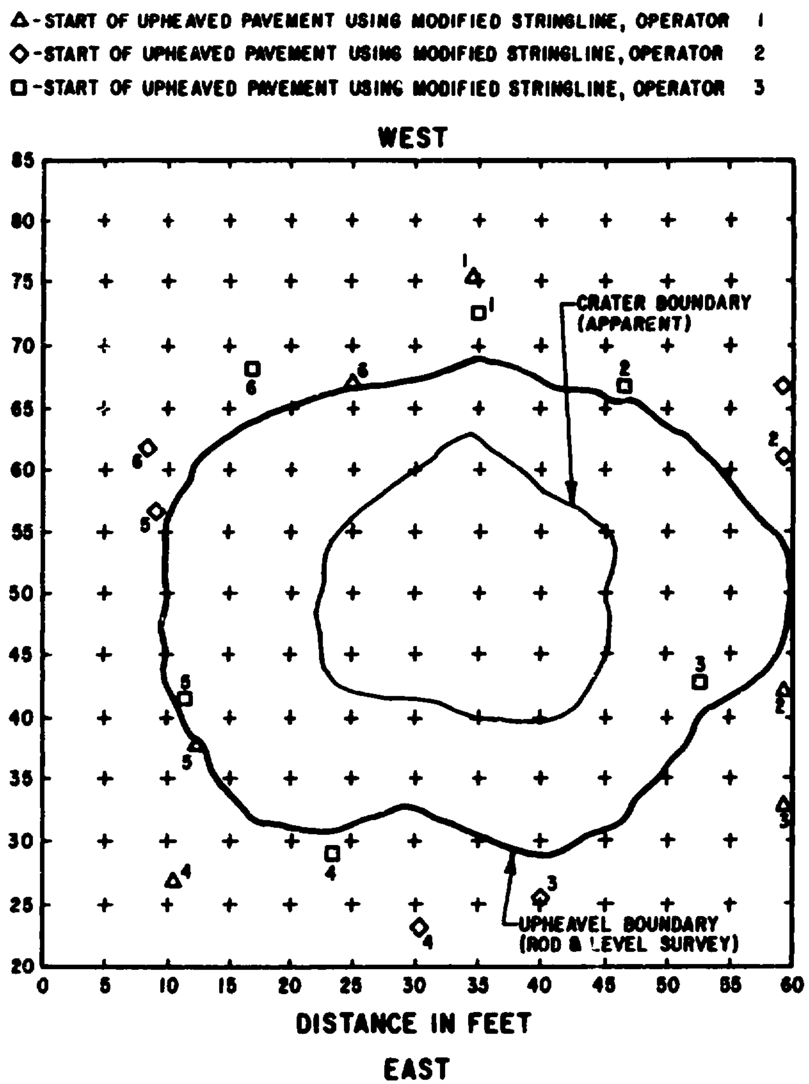
Marked Points	Distance From Upheaval Boundary (Feet)* Operator 1	Operator 2	Operator 3
1	+2	-1	+3
2	+1	+5	-7
3	-1	-4	-4
4	-6	-2	-1
5	-4	-5	-7
6	-6	-1	+5

Marked Points	Elevation Difference (Inches)** Operator 1	Operator 2	Operator 3
1	-0.36	-0.12	-0.48
2	-0.24	-0.12	+1.32
3	0.00	+0.36	-0.24
4	+1.08	+0.12	-0.24
5	+0.72	+0.12	+1.20
6	+0.36	+0.24	-0.48
Measurement Time (min:sec)	3:15	3:20	2:45

* (-): Marked point within upheaved area
(+): Marked point outside upheaved area

** (-): Marked point lower than upheaval boundary
(+): Marked point higher than upheaval boundary

Figure 43. Field 4 Stringline Initial Upheaval Measurement Results



Marked Points	Distance From Upheaval Boundary (Feet)* Operator 1	Operator 2	Operator 3
1	+7	+8	+4
2	+2	+5	+1
3	+9	+4	-2
4	+8	+7	+2
5	0	+2	0
6	+1	+4	+4

Marked Points	Elevation Difference (Inches)** Operator 1	Operator 2	Operator 3
1	-0.72	+0.72	+0.12
2	-0.24	-0.60	+0.12
3	-0.48	-0.24	+0.12
4	-0.60	[illegible]	-0.12
5	0.00	[illegible]	0.00
6	0.00	[illegible]	-0.48
Measurement Time (min:sec)	7:07	[illegible]	4:26

* (-): Marked point within upheaved area
(+): Marked point outside upheaved area
** (-): Marked point lower than upheaval boundary
(+): Marked point higher than upheaval boundary

Figure 44. Field 4 Modified Stringline Initial Upheaval Measurement Results

Figures 45 and 46 show intermediate measurement results for the standard stringline and the modified stringline, respectively. Although only vertical measurements and time were required, horizontal distances from the actual upheaval boundary were reported. Because the upheaval was not removed, the effectiveness of the intermediate measurement as a check on the previously determined values was not possible. However, the effectiveness of using the intermediate procedures as an initial measurement could be studied.

Using the standard stringline, and measuring along the profile lines, mixed results were obtained. For Operator 1, 25 percent of the measured points met the horizontal criterion. For Operator 2, 31 percent of the measured points were acceptable. Each operator, however, was hindered by interference with the crater rim.

Using the modified stringline and again, measuring along the profile lines, better results were obtained. Fifty-six percent of the first operator's measured points were within the established criterion. For Operator 2, 75 percent of the measured points were acceptable.

The measurement times, when compared to the initial measurement time criterion, compared favorably. Each operator measured upheaval in less than the required 30 minutes. (The 15-minute criterion mentioned in the objectives applies only to the intermediate measurement time. As mentioned above, the intermediate measurement was not used as a quality control measurement because the upheaval was not removed.)

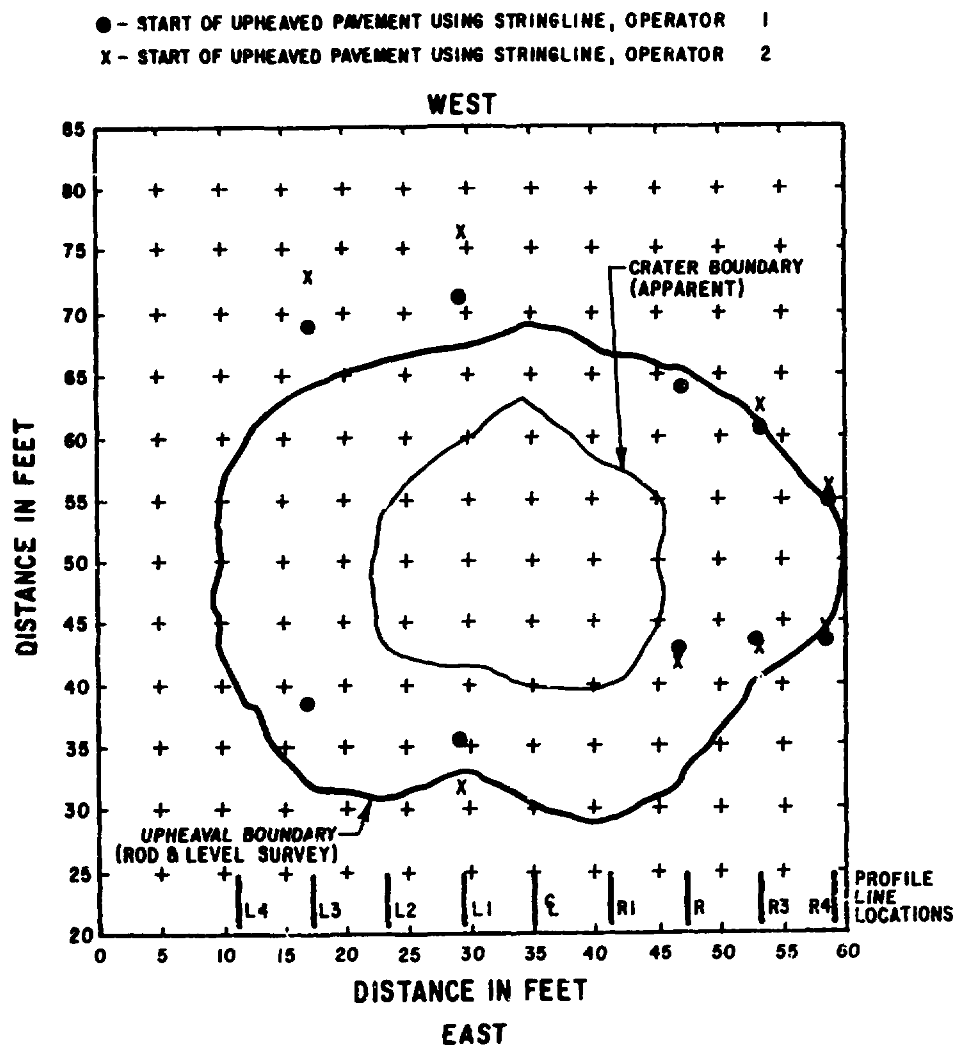
3. Analysis

A statistical analysis of upheaval measurement data from North Field 87 and Field 4 was conducted. Tables 8, 9, and 10 present the mean and standard deviations for the horizontal and vertical accuracies recorded for each upheaval measurement device in relation to the benchmark upheaval points determined by rod-and-level surveys. Table 7 presents the results for the stringline and Dipstick used at North Field. Mean accuracies and standard deviations are given as a function of crater numbers and operator. The overall mean and standard deviation of each device was determined by combining all measurement results for that device.

Tables 9 and 10 report the Field 4 analysis results for initial and intermediate measurements, respectively.

Based on the means given in Tables 8, 9, and 10, the horizontal accuracy of the three tested upheaval measurement devices (regular stringline, modified stringline, and Dipstick) is poor, falling well outside the 2-foot measurement criteria. On the other hand, vertical accuracy of the devices falls within the 0.75-inch criteria. However, for all devices, standard deviations for both vertical and horizontal accuracy indicates they provide poor repeatability of measurement results.

The statistical analysis conducted is based on a limited number of data points. Consequently, a high confidence level in the analysis results is not possible. However, the analysis is adequate in identifying trends in the

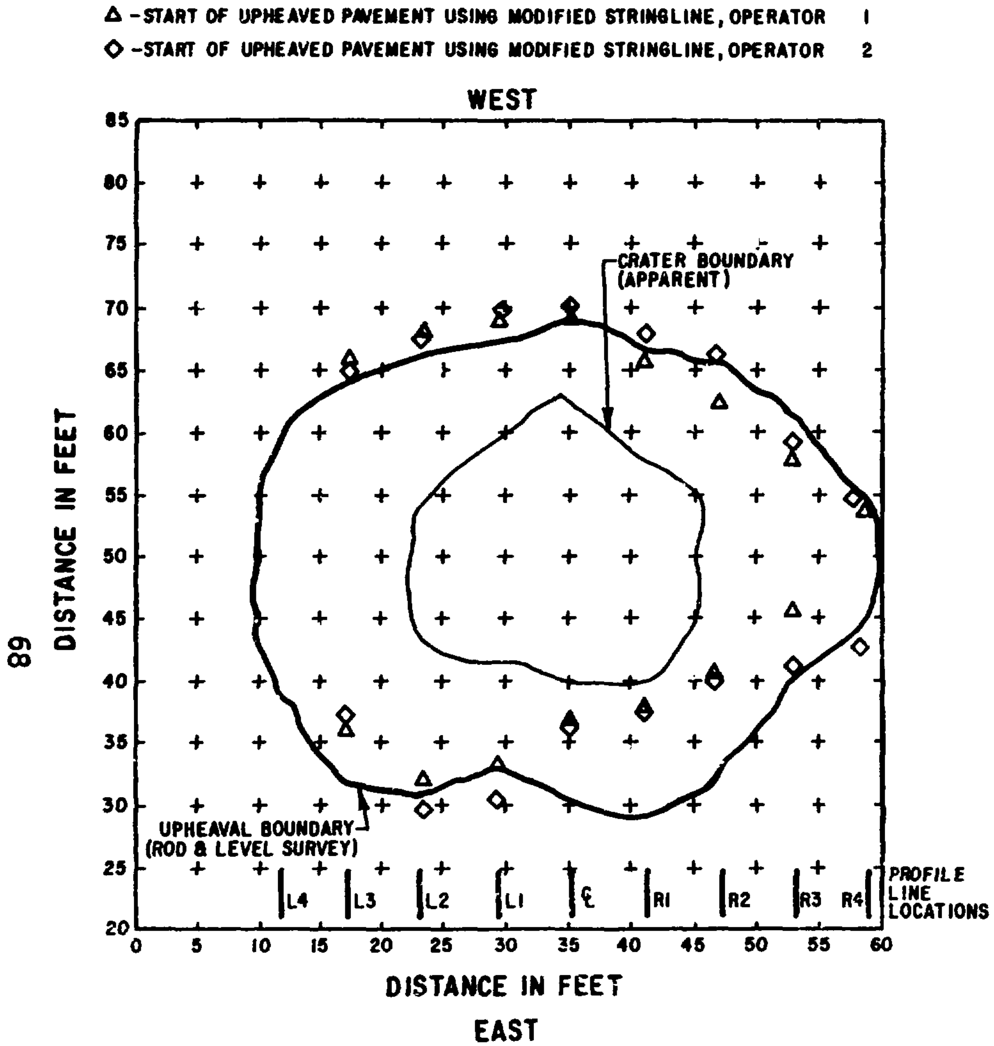


Profile Line	Distance From Upheaval Boundary (Feet)*			
	Operator 1		Operator 2	
	East	West	East	West
L4	----		----	
L3	-7	+5	3	+9
L2	NT***		NT	
L1	-3	+4	+1	+9
CL	NT		NT	
R1	NT		NT	
R2	-10	-2	-9	-1
R3	-4	0	-3	+1
R4	0	0	-1	+1

Profile Line	Elevation Difference (Inches)**			
	Operator 1		Operator 2	
	East	West	East	West
L4	----		----	
L3	+0.36	-0.48	+0.48	-0.72
L2	NT		NT	
L1	+0.48	-0.72	0.00	-0.96
CL	NT		NT	
R1	NT		NT	
R2	+1.20	+0.12	+1.08	0.0
R3	+0.48	0.0	+0.24	-0.12
R4	0.0	0.0	+0.24	-0.24
Measurement Time (min:sec)	4:50		5:02	

* (-): Marked point within upheaved area
(+): Marked point outside upheaved area
** (-): Marked point lower than upheaval boundary
(+): Marked point higher than upheaval boundary
*** NT: Not tested. The standard stringline would not span crater without touching crater lip

Figure 45. Field 4 Stringline Intermediate Upheaval Measurement Results



Profile Line	Distance From Upheaval Boundary (Feet)*			
	Operator 1		Operator 2	
	East	West	East	West
L4	----		----	
L3	-4	+2	-5	+1
L2	-1	+2	+1	+2
L1	0	+2	+2	+2
CL	-6	0	-6	+1
R1	-9	-1	-9	+1
R2	-8	-3	-7	+1
R3	-6	-3	-1	-2
R4	0	0	+1	0

Profile Line	Elevation Difference (Inches)**			
	Operator 1		Operator 2	
	East	West	East	West
L4	----		----	
L3	+0.24	-0.24	+0.24	-0.24
L2	+0.12	-0.24	-0.12	-0.24
L1	0.0	-0.60	0.0	-0.60
CL	+0.48	0.0	+0.48	-0.12
R1	+0.48	+0.24	+0.48	-0.12
R2	+0.84	+0.24	+0.72	-0.12
R3	+0.84	+0.24	0.0	+0.12
R4	0.0	0.0	-0.20	0.0
Measurement Time (min:sec)	9:17		9:10	

* (-): Marked point within upheaved area
(+): Marked point outside upheaved area
** (-): Marked point lower than upheaval boundary
(+): Marked point higher than upheaval boundary

Figure 46. Field 4 Modified Stringline Intermediate Upheaval Measurement Results

TABLE 8. STATISTICAL ANALYSIS OF NORTH FIELD 87 UPHEAVAL MEASUREMENT RESULTS

MEASUREMENT DEVICE	CRATER NUMBER	OPERATOR NUMBER	MEAN HORIZONTAL (FT)	MEAN VERTICAL (IN)	STANDARD DEVIATION HORIZONTAL (FT)	STANDARD DEVIATION VERTICAL (IN)
Standard Stringline	1	---	2.33	0.22	1.03	0.14
	2	---	2.67	0.46	1.37	0.55
Dipstick	1	1	4.25	0.33	2.31	0.33
		2	3.67	0.30	3.60	0.32
	2	1	2.83	0.39	1.47	0.24
		2	3.36	0.50	2.14	0.35
Standard Stringline (Overall)	---	---	2.50	0.34	1.17	0.40
Dipstick (Overall)	---	---	3.46	0.39	2.47	0.31

TABLE 9. STATISTICAL ANALYSIS OF FIELD 4 INITIAL UPHEAVAL MEASUREMENT RESULTS

MEASUREMENT DEVICE	OPERATOR NUMBER	MEAN		STANDARD DEVIATION	
		HORIZONTAL (FT)	VERTICAL (IN)	HORIZONTAL (FT)	VERTICAL (IN)
Standard Stringline	1	3.33	0.46	2.34	0.38
	2	3.00	0.18	1.90	0.10
	3	4.50	0.66	2.35	0.48
Modified Stringline	1	4.50	0.34	3.94	0.31
	2	5.00	0.58	2.19	0.32
	3	2.17	0.16	1.60	0.16
Standard Stringline (Overall)	---	3.16	0.43	2.17	0.39
Modified Stringline (Overall)	---	3.89	0.36	2.89	0.31

TABLE 10. STATISTICAL ANALYSIS OF FIELD 4 UPHEAVAL INTERMEDIATE MEASUREMENT RESULTS

MEASUREMENT DEVICE	OPERATOR NUMBER	MEAN		STANDARD DEVIATION	
		HORIZONTAL (FT)	VERTICAL (IN)	HORIZONTAL (FT)	VERTICAL (IN)
Standard Stringline	1	3.50	0.38	3.27	0.38
	2	4.30	0.41	3.89	0.38
Modified Stringline	1	2.94	0.30	2.91	0.28
	2	2.63	0.24	2.63	0.22
Standard Stringline (Overall)	---	3.90	0.40	3.52	0.38
Modified Stringline (Overall)	---	2.78	0.27	2.73	0.25

upheaval data, which indicate the tested upheaval measurement devices need additional development.

D. CONCLUSIONS AND RECOMMENDATIONS

1. Objective 1

All three upheaval measurement devices (standard and modified stringlines and Dipstick) were unable to consistently measure the location of upheaval within the 2-foot horizontal accuracy criterion. Except for two cases, all devices identified the start of upheaval inside the actual upheaval boundary established by the rod-and-level survey.

Intermediate measurements were not taken at North Field, and at Field 4, intermediate measurements were taken before the upheaved pavement was removed.

Poor horizontal accuracy during upheaval identification need not mean that SRC will be violated. Test results indicate that horizontal accuracy can be off by up to 8 feet and still meet the 3/4-inch vertical criterion, depending on the slope of the upheaval. However, overestimation of upheaval, to the extent seen during testing, would extend crater repair time.

2. Objective 2

Analysis of test results show that none of the devices (intermediate measurements for the stringlines and initial measurements for the Dipstick) give repeatable results. However, most measurements were consistently short, that is, the identified boundary was located on upheaved pavement. Field 4 testing showed that neither stringline provides repeatable results when conducting initial measurements.

3. Objective 3

As reported, all devices met the 10-minute initial measurement criterion. However, because the time reported for the Dipstick does not include the time to move the equipment to the next profile line, the 10-minute completion reported for the Dipstick is a minimum time and not a true operational time. The procedure for the intermediate stringline measurement met the 15-minute intermediate time criteria.

4. Overview

The selection of one device over another as most accurate remains inconclusive. None of the candidate devices were able to determine the preselected upheaval boundary more than 75 percent of the time and, typically, met the criterion less than 50 percent of the time. The statistical analysis of results indicates the accuracy of both devices is poor.

All devices located upheaval points within the actual upheaval boundary more often than outside the actual upheaval boundary. Also, the elevation of some points which were on the upheaved pavement met vertical tolerances.

The modified stringline showed improved performance over the standard stringline when measurements were taken along the profile lines rather than in a triangle.

Initial upheaval profiles measured parallel to the direction of traffic are more accurate than those measured in the triangular pattern, because the parallel profile eliminates the runway crown as a measurement factor. The triangle pattern was used originally because the standard stringlines, with 6-inch base posts, could not go over the crater lip. Parallel profiles are possible with the modified stringline because the taller base posts on the modified stringline enable the stringline to cross the lip and span the crater. Based on Field 4 results, initial stringline measurement procedures should be changed in favor of parallel profiles.

On the basis of time, the modified stringline showed more promise than the Dipstick. Further testing should be conducted to determine the time efficiency of the modified stringline using the revised procedures.

SECTION IV

RELIABILITY AND MAINTAINABILITY EVALUATION

The Hand-Mixed Polymer Spall Repair and MOS Marking Systems were evaluated as formal IOT&E objectives with results reported in USAFTAWC report, Rapid Runway Repair (RRR) Subsystem for MOS Marking and Hand Mixed Polymer Spall Repair (TAC Project 87C-068T). In addition, equipment components from the Hand-Mixed Polymer Spall Repair, MOS Marking, and Crater Upheaval Measurement Systems were monitored for reliability and maintainability (R&M).

The major items of interest included the paint machine and edge and distance-to-go markers for the MOS Marking System, the polymer dispensing apparatus for the Spall Repair System, and the Dipstick and modified stringline for the Crater Upheaval Measurement System. Although this effort concentrated on mechanical items, logistical elements, such as materials and procedures, also were observed.

A Joint Reliability and Maintainability Evaluation Team (JRMET) was comprised of the IOT&E test director, the DT&E test director, and several R&M specialists. The JRMET met throughout the test to review actions that required maintenance or repair and to establish the cause and extent of suspected failure. The R&M observations contained below are the result of the JRMET analysis.

A. MOS MARKING SYSTEM

The MOS Marking System consisted of a commercially produced, Air Force-modified paint machine, distance-to-go markers, reflective runway edge markers, white and black paint, a pickup truck for carrying the distance-to-go markers, and a trailer with marking cones for laying out the MOS pattern. The system is operated by a four-worker team and is designed for marking a 50- by 5000-foot MOS in the pattern shown in Appendix G, Figure 6.

For the North Field Test, two, four-worker teams were formed by members of the Prime BEEF unit from Shaw AFB. Training in basic equipment operation and MOS layout was conducted for 1 week at Tyndall AFB. The paint machine operators received additional hands-on training at North Field before the test. Training details are found in Section V.

Although the logistical impact of the entire system was examined, R&M of the paint machine was a primary consideration.

1. Test Description

Test procedures at North Field consisted of marking up to 12 MOSs under day and night conditions, with some MOSs marked by personnel in individual protection equipment (IPE). Marking was performed in accordance with the proposed "Revision to Air Force Pamphlet 93-12, Volume II, Chapter 7: Airfield Marking Procedures," 1 July 1987. The MOS marking procedures included equipment preparation (loading paint, etc.), overpainting the existing runway markings, laying out the MOS pattern with traffic cones, deploying edge and distance-to-go markers, and painting the MOS. All MOSs were 50 by 5000 feet, and seven were expanded to a maximum of 90 by 7400 feet. Table 11 lists each of the MOS marking events conducted at North Field.

2. R&M Observations

a. Paint Machine

The paint machine used at North Field (Idaho Norland, Model INHV) was a prototype used previously at SALTY DEMO and for tests conducted by AFESC. The machine, shown in Figure 47, was monitored during the pretest training and during the actual test phases. The paint machine arrived at North Field with 305.2 engine hours and ended the test with 349.4 hours, accumulating 44.2 hours during the test. The machine experienced numerous malfunctions before and during the test. Tables 12 and 13 detail the number and types of malfunctions.

The criteria for R&M were determined jointly by AFESC and USAFTAWC. Reliability was defined as the number of successful events per the number of attempted events; a value of a .9 or greater was considered acceptable. A successful event was one in which the old MOS was completely overpainted and a new MOS completely painted with no depot-level maintenance required. For the 12 MOS events in which a 50- by 5000-foot MOS was attempted, nine were successful, yielding a reliability value of .75. From the number of MOS events, including not only the 50- by 5000-foot MOSs, but also the expanded MOSs, 13 of 18 were successful. This yields a reliability value of .72.

Maintainability was calculated for operator maintenance, depot-level maintenance, and overall maintenance. Maintainability, measured in mean man-hours to repair, is calculated by the maintenance man-hours per number of maintenance actions. The acceptable criterion is .5 man-hours or less.

For operator maintenance, 15 maintenance events took 1.3 hours, yielding .09 man-hours. For depot-level maintenance, 3.48 hours were spent on seven maintenance events. The resulting value was .5 man-hours. The overall maintenance time was 4.78 hours. For 22 maintenance events, the mean man-hours to repair was .22.

Availability of the paint machine was measured by up-time ratio, defined as the amount of possessed time minus the downtime, divided by the possessed time. Paint machine availability was acceptable if the ratio was .9 or greater. At North Field, possession time measured 76 hours. The machine was down 4.78 hours, yielding an availability ratio of .94.

TABLE 11. NORTH FIELD MOS MARKING TEST EVENTS

EVENT	DATE	TEAM	OVERPAINT TIME (MIN : SEC)	PAINT TIME (MIN : SEC)	COMMENTS
1	Aug 26	A	8:40	14:30	Machine ran out of paint
2*	Aug 26	A	10:12	13:15	Night operation
3*	Aug 27	B	8:47	18:59	
4	Aug 27	A	14:20	-----	Machine malfunctioned; event terminated
5*	Aug 27	B	15:03	22:55	Did not include edge markers; night operation
6	Aug 28	A	10:15	10:15	With individual protection equipment (IPE)
7*	Aug 28	A	11:05	9:25	
8	Aug 28	B	----	-----	Machine malfunctioned; event terminated
9*	Aug 28	B	10:24	11:57	Night operation, with IPE
10*	Aug 29	B	~ 12	~ 18	Day operation with IPE
11	Sept 2	A	8:55	13:15	Distance-to-go markers not deployed
12*	Sept 2	A	Ran out of paint	13:45	Night operation, with IPE; no distance-to-go markers

* MOS expanded to a maximum of 90 by 7400 feet

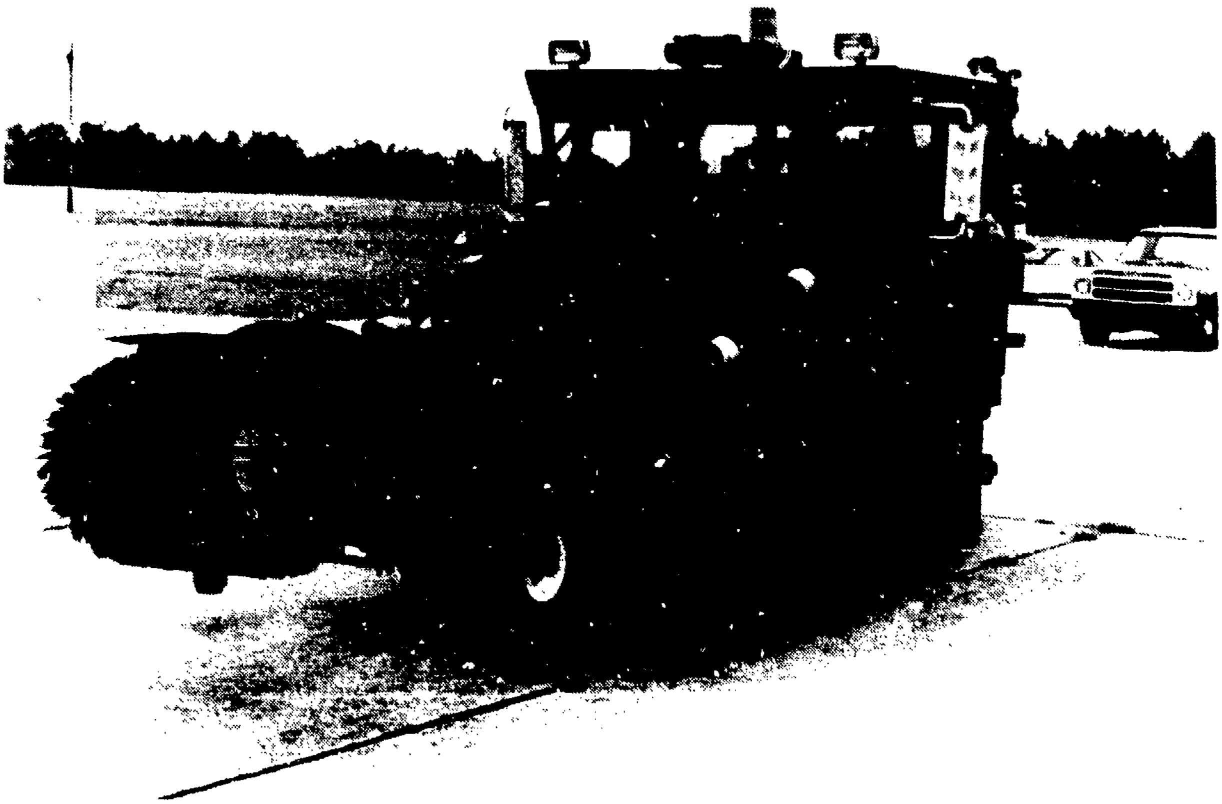


Figure 47. MOS Marking System Paint Machine

TABLE 12. PAINT MACHINE FAILURES DURING TRAINING AND OPERATIONAL CHECKOUT

FAILURE	CAUSE	REPAIR	TIME TO REPAIR (IN HOURS)
1. Drive shaft sheared	Poor weld in modified part	Remove, repair	.60
2. Paint gun misaligned	Vibration during transport	Adjusted paint gun	.10
3. Paint-level gauges would not calibrate	Moisture contributed by poor design	Problem not corrected	----
4. Microprocessor failed	Unknown	Replaced with new microprocessor	.10
5. During night operations, all lights extinguished when paint machine was placed in reverse. Circuit breaker was opening.	Circuit overload	Problem not corrected, however backup lights were temporarily disconnected.	.10
6. High-pressure pump not operating	Vibration-induced misalignment of microswitch	High-pressure pump switch tapped with hand tool.	.10

TABLE 13. PAINT MACHINE FAILURE DURING TEST EVENTS

FAILURE	CAUSE	REPAIR	TIME TO REPAIR (IN HOURS)
1. High-pressure pump not operating	Vibration-induced misalignment of microswitches	High-pressure pump switch tapped with hand tool	.10 each (seven times)
2. Paint Gun 5 out of alignment; paint not properly directed to ground	Result of vibration (7 times), Contact with traffic cone (2 times)	Adjusted paint gun	.10
3. Paint quick-disconnect would not seat	O-Ring swelling (Reaction to toluene), Dry paint accumulation around neck of quick-disconnect	Replaced O-Rings	.10 each (nine times)
4. High-pressure paint filter leaking	Failure to replace O-ring during normal filter cleaning	Replaced O-Rings	.10 each (nine times)
5. Paint beads spilled from gun	Bead seat worn by abrasive action of beads	Bead gun seat replaced	.10
6. Automatic control failed	Temporary, cause unknown	Replaced with manual control	.10
7. Number 3 bead gun spilled beads	Bead seat worn by abrasive action of beads	Replaced bead gun seat	.10
8. Parking brake would not release	Loose nut locking knob caused shaft to jam	Adjusted nut on release shaft	.10
9. Paint hose ruptured	Operator error	Replaced hose	1.0
10. Paint heater clutch overheated	Worn bearing	Problem not corrected; heater not used.	------

TABLE 13. PAINT MACHINE FAILURE DURING TEST (CONCLUDED)

FAILURE	CAUSE	REPAIR	TIME TO REPAIR (IN HOURS)
11. Paint Guns' 4 and 6 spray tips clogged	Insufficient post operation maintenance	Replaced tips	.50
12. Paint machine failed to start (weak battery)	Alternator problem		.30
14. Encoder failed	Unknown	Replaced encoder	.10
15. White high-pressure hose ruptured	Weak spot in hose core	Repaired hose	.50
16. Encoder failed	Spike in electrical circuit	Problem not corrected; used machine in manual mode	----
17. Alternator failed	Voltage regulator failed because of wiring problem in charging circuit	Problem not corrected; vehicle jump started	----
		TOTAL	6.15 hours*

* The time usec in availability and maitainability calculations was 4.78, a number determined by the IOT&E test director, did not include all the failure events in the table.

Black paints from two different manufacturers were used at North Field and are listed in Table 14. Paint was stored in 5-gallon buckets. Although both types of paint contained some sediment at the bottom of each bucket, the Chemray paint contained sediment equal to 1/3 the bucket volume; the Bauer paint contained much less. One reason for this is that the Chemray paint, purchased through Government Supply Agency (GSA), was probably in storage longer than the Bauer paint, which was purchased directly from the manufacturer.

TABLE 14. PAINTS USED AT NORTH FIELD

Manufacturer	Type	Number	Specification
Bauer	White, Type II, traffic paint	1534A9	FED Spec TT-P-115F
Bauer	Yellow, Type II, traffic paint	1535A9	FED Spec TT-P-115F*
Bauer	Black, Type II, traffic paint	2347A9	FED Spec TT-P-110C
Chemray	Black, Type I	37038	FED Spec TT-P-110C

* Used only in training

The paint was loaded into the machine by dumping the paint from the 5-gallon buckets into a 55-gallon drum. The paint then was vacuum-pumped into the machine through an intake hose. The paint machine processed paint from the 55-gallon drum without difficulty; however, when paint was poured from the 5-gallon buckets, the sediment bulk caused paint in the drum to splash onto the operator and the surrounding area.

b. Edge Markers

The edge markers used at North Field, illustrated in Figure 48, were manufactured by Eastern Metals, Inc. Elmira, NY. Design changes resulting from previous tests were incorporated. Up to 70 edge markers were used in each MOS layout. Crews deployed the edge markers from a MOS marking trailer towed by a pickup truck. Workers carried each marker from the trailer to its position in the MOS pattern.

During the MOS marking test events, 15 edge markers developed broken hinges. One marker lost the rubber mat from its base.

c. Distance-to-go Markers

Distance-to-go markers line each side of the marked MOS in 1000-foot increments to indicate to the pilot the distance remaining to the

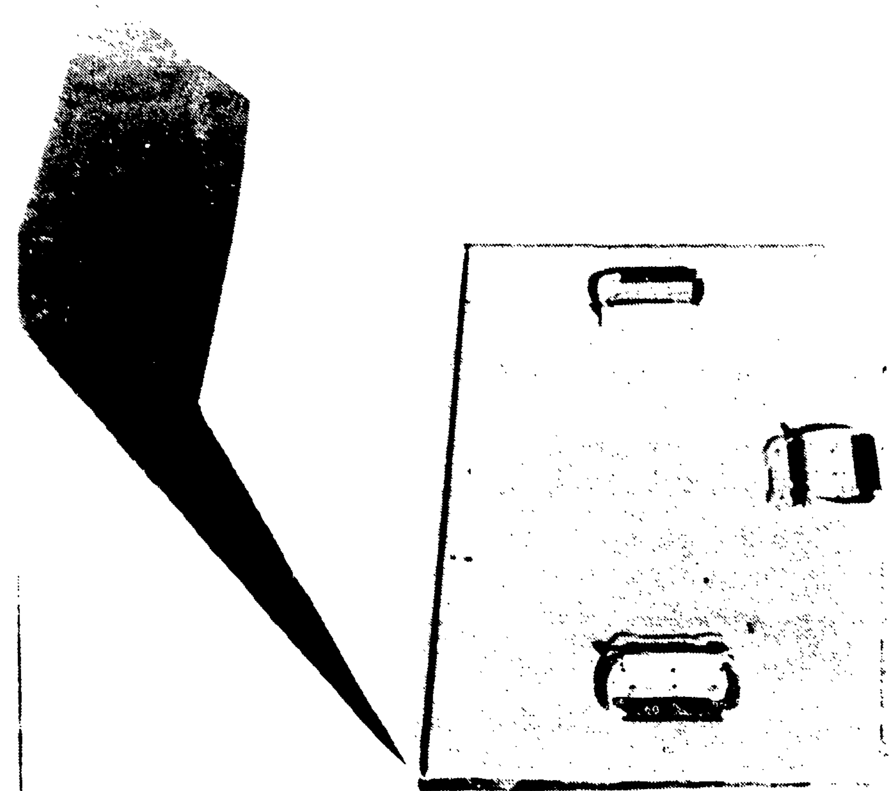


Figure 48. MOS Edge Marker

end of the MOS. Each marker, such as the one shown in Figure 49, consists of a 4- by 4-foot upright wooden frame attached to a flat base. The upright portion is attached to the center of the base and is held with bungee cords. This configuration allows the framed upright portion to pivot at the base, then to return to its normal, upright position. Two 1/8-inch polycarbonate sheets, covered with reflective sheeting, are affixed to the upright frame. Large white silk-screened numerals are affixed to the reflective sheeting. Two markers in the set are painted with a large, yellow, solid circle, indicating the location of the arresting barrier. The markers are designed to be lifted into place from the bed of a pickup truck by two workers.

The construction quality of the markers used at North Field was poor. The glue holding the numeral sheet to the upright frame became loose and had to be reinforced with screws on all the markers. The eye bolts and hardware were too large for the frame size and split the wood. In addition, one bungee cord failed completely.

Operationally, the 42-inch spacing between the distance-to-go marker handles was too wide for people of small to medium build to handle.

3. Conclusions and Recommendations

The MOS Marking System was tested extensively. The edge markers appeared to perform well from an R&M standpoint, but were too heavy for the workers to lift easily.

The prototype paint machine experienced numerous problems, exhibiting a low reliability. Despite this, it proved highly maintainable.

Operator maintenance training was good, but not sufficient to allow the operator to quickly locate and repair complex problems involving valve-sequencing, high air pressure, and electrical problems. However, the operators were successful in locating and repairing most minor problems. Also, the machine was designed to handle three different paint colors which increases the machine complexity. (The fielded machine will require only two paint colors).

Mixing and pouring paint from 5-gallon containers into a 55-gallon drum, before loading it into the paint machine is not acceptable. This procedure was time-consuming, labor-intensive, and messy.

The distance-to-go and barrier markers performed satisfactorily; however, several changes in hardware and structural design could improve reliability.

Recommended changes and improvements to the system include:

a. High standards of reliability and maintainability, as well as painting capability, should be emphasized in performance specifications for the paint machine.

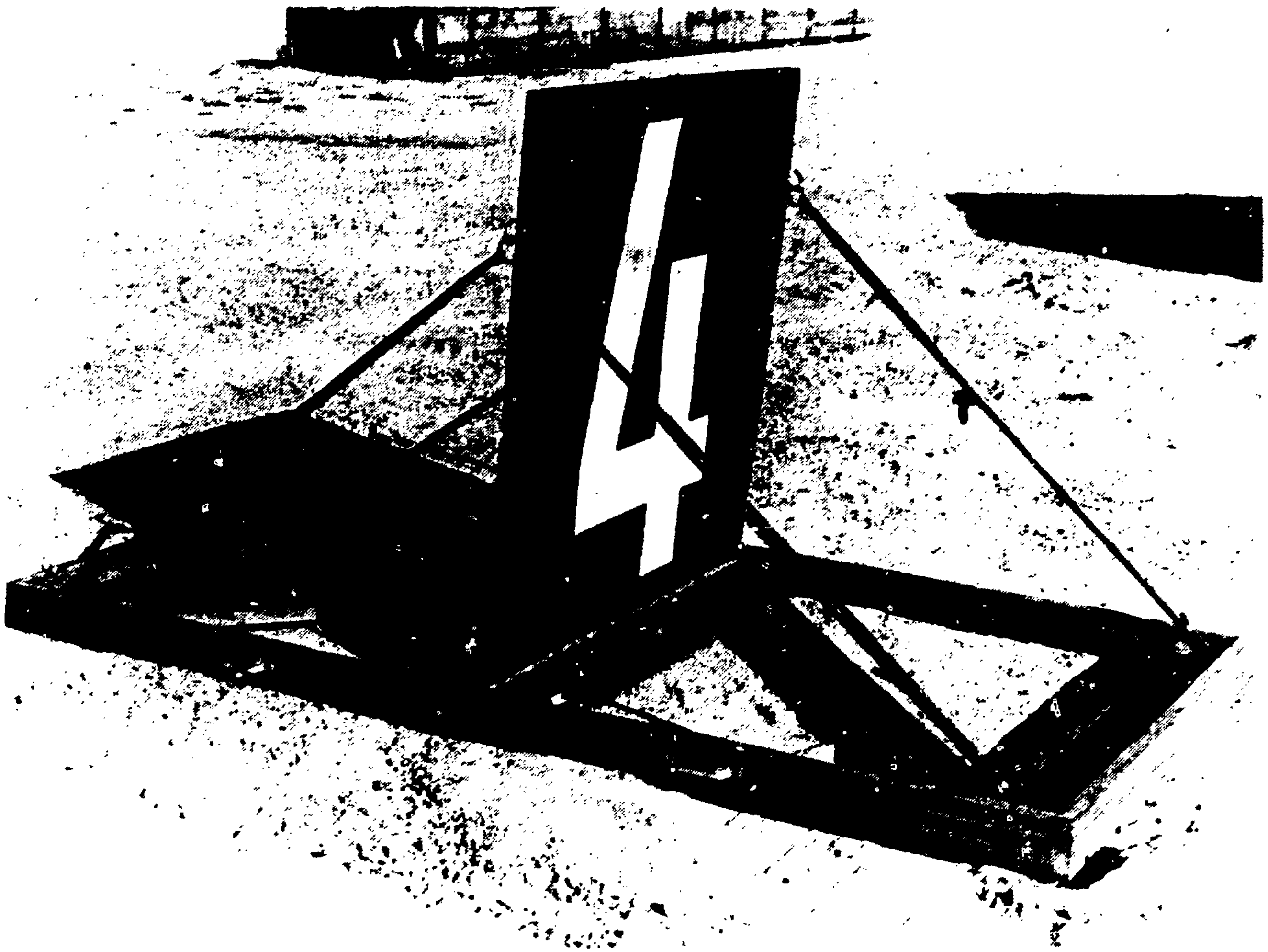


Figure 49. Distance-To-Go Marker

b. Identify a suitable method of mixing paint in a 55-gallon drum, which would allow the paint to be purchased and handled in large quantities.

c. If b is not feasible, prepare paint with a shaker before attempting to pour it into the 55-gallon intermediate drum.

B. HAND-MIXED POLYMER SPALL REPAIR

In the Hand-Mixed Polymer Spall Repair System, two monomer resins, contained in separate 55-gallon drums, are mixed together in buckets and poured into an aggregate-filled spall. The mixture solidifies in a few seconds, producing a polyurethane concrete with a hard, level, trafficable surface. A catalyst, added to one of the liquid resin drums during equipment preparation, determines the set time. The quantity of catalyst added is a function of temperature and the desired set time.

Two four-worker spall repair teams were formed by selected Prime BEEF personnel from Shaw AFB. At North Field, the teams were trained in equipment preparation, safety, and procedures. Training details are found in Section V.

1. Test Event Summary

Spall repairs were to be conducted by each team in ambient dry and wet conditions, with and without IPE. Three events were conducted. During the first event on 26 August, Team A repaired 63 spalls in 4 hours. On 27 August, Team A conducted a night repair in IPE with simulated rain. Thirty spalls were repaired in 68 minutes. On 28 August, Team B repaired 133 spalls during a daylight operation without IPE. One hundred fifteen of these spalls were repaired in 4 hours. The daily temperature range, which affects both team performance and catalyst set time, is found in Appendix F.

2. Repair Description

Spall repair followed procedures found in the proposed "Revisions to Air Force Pamphlet 93-12, Volume II, Chapter 6, Spall Repair," 1 July 1987. Spalls were repaired by first cleaning and drying each spall with a jet of air. Although they were provided with both an air compressor and a backpack leafblower, the teams chose to use the leafblower because it was easier to operate and control, more flexible, and less noisy than the air compressor-wand combination. Most stones and debris were blown from the spalls, and large chunks of debris were removed with rakes or by hand. Aggregate (Number 6, in accordance with ASTM D448), stored in sandbags, was placed in each spall and screeded level with the pavement. Polymer materials (Ashland Resins 65-088 and B65-032) were dispensed from 55-gallon drums (shown in Figure 50) into separate 10-quart buckets, mixed together in a 5-gallon bucket, then poured in a spall. A catalyst (Ashland Catalyst 65-018) for controlling set time was added and mixed in the drum during equipment preparation. After spalls in a given area were repaired, the team moved to another area. A pickup truck towed the dispensing equipment, and a dump truck towed the air compressor.

Figure 50. Hand-Mixed Polymer Spall Repair System

For night spall repair, the spall repair teams used a Porta-Lite Model B1, portable lighting unit to illuminate the immediate spall area. The lighting unit, manufactured by Portable Power and Light Company, consisted of an 8-foot stand with a removable tower. The light consists of a 1000-watt, metal halogen bulb and was powered by a 2000-watt Homelite generator. The light was transported to the repair area in the bed of the pickup truck.

3. R&M Observations

The Hand-Mixed Polymer Repair System proved satisfactory. Approximately 1000 gallons of polymer was used to fill 226 spalls. The only major difficulty was the polymer material's poor bond with the wet pavement.

Minor equipment and procedural problems that may have affected system performance include the following:

a. One 2-inch gate valve was difficult to operate, and two 2-inch gate valves seized and could not be adjusted. It was suspected that the valves had come in contact with both resins.

b. Bails on 10 of the 10-quart buckets (NSN 7240-00-060-6006) pulled out on one or both sides.

c. In six of the 5-gallon buckets (NSN 7240-00-575-2243), the reacting polymer delaminated the buckets' sides. The side of one bucket became thin and allowed polymer to leak out.

d. During strong gusts of wind, the control valves could not adjust the liquid flow in time to prevent splatter spills.

e. The lightweight, chemical-resistant gloves stuck to equipment and other objects containing wet polymer residue. In some cases, the gloves were torn when the object was released.

f. The hand-held bung mixer was difficult to control and required full-time attendance. On one occasion, the bit detached from the drill and fell into the drum. The bit was not tightened properly because the chuck was not attached to the drill and could not be located.

4. Conclusions and Recommendations

From an R&M standpoint, the Spall Repair System is satisfactory except in a wet environment. Several adjustments in materials and equipment are recommended:

a. Develop improved materials to allow better material set time and control and a better bond with wet pavement.

b. Increase the quantity of chemical-resistant gloves from eight to 12 pair per team, and use heavy-duty (thick-layer) gloves.

c. Use valves with more positive control (example, ball valve with 90-degree on/off).

d. Use polyvinyl chloride (PVC) valves for dispensing hardware to reduce weight.

e. Increase the number of 10-quart buckets to 14, and decrease the number of 5-gallon mixing buckets to five.

f. Provide three plastic 250 mL and five 50 mL beakers per team for measuring catalyst.

g. Provide bung-mixer shafts for mixing the catalyst through either the end or side bung. Also, provide an electric screw-in bung entering mixer to eliminate the attendance requirement.

C. UPHEAVAL MEASUREMENT SYSTEM

1. Test Summary

Three upheaval measurement devices--a standard stringline, a modified stringline, and a Dipstick pavement profiler--were evaluated for ease of operation and effectiveness in determining crater upheaval. The standard stringline and Dipstick were evaluated at North Field. The modified stringline was not tested at North Field, because its steel cable broke during training activities before the test. The cable had been frayed by the guide bar used to hold the cable at a predetermined height above the ground and to direct the cable on or off the winch drum when tightening the line. During training, when tension was applied to the cable, the damaged portion of the cable failed. The modified stringline was evaluated at Field 4, Eglin AFB in October 1987, using the North Field test objectives. Reliability and maintainability were not formally monitored at Field 4. However, no problems or equipment failures were reported.

2. Conclusions and Recommendations

The Dipstick-computer system was not tested sufficiently to adequately evaluate reliability and maintainability. The 9-volt batteries on the Dipstick computer became too weak to use after 1 hour. It could not be determined if the weak batteries resulted from normal operation or from previous use. However, from initial observations at North Field, and based on an R&M standpoint, the Dipstick performed satisfactorily.

Also, from an R&M standpoint, the modified stringline performed satisfactorily (see Section III). The standard stringline requires little logistical analysis. Based on the analysis of the cable failure in the modified stringline, the guide bar should be replaced with a roller.

SECTION V

NORTH FIELD TRAINING

Before the North Field test, Air Force personnel from Shaw AFB, SC, were trained in three RRR subsystems to be tested at North Field: (1) MOS Marking, (2) Spall Repair, and (3) Upheaval Measurement. MOS Marking and Spall Repair training were evaluated as part of the system IOT&E.

Because the systems are relatively new to the field, in-depth training packages for personnel completely unfamiliar with each system were developed, used, and evaluated. The training packages developed for North Field were intended as prototypes for the actual training programs to be used by the Air Force when the subsystems are fielded.

The purpose of this section is to outline briefly the training each team received, by system; to discuss training results; and to recommend improvements for future training developments.

A. MOS MARKING

1. Summary

MOS marking training was separated into two categories. The first category involved laying out a MOS by placing edge, distance-to-go, and barrier markers; placing traffic cones; and painting the centerline stripe of the MOS and threshold triangles with the paint machine. The second category was devoted entirely to the paint machine and included maintenance, loading paints and solvents, troubleshooting, and safety. For both categories, training was conducted in the classroom and in the field.

MOS marking training was conducted at two locations. In July 1987, training was conducted at Tyndall AFB, Florida. In August 1987, additional MOS marking training was conducted at North Field immediately before the test.

a. Tyndall AFB Training (July 1987)

This training involved familiarizing the two test teams (three personnel per team) with the MOS Marking System and the paint machine, then practicing laying out a MOS using the paint machine. Training consisted of approximately 16 hours of classroom instruction (4 hours for the system and 12 hours for the paint machine) and 8 hours of field training. Classroom instruction on the MOS Marking System consisted of system purpose, importance, requirements, and limitations. For the paint machine, classroom instruction primarily involved an overview of the mechanical makeup of the paint machine, in-depth instruction on procedures for filling the machine with paints and solvent, routine maintenance requirements, troubleshooting small problems, safety, and paint machine use for MOS marking.

Field training was conducted on the drone runway at Tyndall AFB. Originally 3 days (24 hours) were scheduled on the runway to lay out MOSs of varying widths and lengths. These MOSs were laid out using markers (edge, distance-to-go, and barrier) and traffic cones to guide the paint machine while it simulated painting the centerline stripe and threshold markers of the MOS with water-soluble oil. However, because of scheduling conflicts, the drone runway field training was reduced to 8 hours. Additionally, because of mechanical problems with the paint machine, 4 of the 8 hours involved placing markers and traffic cones only.

b. North Field Training (August 1987)

Refresher training was held at North Field for the two test teams. This training included practicing laying out a MOS under both day and night conditions. For night training, team personnel donned IPE. Training consisted of approximately 16 hours of refresher classroom and hands-on instruction (2 hours for the entire system and 14 hours for the paint machine) and 12 hours of team performance field training (4 days and 8 nights) using the east-west runway at North Field. In addition, material safety (paints, solvents, and generated waste) was discussed in detail with the two test teams.

2. Conclusions and Recommendations

Performance during the test indicated that the overall system and procedures of MOS marking were easily learned. However, the paint machine tested at North Field was complex and required significant (i.e., 40 hours) operator training for the crew to be effective during the test.

Based on test team debriefings on the MOS marking training program, three major recommendations can be made. First, paint machine operation instruction should be conducted in a hands-on manner in the field, instead of in the classroom. Team personnel thought this would help in rapidly understanding the use and maintenance of the paint machine. Second, team personnel thought that more emphasis should be placed on practicing and performing laying out MOSs in the field, with less emphasis on classroom instruction. Finally, facilities at the contingency training site should be devoted to MOS marking field training.

B. HAND-MIXED SPALL REPAIR TRAINING

1. Summary

Two four-man teams were trained in the hand-mixed spall repair method. Training was conducted in three phases. Phase One consisted of approximately 3 hours of classroom instruction, comprising an overview of spall repair system equipment, materials, procedures, and safety. Phase Two training consisted of instructor demonstration of equipment, materials, procedures, hardware setup, material mixing, and repairing four practice spalls. The practice spalls were formed in plastic-lined 2- by 2-foot shallow boxes. Phase Three training consisted of inventorying team equipment, mixing catalyst, setting up a resin kit, and repairing 20 training spalls in the concrete.

All spall repair training was conducted at North Field the week of 24 August 1987, before testing. Each team first repaired 10 spalls, using current materials and procedures. Several onsite modifications were made to the procedures during the training sessions because the catalyst material increased in strength with temperature.

2. Conclusions and Recommendations

The major conclusion drawn from team member debriefings was that practical application and field training were more effective than the classroom and demonstration training.

For future training, field instruction of spall repair should be done with a variety of realistic spalls.

Also, the effectiveness of training decreases when training is conducted concurrently or consecutively with testing activities. The North Field test schedule changed frequently, segmenting the spall training sessions and disrupting the smooth, orderly information flow. In future tests, training should be completed before testing.

C. UPHEAVAL MEASUREMENT

1. Summary

Training consisted of instructing individual teams on three upheaval measurement devices. One team (two personnel) was trained on the dipstick upheaval measurement device, and two teams (three personnel each) were trained on the standard and modified stringlines. Upheaval measurement test results from North Field can be found in Section III of this report.

Upheaval measurement training was conducted at North Field in August 1987 immediately before testing. Training consisted of classroom instruction, with an equal amount of field training. The main problem encountered throughout upheaval measurement training was the lack of an explosively formed crater for training personnel on the use and limitations of each measurement device.

a. Dipstick Training (20 and 21 August)

The team consisted of two workers. Training included approximately 1 hour of classroom instruction, followed by 2 hours of field instruction. Classroom instruction emphasized upheaval measurement importance to RRR; the upheaval measurement process; and Dipstick use, maintenance, and limitations. Field training consisted of familiarizing team personnel with using the Dipstick by measuring the levelness of a runway pavement. However, the pavement was undamaged, making this portion of training less effective than if an explosively formed crater was available for practice.

The Dipstick team trained briefly on Crater 1 on 24 August. To prevent biased test data, the team measured upheaval in a north-south direction, rather than the east-west direction required for the test.

b. Standard Stringline Training (20 and 21 August)

The standard stringline team consisted of three workers. Training included approximately 1 hour of classroom instruction, followed by 1 hour of field instruction. Classroom instruction emphasized upheaval measurement importance to RRR; the upheaval measurement process; and stringline use, maintenance, and limitations. Field training consisted of familiarizing team personnel with using the stringline by measuring the levelness of a runway pavement. However, once again, the pavement was undamaged, making this portion of training less effective than if an explosively formed crater was available for practice.

c. Modified Stringline Training (20 and 21 August)

The modified stringline team consisted of three workers. Training comprised approximately 1 hour of classroom instruction. It also was intended to provide 1 hour of field instruction with the modified stringline. However, at the start of the field instruction, the 1/16-inch stainless steel cable of the modified stringline broke. The cable could not be repaired in time for the modified stringline to be tested at North Field. Consequently, makeup training and testing with the modified stringline were conducted at Field 4, Eglin AFB, Florida during the week of 12 October 1987. Training at Field 4 consisted of 1 hour of classroom instruction, followed by 1 hour of field instruction. Field instruction at Field 4 involved measuring the upheaval around an explosively formed crater.

2. Conclusions and Recommendations

Team member debriefings resulted in two major conclusions. First, field training should be conducted on explosively formed craters. Without realistic craters, team members did not feel adequately trained at North Field. At Field 4, where an explosively formed crater was available for training, team members felt more confident with the instruction. Second, the Dipstick requires more training than the two stringlines. Dipstick team members felt at least 8 hours of field training on an explosively formed crater would be required for adequate training on the Dipstick.

If fielded, a more intensive and extensive training program should be developed for the Dipstick, with emphasis on upheaval measurement repetitions. Because Upheaval Measurement Training was conducted at North Field, it was affected by the frequently changing test schedule. In future tests, training should be completed before testing begins.

SECTION VI

OVERALL CONCLUSIONS AND RECOMMENDATIONS

This section contains the conclusions and recommendations from the DT&E portion of the North Field '87 RRR Test, as well as the conclusions and recommendations from the R&M evaluation and from training.

A. FFGM TEST

1. Conclusions

Overall, the FFGM Repair System exceeded minimum performance requirements. Each repair sustained more than 100 aircraft trafficking passes, remained within surface roughness tolerance limits, and did not require maintenance necessitating mat removal. The commercially manufactured, hinged, fiberglass mats performed well. Mat 1 did not exhibit permanent deformation (tears, rips, etc.,) or delamination. Mat 2 also performed well, except for a 2- to 3-foot easily repaired tear and minor delamination.

Hinge orientation had no significant effect on repair performance.

In general, the anchoring system held the mats solidly throughout the test, and no anchor bolt damage was reported. However, each type of bushing loosened often, with the conventional bushings holding longer than the modified bushings. The modified bushings also performed below the acceptable test criterion of 30 passes before requiring tightening. The loose bushings could have resulted, in part, from drilling anchor bolt holes at an angle.

2. Recommendations

a. Additional testing should be conducted on both hinge orientation and the mat anchoring system.

b. The effects of hinge orientation on rutting should be examined in a more controlled environment.

c. Further tests should be conducted to determine, under controlled conditions, the effects of angled bolt holes on bushing tightness. If warranted, use of a drill guide should be investigated.

B. UPHEAVAL MEASUREMENT TEST

1. Conclusions

Although, none of the measurement devices consistently met the criterion for horizontal accuracy, all but four elevation measurements were within the 3/4-inch vertical upheaval tolerance. Furthermore, test results show that none of the three devices gave repeatable results. Both stringlines met the 10-minute initial and 15-minute intermediate measurement criteria.

For the Dipstick, the reported time for each profile, plus additional setup time, indicated that it would exceed the time criteria.

2. Recommendations

a. Revise the procedures for the modified stringline to initially measure upheaval in a line parallel to traffic, rather than in a triangular pattern around the crater.

b. Concentrate on future development and testing of the modified stringline, with emphasis on improved accuracy.

C. RELIABILITY AND MAINTAINABILITY

Conclusions and recommendations are made on the reliability and maintainability of the MOS Marking System and the Hand-Mixed Polymer Spall Repair System.

1. MOS Marking System

a. Conclusions

The MOS Marking System was tested extensively. The edge markers appeared to perform well from an R&M standpoint, but were too heavy for the workers to lift easily.

The prototype paint machine experienced numerous problems, exhibiting low reliability. Despite this, it proved highly maintainable. Lessons learned from North Field and other tests will improve the performance specification being written for the production prototype.

Operator maintenance training was good, but not sufficient to allow the operator to quickly locate and repair complex problems involving valve-sequencing, high air pressure, and electrical problems. However, the operators were successful in locating and repairing most minor problems. Also, the machine was designed to handle three different paint colors, which increases the machine complexity.

The mixing paint and pouring it from 5-gallon containers into a 55-gallon drum, before loading it into the paint machine, is not acceptable. This procedure was time-consuming, labor-intensive, and messy.

The distance-to-go and barrier markers performed satisfactorily; however, several changes in hardware and structural design could improve reliability.

b. Recommendations

(1) High standards of reliability and maintainability, as well as painting capability, should be emphasized in performance specifications for the paint machine.

(2) Identify a suitable method of mixing paint in a 55-gallon drum, which would allow the paint to be purchased and handled in large quantities.

(3) If (2) is not feasible, prepare paint with a shaker before attempting to pour it into the 55-gallon intermediate drum.

2. Spall Repair System

a. Conclusions

The Spall Repair System worked satisfactorily, except in a wet environment. Minor equipment and procedural problems were also noted.

b. Recommendations

(1) Develop improved materials to allow better material set time and control and a better bond with wet pavement.

(2) Increase the quantity of chemical-resistant gloves from eight to 12 pair per team, and use heavy-duty (thick layer) gloves.

(3) Use valves with more positive control (example, ball valve with 90-degree on/off).

(4) Use polyvinyl chloride (PVC) valves for dispensing hardware to reduce weight.

(5) Increase the number of 10-quart buckets to 14, and decrease the number of 5-gallon mixing buckets to five.

(6) Provide three plastic 250 ml and five 50 ml beakers per team for measuring catalyst.

(7) Provide bung-mixer shafts for mixing the catalyst through either the end or side bung. Also, provide an electric screw-in bung entering mixer to eliminate the attendance requirement.

D. TRAINING

Training was conducted for MOS marking, spall repair, and upheaval measurement.

1. MOS Marking Training

a. Conclusions

Performance during the test indicated that the overall system and procedures for MOS marking were easily learned. However, the paint machine tested at North Field was complex and required significant (i.e., 40 hours) operator training for the crew to be effective during the test.

b. Recommendations

(1) Hands-on paint machine operation instructions should be conducted in the field, instead of in the classroom.

(2) More emphasis should be placed on practicing MOS layout in the field rather than in the classroom.

(3) Facilities at the contingency training site should be devoted to MOS marking field training.

2. Spall Repair Training

a. Conclusions

For spall training, practical application and field training were more effective than the classroom and demonstration training. Also, conducting the training concurrently with the test decreased the effectiveness of the training.

b. Recommendations

(1) Complete training before testing begins.

(2) For field instruction, repairs should be demonstrated with a variety of realistic spalls.

3. Upheaval Measurement Training

a. Conclusions

For upheaval measurement training, teams felt more confident after training on a realistic crater at Field 4, than at North Field where training was conducted on inclined pavement. Also, the Dipstick method requires at least 8 hours of field training, whereas the stringline method required about 1 hour.

b. Recommendations

(1) Conduct all upheaval measurement training as realistically as possible, preferably on an explosively formed crater.

(2) Complete all training before the test begins.

(3) If the Dipstick is selected as the upheaval measurement method, develop a more intensive and extensive training program for the Dipstick Operators, with emphasis on upheaval measurement repetitions.

APPENDIX A

SOILS TEST RESULTS

This Appendix contains the results of soils test conducted by Law Engineering Company in support of the North Field Tests. Included in this Appendix are results of the pavement compressive strength test (ASTM C-42), quality control checks on the spall and crater aggregate and ballast rock (ASTM C-136), Proctor (ASTM D-1557-A) and specific gravity results of the crushed stone, and Atterburg limits and grain-size distribution (ASTM C-136) of the soil underlying the runway.

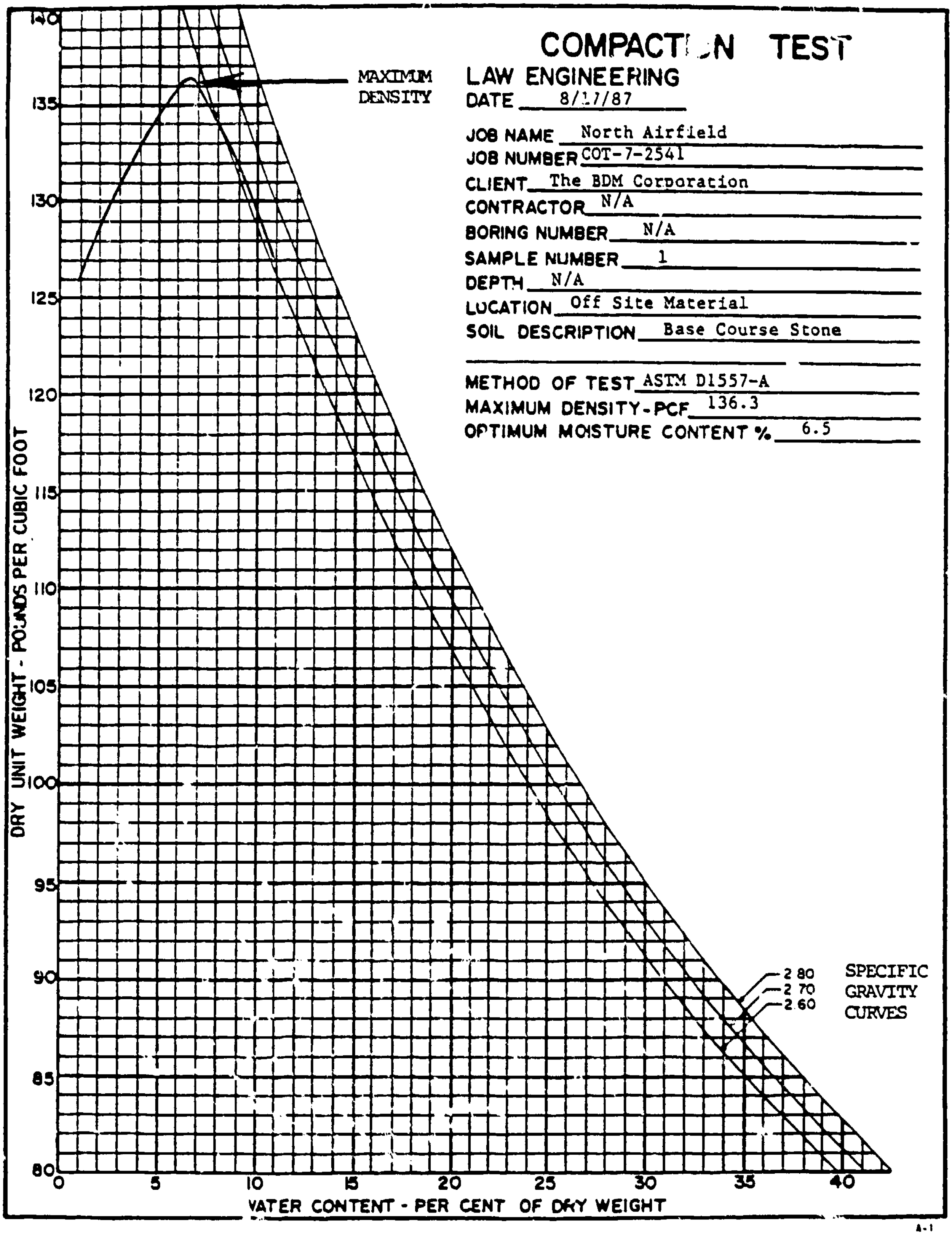


Figure A-1. Crushed Stone Proctor Test, Sample 1 Results

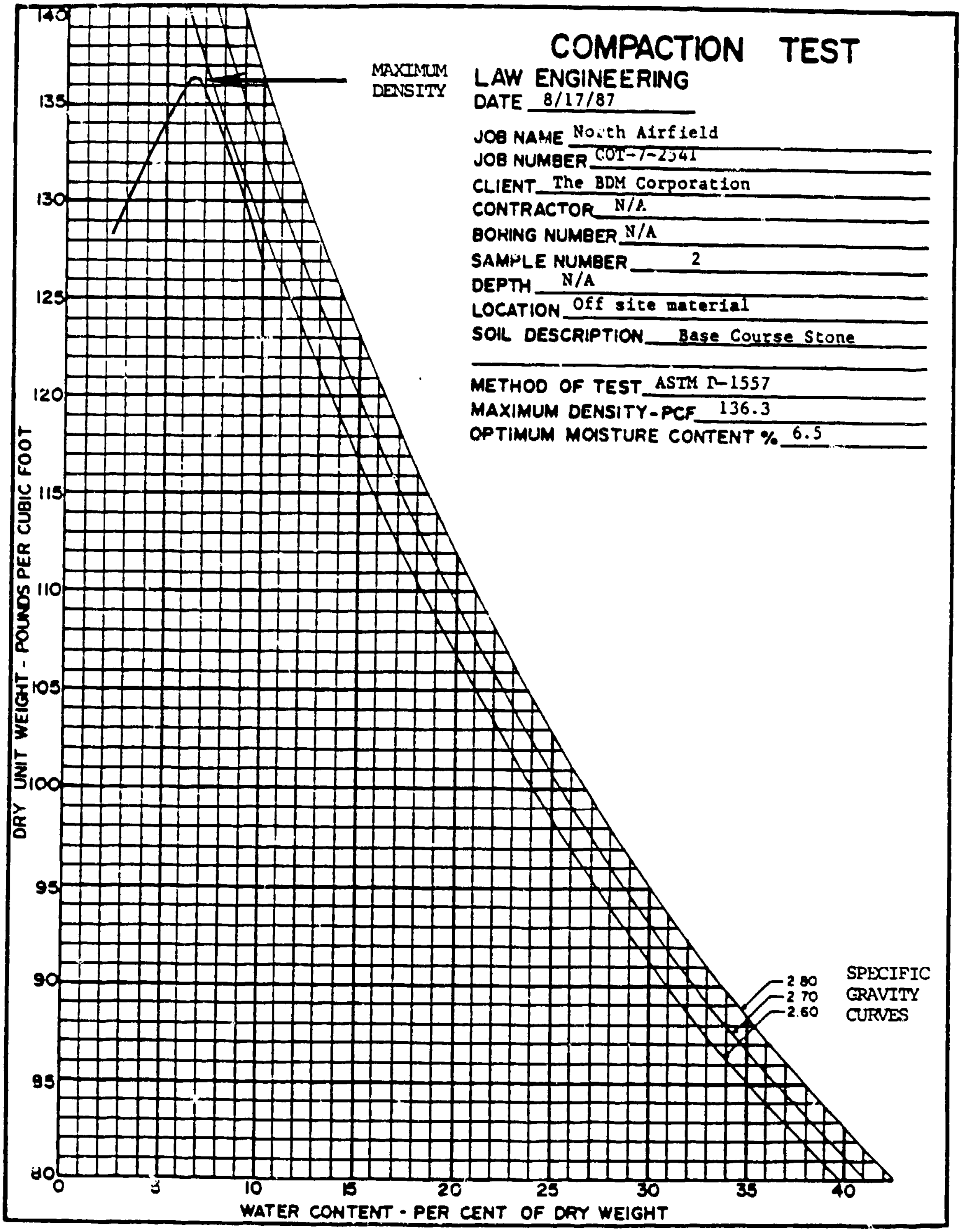


Figure A-2. Crushed Stone Proctor Test, Sample 2 Results

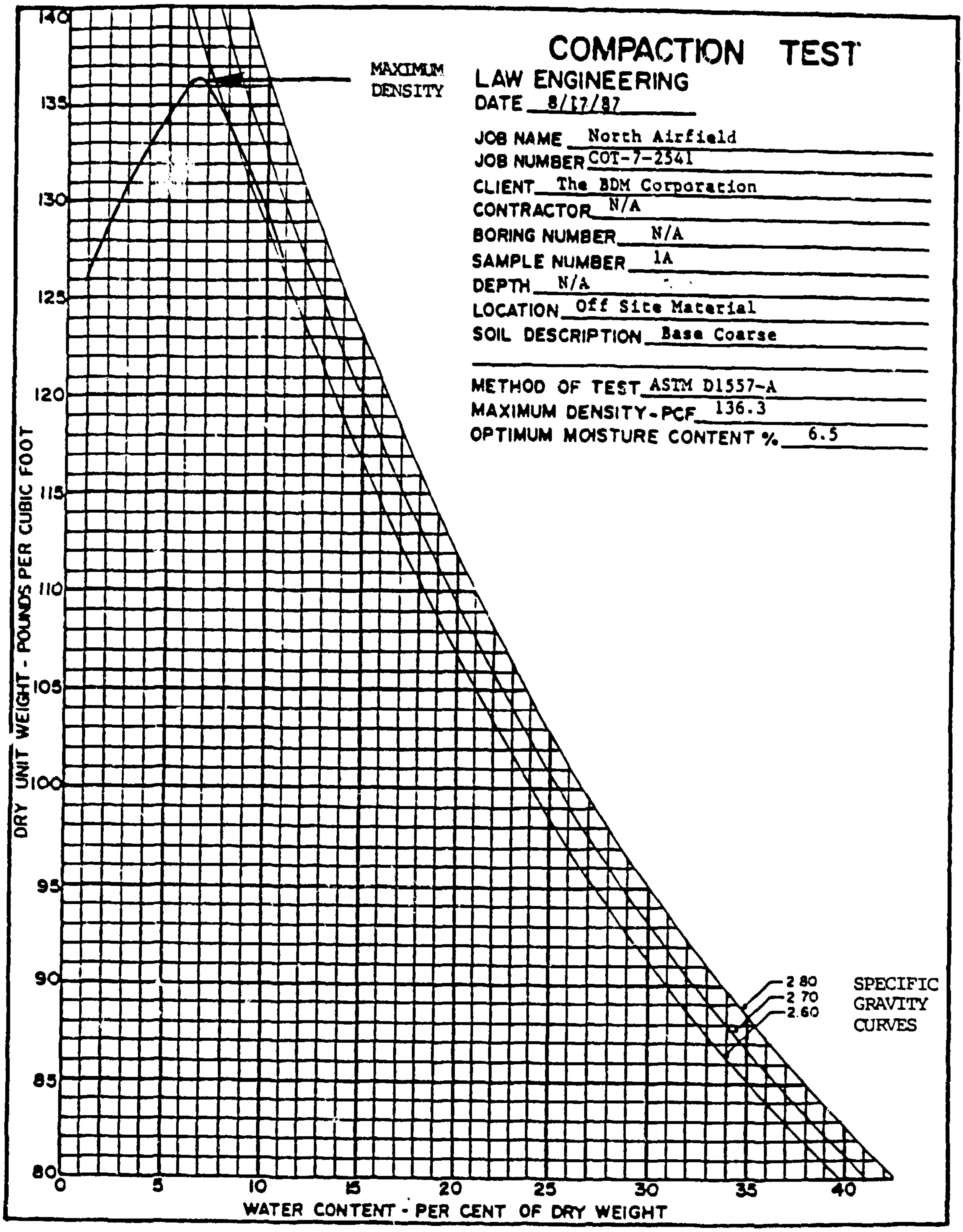


Figure A-3. Crushed Stone Proctor Test, Sample 1A Results

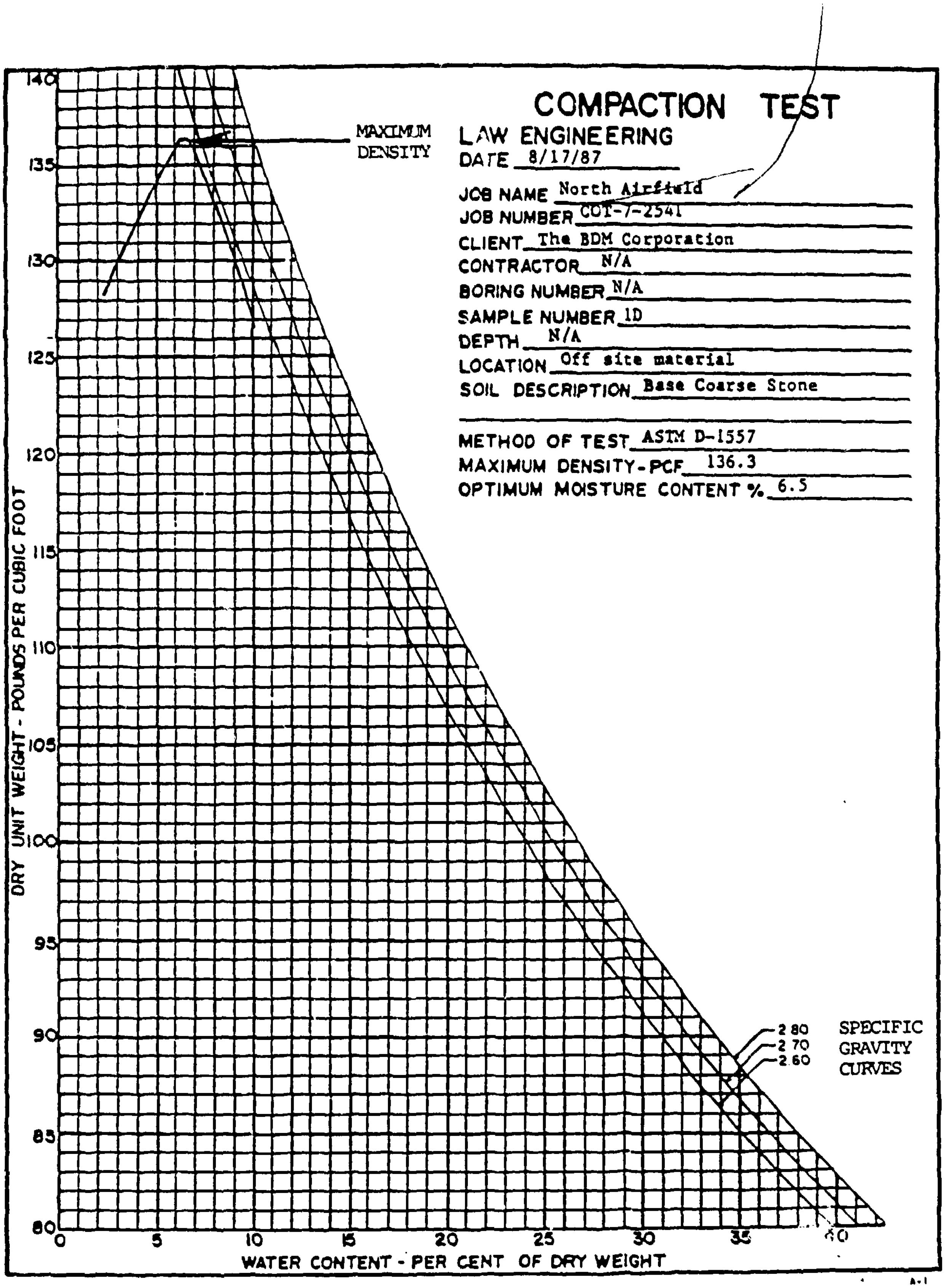


Figure A-4. Crushed Stone Proctor Test, Sample 1D Results

LAW ENGINEERING

P.O. BOX 21879, 720 GRACERN ROAD, SUITE 132

COLUMBIA, SOUTH CAROLINA 29221

(803) 798-1200

LABORATORY TESTING OF BASE COURSE STONE

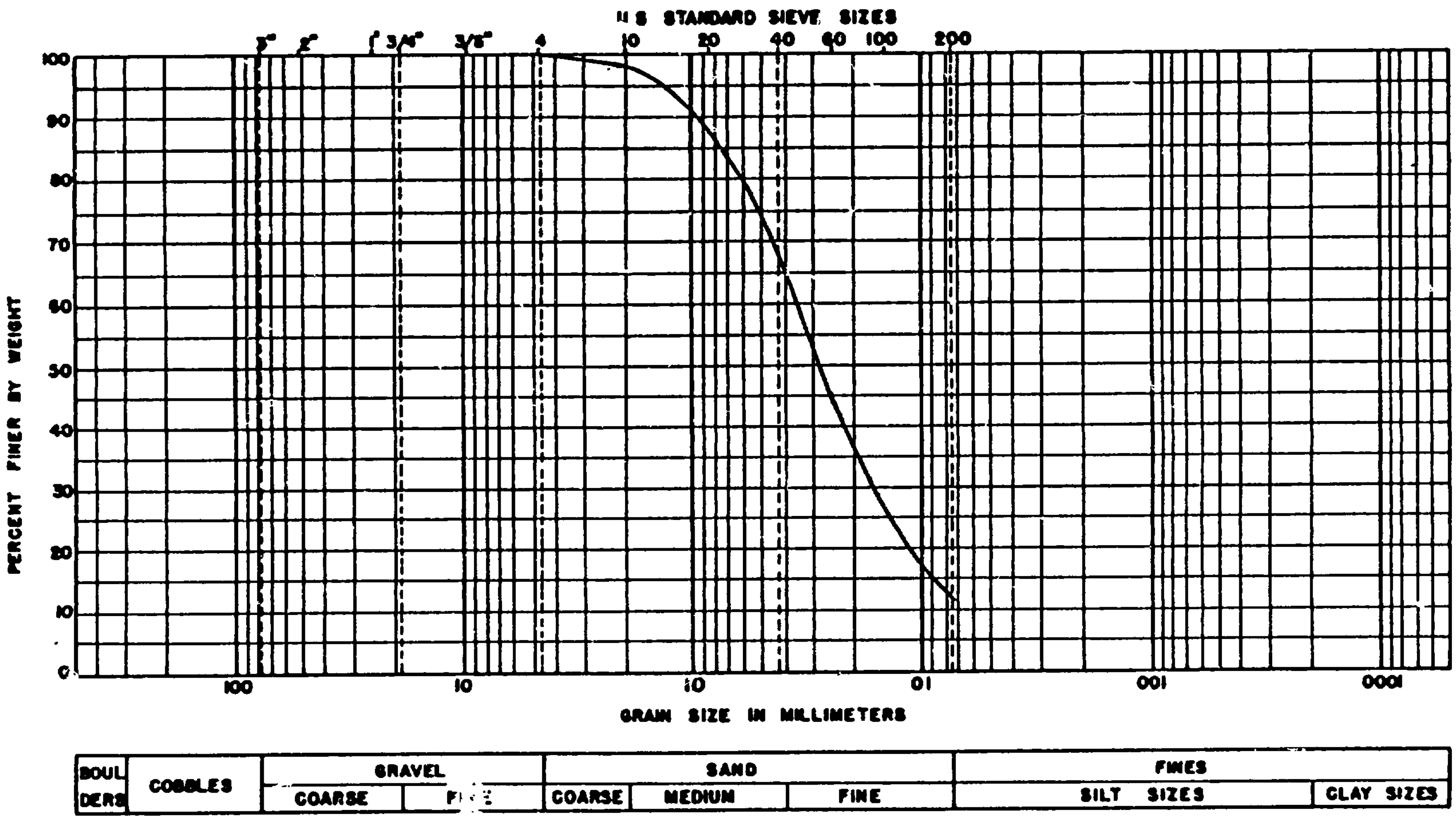
THE BDM CORPORATION
NORTH AIRFIELD REPAIRS
NORTH, SOUTH CAROLINA
LAW ENGINEERING PROJECT NO. COT-7-2541

Date: 8/24/87 Technician: M. Okorie

SPECIFIC GRAVITY TEST

Sample No.	Sample Type	Specific Gravity
1	Base Course Stone	2.540
2	Base Course Stone	2.582
	Average:	2.561

Figure A-5. Crushed-Stone Specific Gravity Results



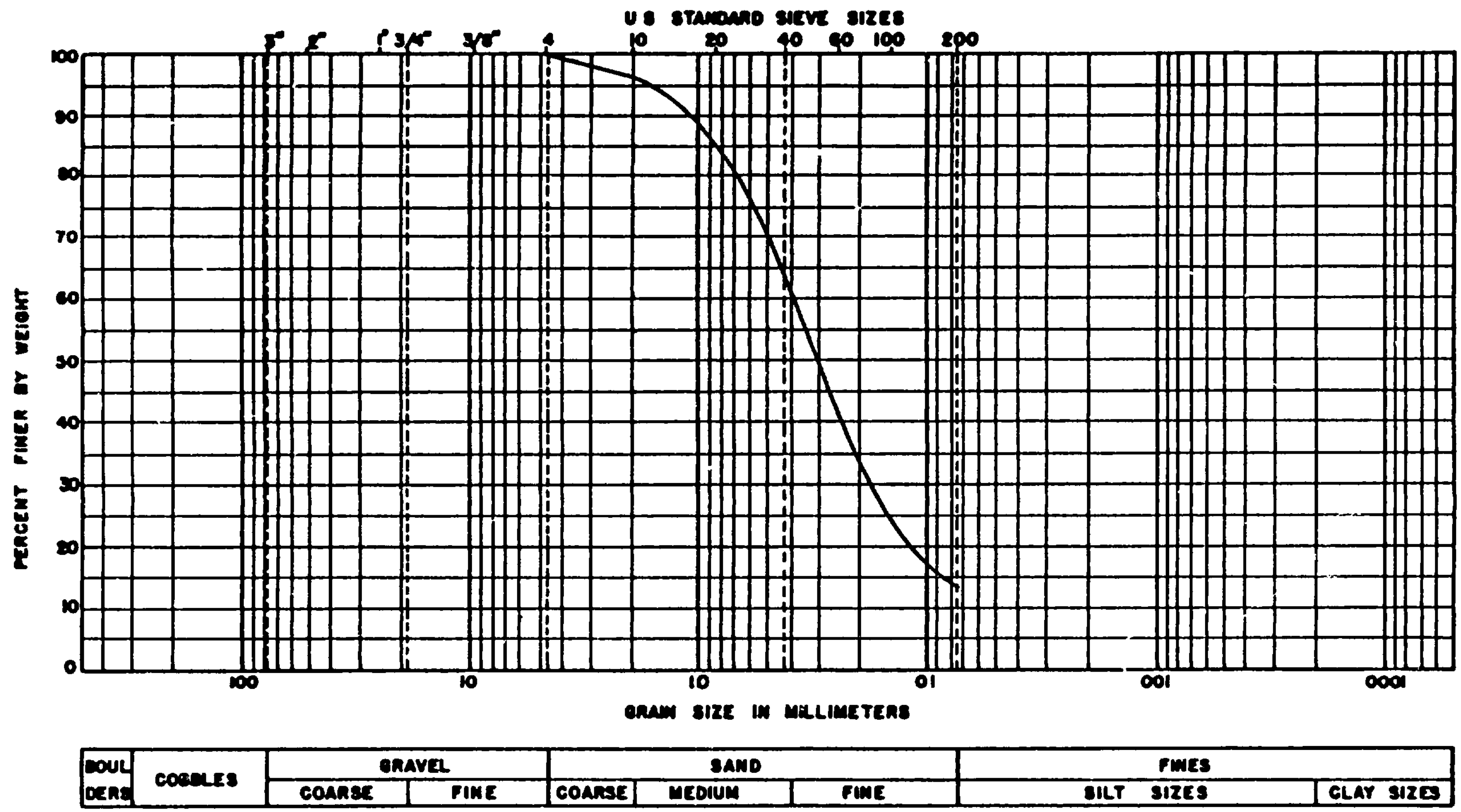
BORING NO	ELEV OR DEPTH	NAT WC	L L	P L	P I	DESCRIPTION OR CLASSIFICATION
Sample # 3 Crater # 1	N/A	N/A	N/A	N/A	N/A	Tan slightly silty fine to medium SAND

GRAIN SIZE DISTRIBUTION

JOB NO. COT-7-2541

LAW ENGINEERING

Figure A-6. Grain Size Distribution of Underlying Soil, Crater 1



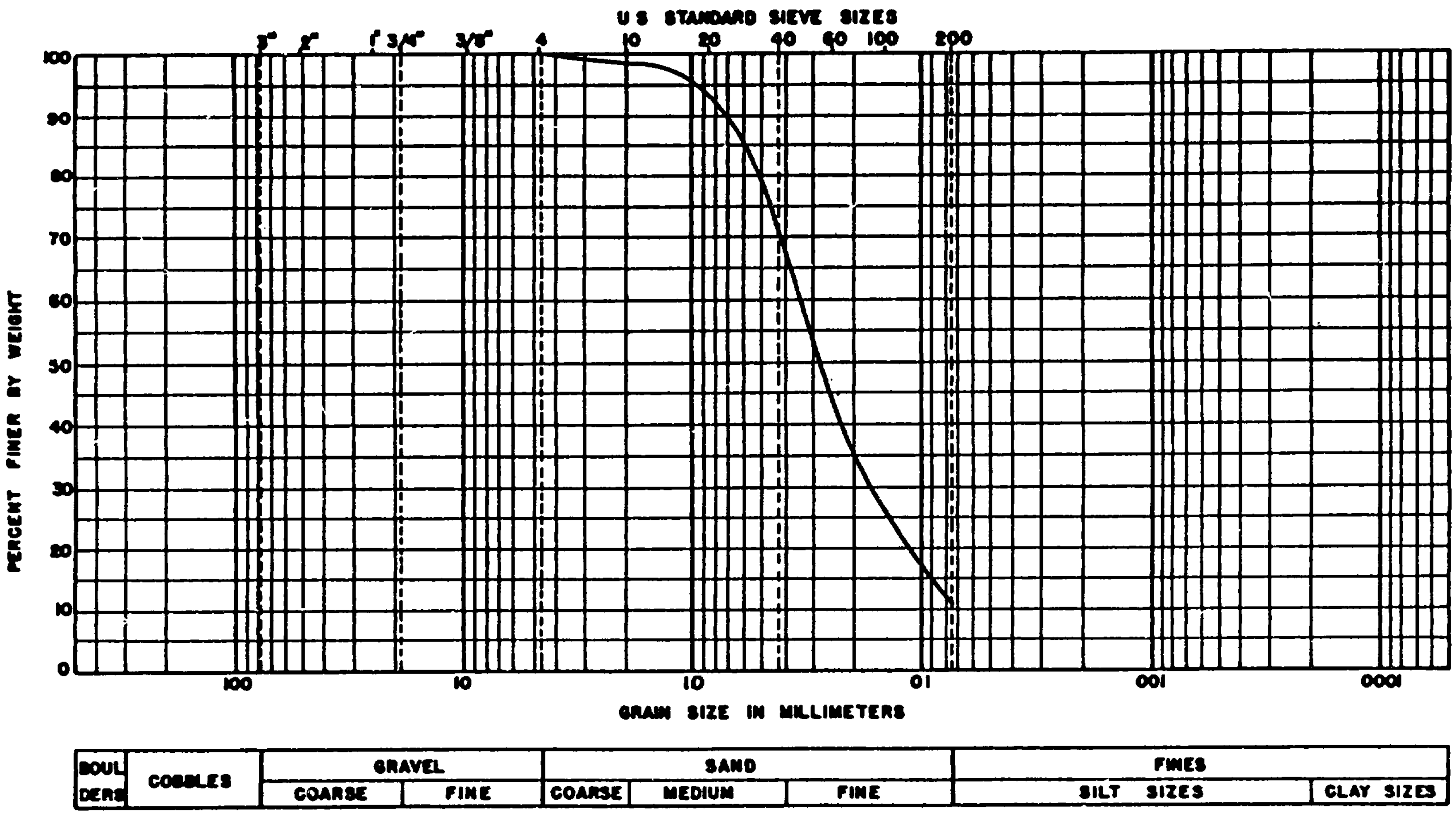
BORING NO	ELEV OR DEPTH	NAT WC	L L	P L	P I	DESCRIPTION OR CLASSIFICATION
Sample # 4 Crater # 1	N/A	N/A	41	25	16	Red slightly clayey fine to medium SAND SC/SM

GRAIN SIZE DISTRIBUTION

JOB NO. COT-7-2541

LAW ENGINEERING

Figure A-7. Grain Size Analysis and Atterburg Limits of Underlying Soil in Crater 1



BORING NO	ELEV OR. DEPTH	NAT WC	L L	PL	P I	DESCRIPTION OR CLASSIFICATION
Sample # 1 Crater # 2	N/A	N/A	N/A	N/A	N/A	Tan slightly silty fine to medium SAND

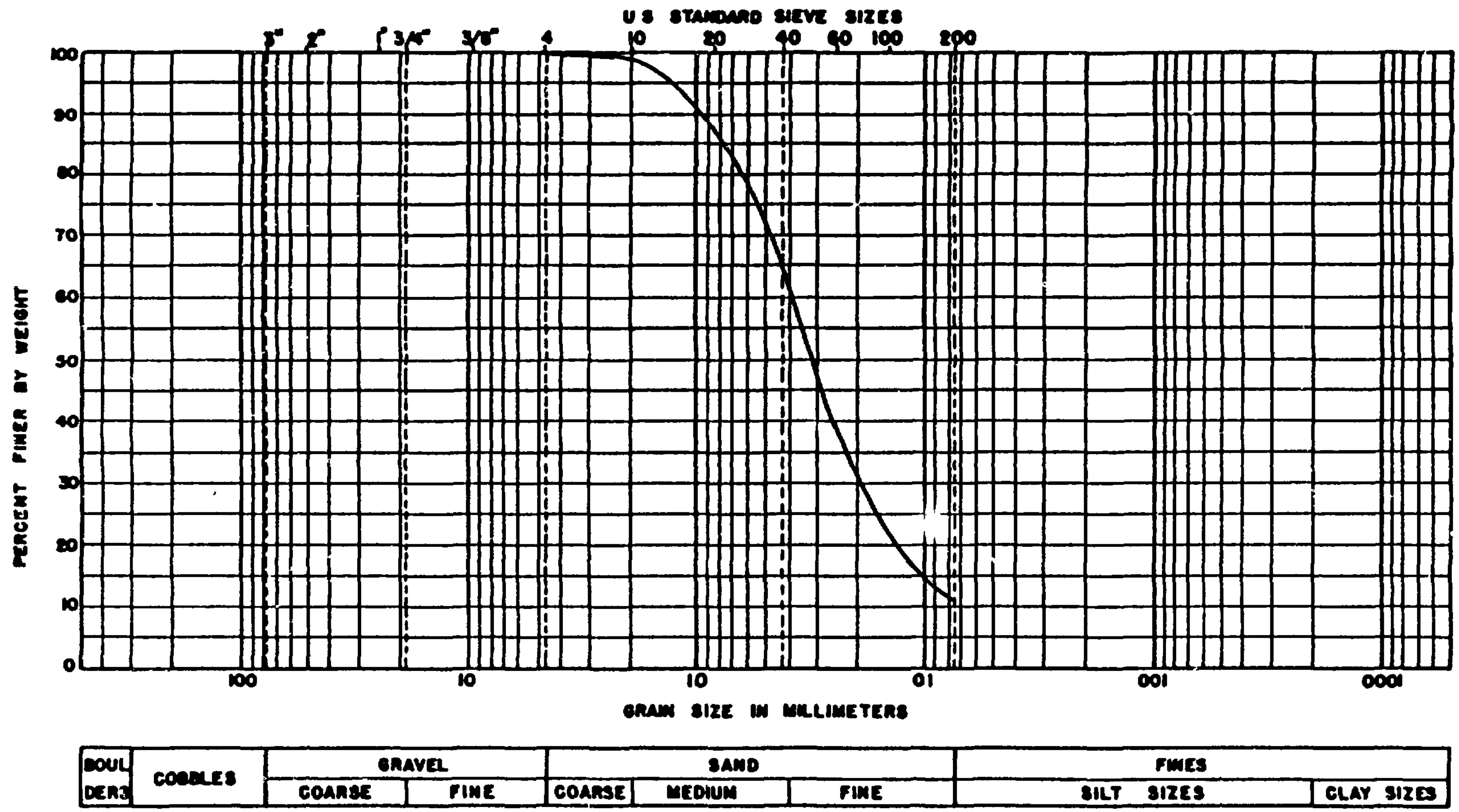
GRAIN SIZE DISTRIBUTION

JOB NO. COT-7-2541

LAW ENGINEERING

G-1

Figure A-8. Grain Size Analysis of Underlying Soil in Crater 2



BORING NO	ELEV OR DEPTH	NAT WC	L L	PL	P I	DESCRIPTION OR CLASSIFICATION
Sample # 2 Crater # 2	N/A	N/A	39	22	17	Red slightly clayey fine to medium SAND SC

GRAIN SIZE DISTRIBUTION

JOB NO. COT-7-2541

LAW ENGINEERING
6-1

Figure A-9. Grain Size Distribution and Atterburg Limits of Underlying Soil in Crater 2

TABLE A-1. RUNWAY PAVEMENT COMPRESSIVE STRENGTH RESULTS

LAW ENGINEERING TESTING COMPANY

COMPRESSIVE STRENGTH TEST RESULTS FOR CORES

ASTM C 42

CLIENT: The BDM Corporation

PROJECT: North Airfield Repairs

JOB NO.: COT-7-2541

CORE NO.	DATE OBTAINED	TEST DATE	DIAMETER (in)	LENGTH UNCAPPED (in.)	LENGTH CAPPED (in.)	AREA (in^2)	LOAD (lbs)	COMPRESSIVE STRENGTH (psi)	LENGTH TO DIAMETER RATIO	CORRECTION FACTOR	CORRECTED COMPRESSIVE STRENGTH (psi)
1	N/A	8/31/87	2.72	5.5	5.5	5.81	59,500	10,240	N/A	N/A	10,240
2	N/A	8/31/87	2.72	5.3	5.4	5.81	58,000	9,980	N/A	N/A	9,980
3	N/A	8/31/87	2.72	5.2	5.5	5.81	55,000	9,470	N/A	N/A	9,470
4	N/A	8/31/87	2.72	5.3	5.5	5.81	63,000	10,840	N/A	N/A	10,840

Type of curing prior to testing: Dry

Moisture condition at time of testing: Dry

Nominal maximum size of aggregate: Measured 1 1/2" - 2"

Direction of load application on the specimens: Compression

Tests performed by: H. Davis

Checked By: J. Rawl

Date: 8/31/87

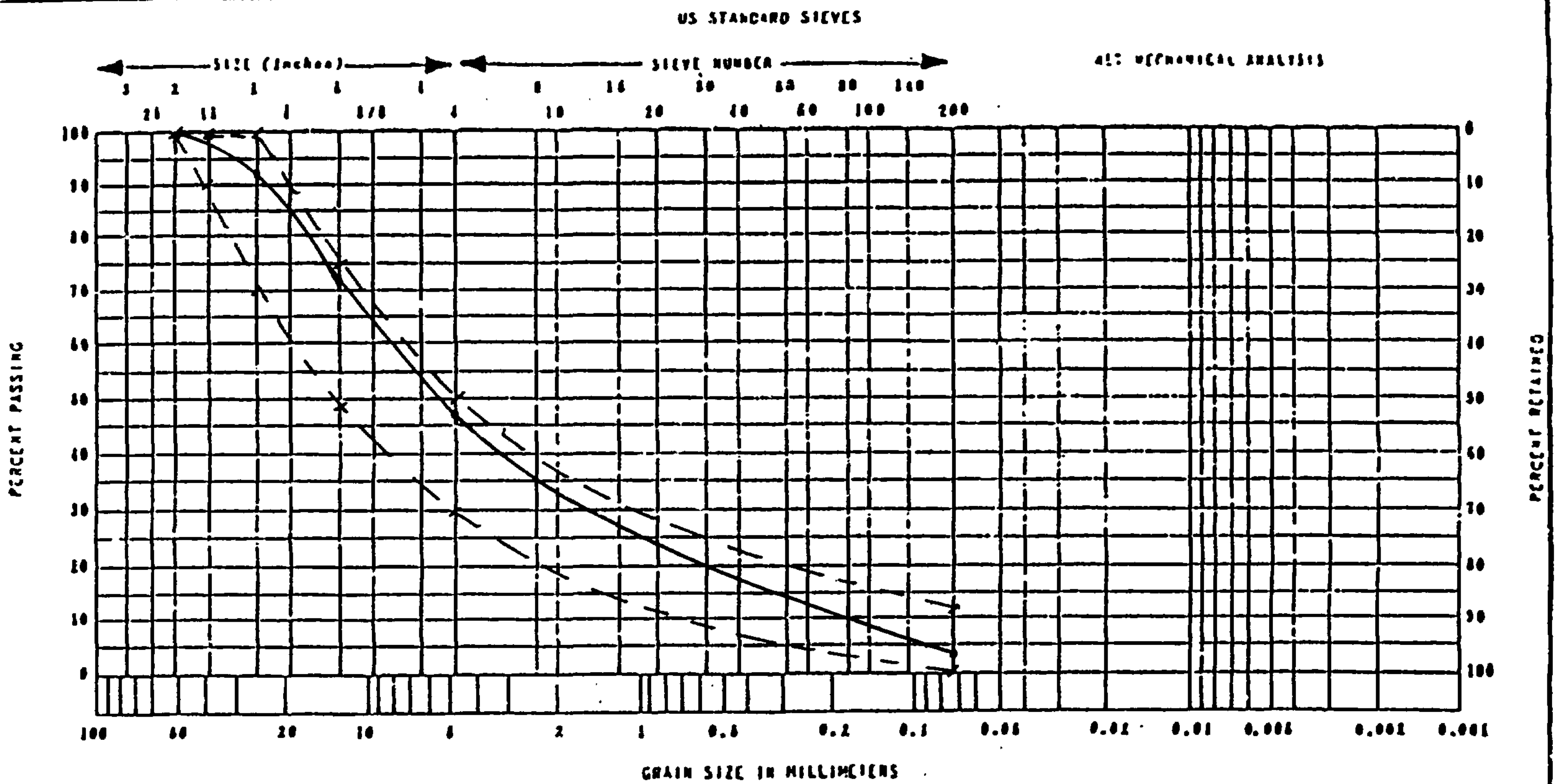
LAW ENGINEERING TESTING COMPANY

NOTE: Cores were obtained by contractor and supplied to Law Engineering for compressive strength testing. The testing revealed that in order for the cores to meet ASTM C42 standards, they would need to have a minimum diameter of 4.0" based on the size of the largest aggregate. The large coarse aggregate encountered during testing could contribute to the high PSI indicated.

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE 12-31-87

PROJECT NORTH FIELD CRUSHED STONE, SIEVE ANALYSIS AND WASH 200 DATA



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	1A						TOTAL SAMPLE WEIGHT 17,212 gm
							----- SPECIFICATION BOUNDARY
							—— ACTUAL GRAIN SIZE

TECHNICIAN (Signature)

PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans

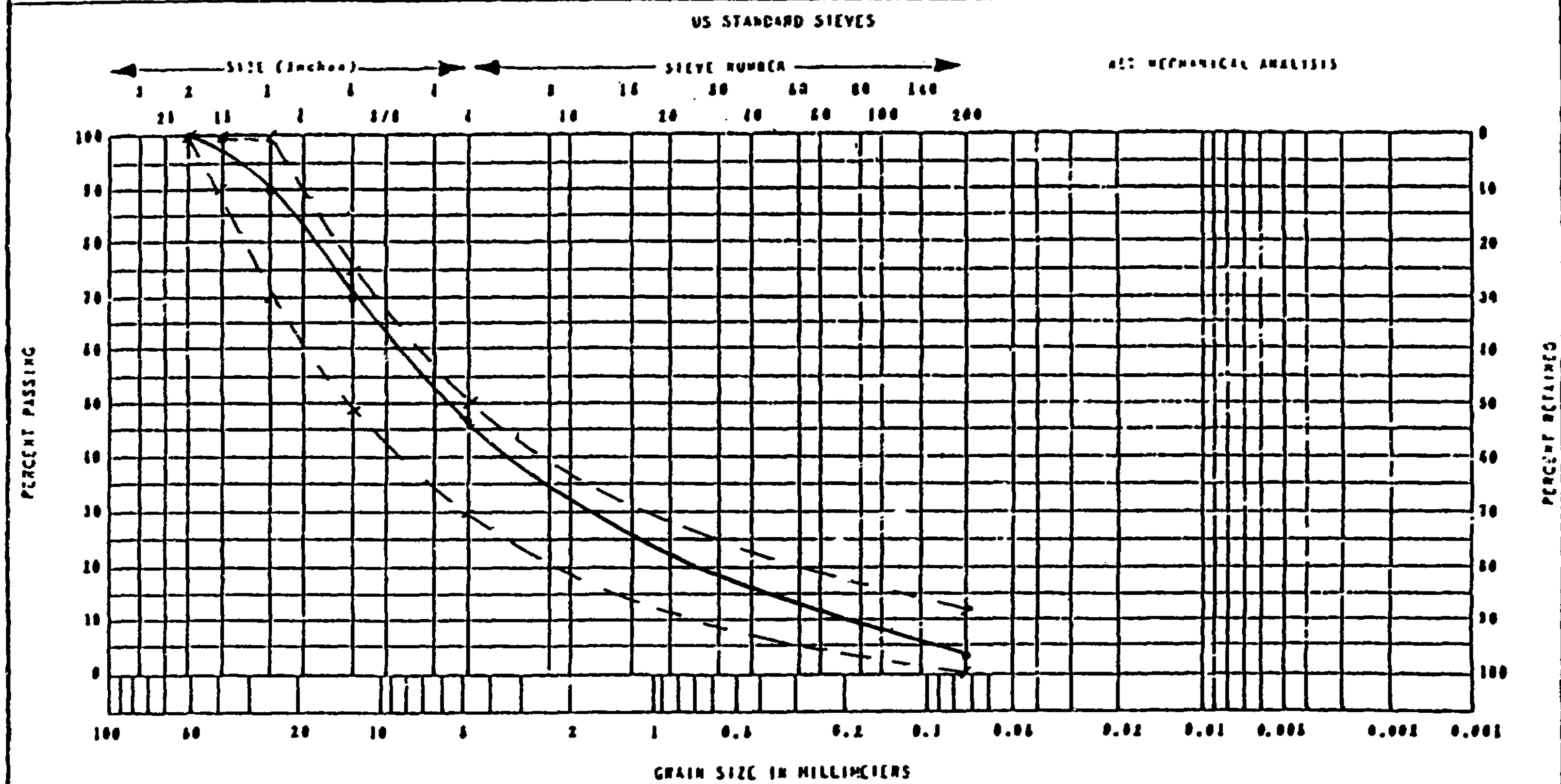
DD FORM 1 AUG 51 1207

Figure A-10. Crushed Stone Specifications and Sieve Analysis, Sample 1A

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE 12-31-87

PROJECT NORTH FIELD CRUSHED STONE, SIEVE ANALYSIS AND WASH 200 DATA



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	1B						TOTAL SAMPLE WEIGHT 16,525 gm
							----- SPECIFICATION BOUNDARY
							—— ACTUAL GRAIN SIZE

TECHNICIAN (Signature)

PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans

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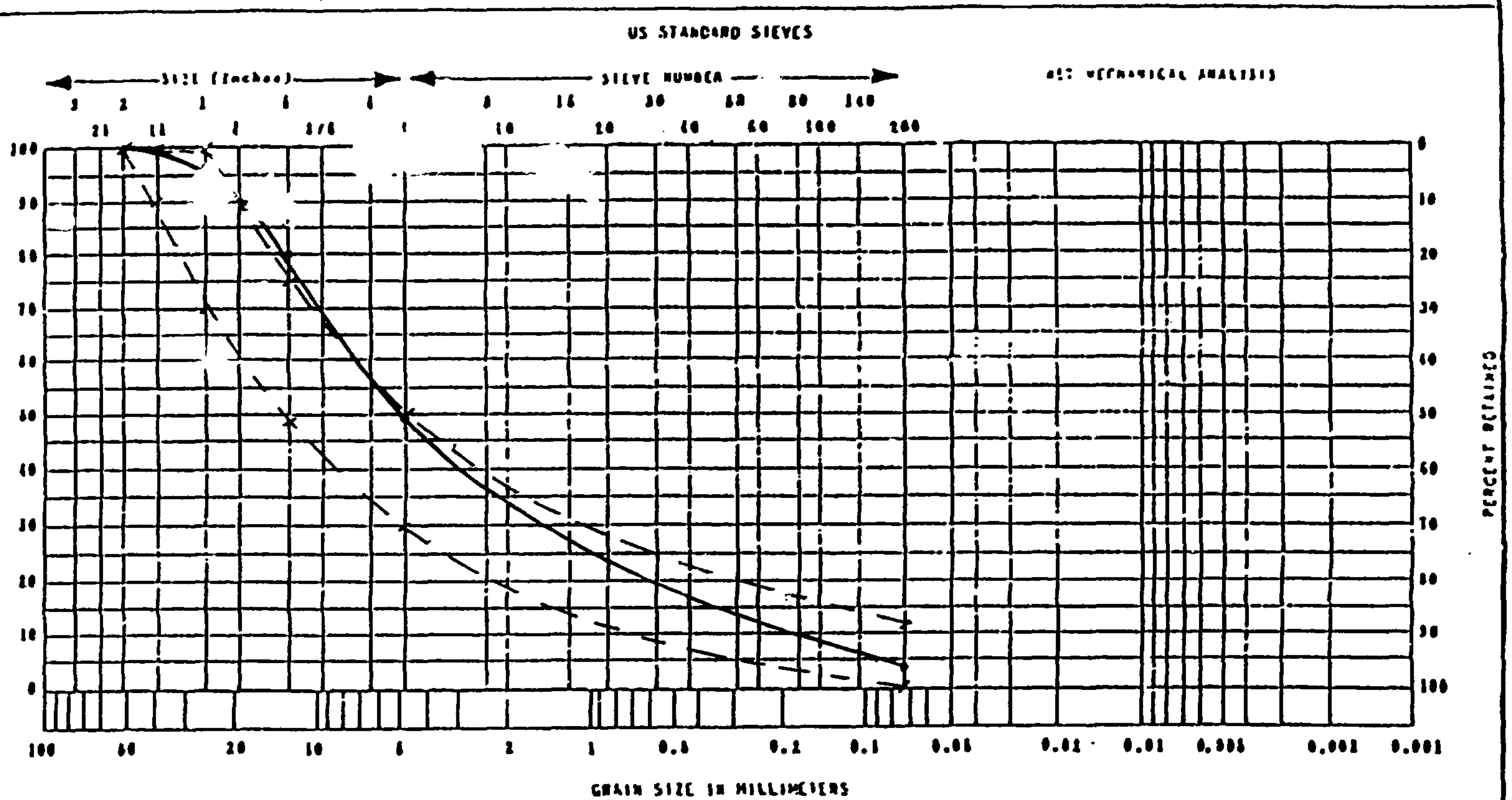
Figure A-11. Crushed Stone Specifications and Sieve Analysis, Sample 1B

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 12-31-87

PROJECT: NORTH FIELD CRUSHED STONE, SIEVE ANALYSIS AND WASH 200 DATA



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	1D						* ½ INCH OUT OF SPECIFICATIONS
							TOTAL SAMPLE WEIGHT 16,571 gm
							------ SPECIFICATION BOUNDARY
TECHNICIAN (Signature)			PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans				——— ACTUAL GRAIN SIZE

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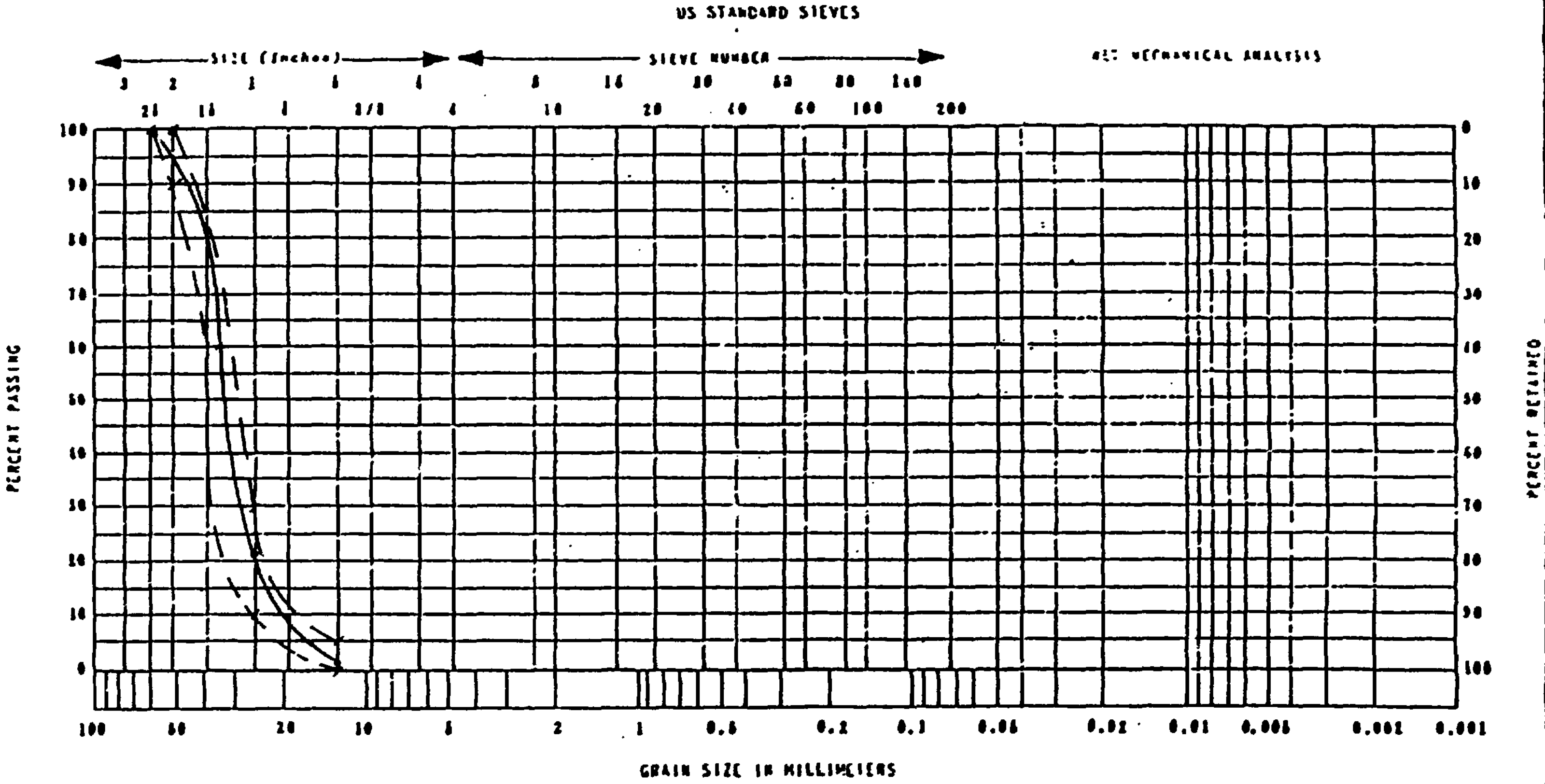
Figure A-12. Crushed Stone Specifications and Sieve Analysis, Sample 1D

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART	DATE 12-31-87
PROJECT NORTH FIELD BALLAST ROCK, SIEVE ANALYSIS AND WASH 200 DATA	



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	2A						TOTAL SAMPLE WEIGHT 22,075 gm
							----- SPECIFICATION BOUNDARY
							——— ACTUAL GRAIN SIZE

TECHNICIAN (Signature)	PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans	

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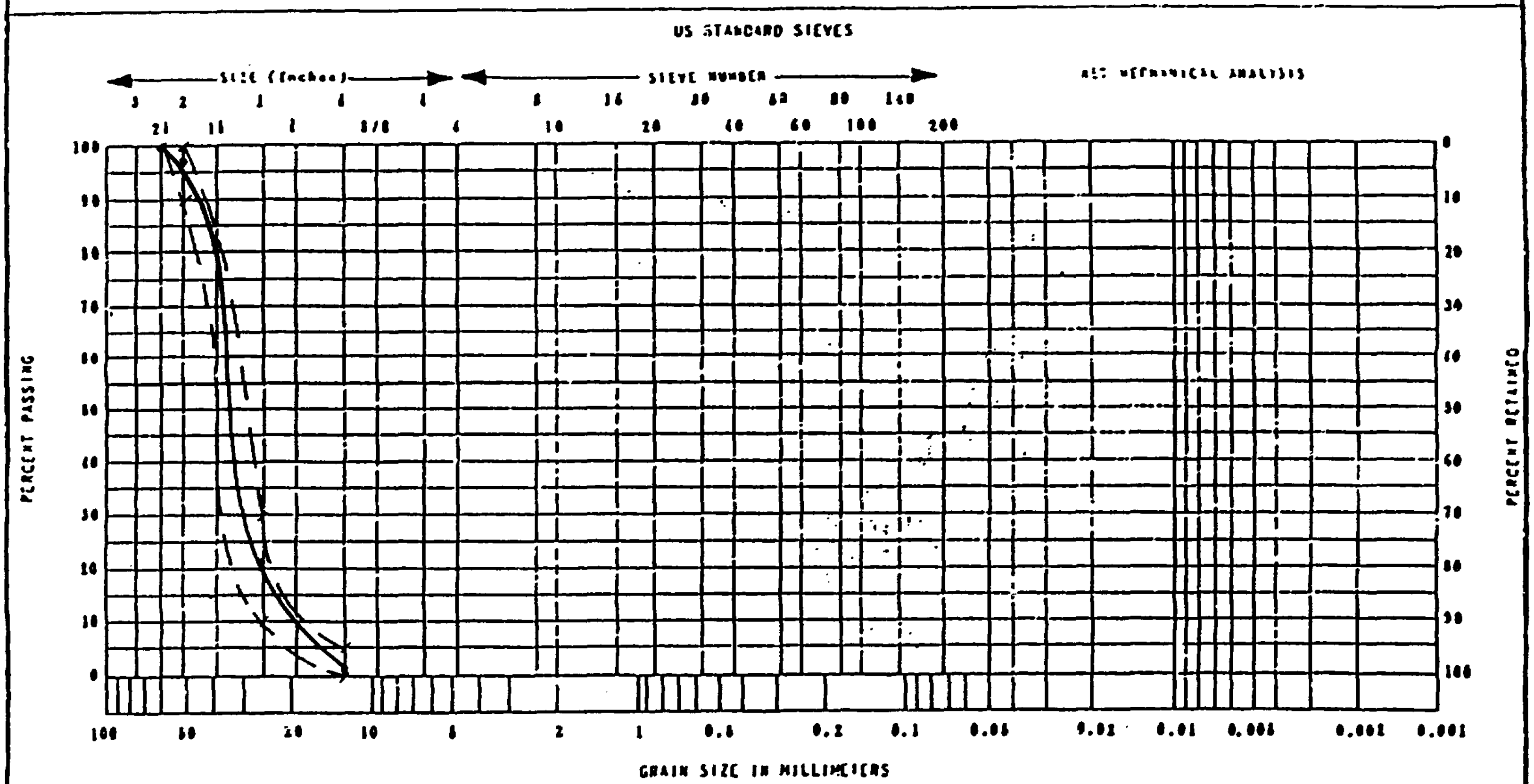
Figure A-13. Ballast Rock Specifications and Sieve Analysis, Sample 2A

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE 12-31-87

PROJECT NORTH FIELD BALLAST ROCK, SIEVE ANALYSIS AND WASH 200 DATA



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	2B						TOTAL SAMPLE WEIGHT 23,400 gm
							------ SPECIFICATION BOUNDARY
							——— ACTUAL GRAIN SIZE

TECHNICIAN (Signature)

PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans

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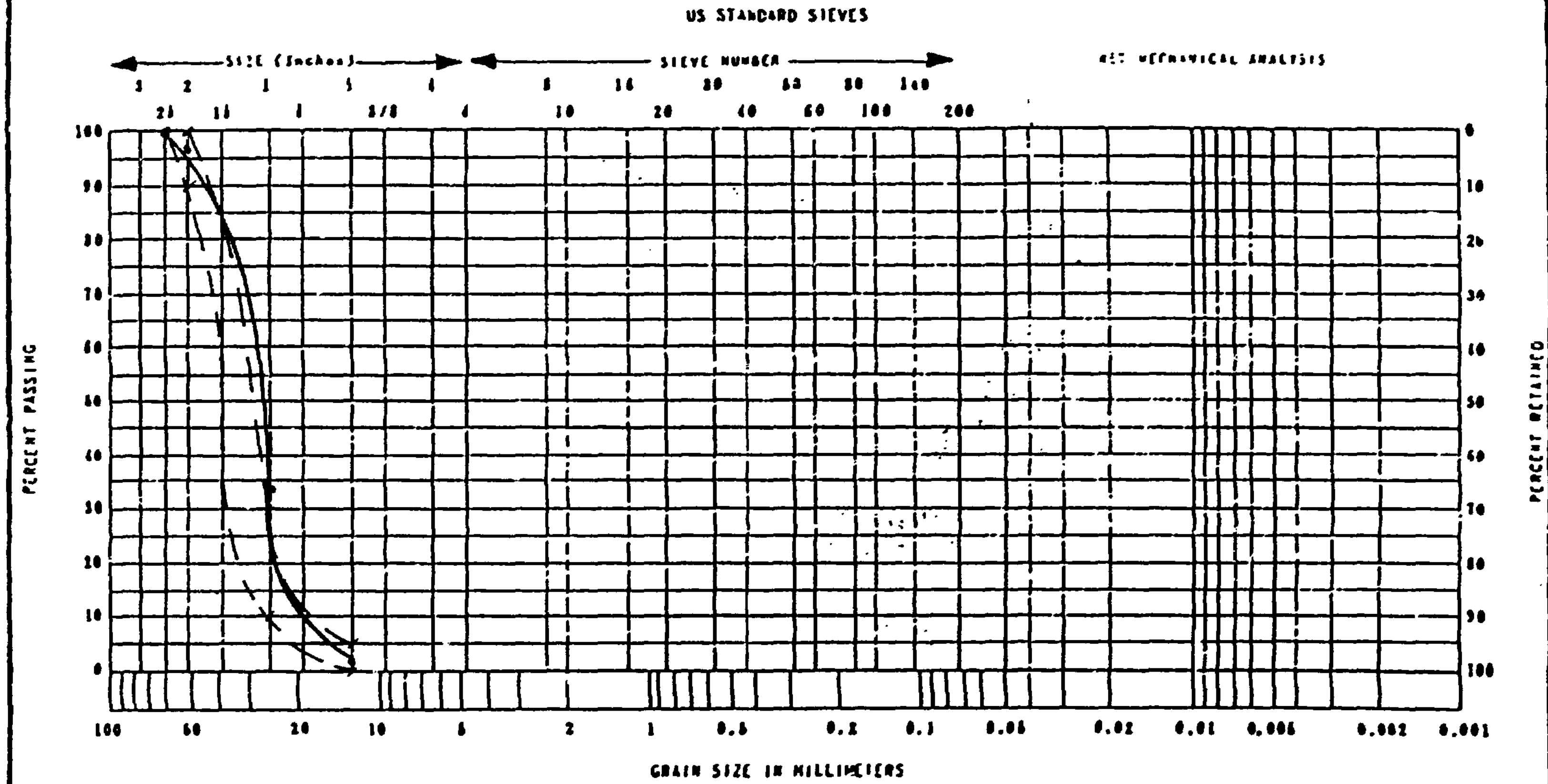
Figure A-14. Ballast Rock Specifications and Sieve Analysis, Sample 2B

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE 12-31-87

PROJECT NORTH FIELD BALLAST ROCK, SIEVE ANALYSIS AND WASH 200 DATA



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	2C						* 1 INCH OUT OF SPECIFICATIONS
							TOTAL SAMPLF WEIGHT 21,530 gm
							------ SPECIFICATIUN BOUNDARY
TECHNICIAN (Signature)		PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans					——— ACTUAL GRAIN SIZE

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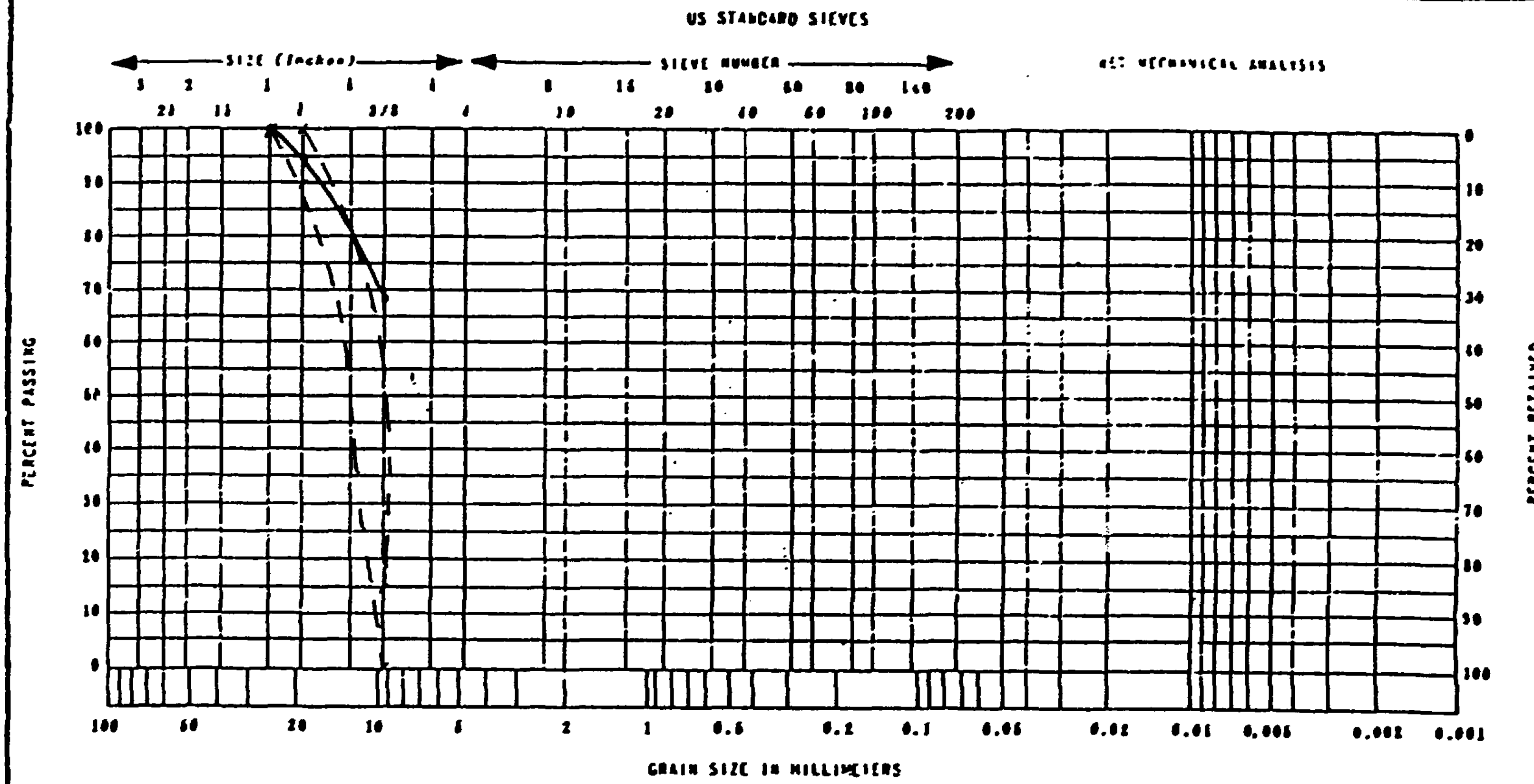
Figure A-15. Ballast Rock Specifications and Sieve Analysis, Sample 2C

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART DATE 12-31-87

PROJECT NORTH FIELD NUMBER 6 STONE, SIEVE ANALYSIS AND WASH 200 DATA



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	3A						* 3/8 INCH OUT OF SPECIFICATIONS
							TOTAL SAMPLE WEIGHT 12,338 gm
							----- SPECIFICATION BOUNDARY
TECHNICIAN (Signature)			PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans				——— ACTUAL GRAIN SIZE

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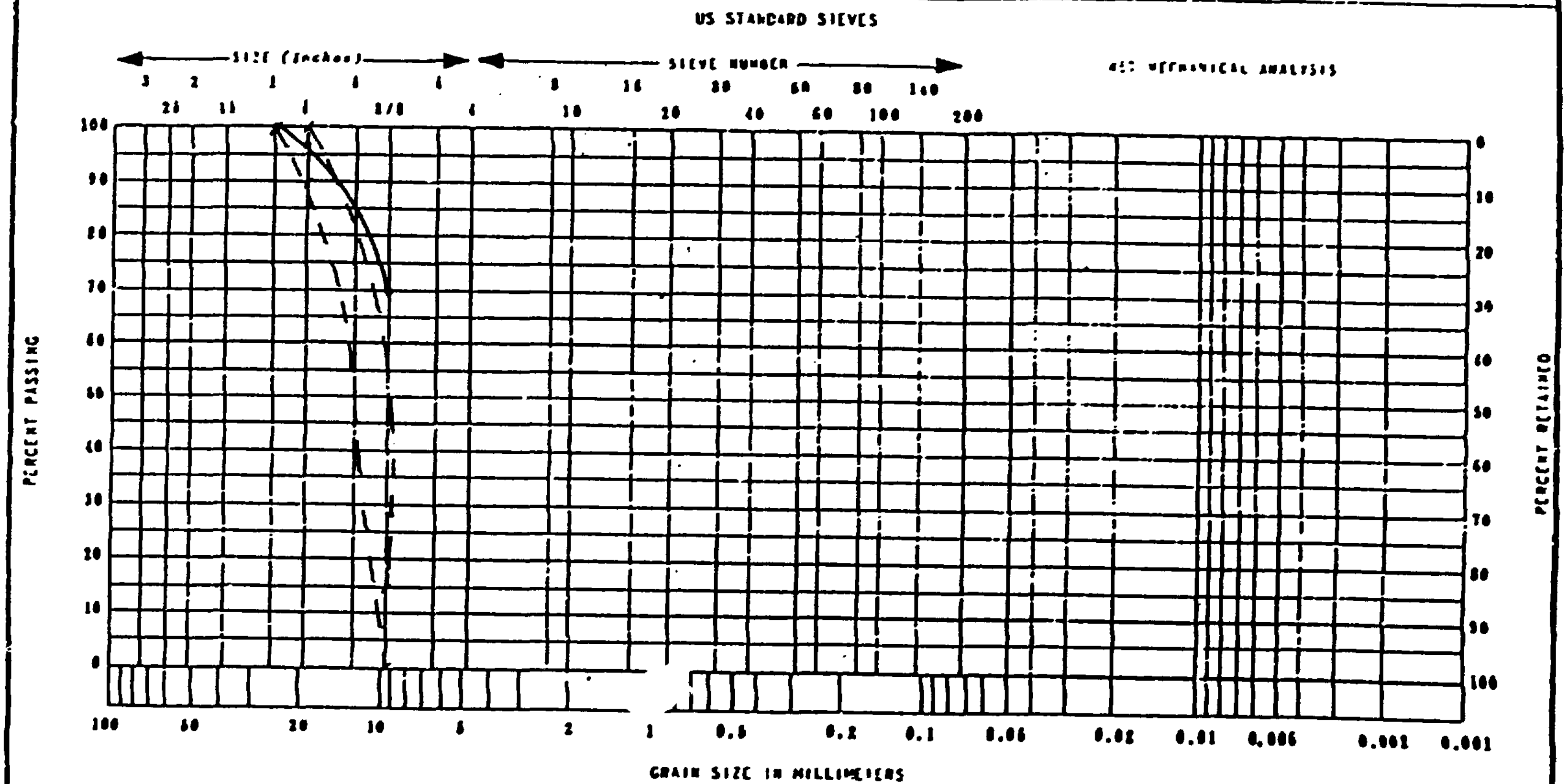
Figure A-16. Number 6 Stone Specifications and Sieve Analysis, Sample 3A

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE: 12-31-87

PROJECT: NORTH FIELD NUMBER 6 STONE, SIEVE ANALYSIS AND WASH 200 DATA



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	3B						* 3/8 INCH OUT OF SPECIFICATIONS
							TOTAL SAMPLE WEIGHT 16,400 gm
							----- SPECIFICATION BOUNDARY
TECHNICIAN (Signature)			PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans				—— ACTUAL GRAIN SIZE

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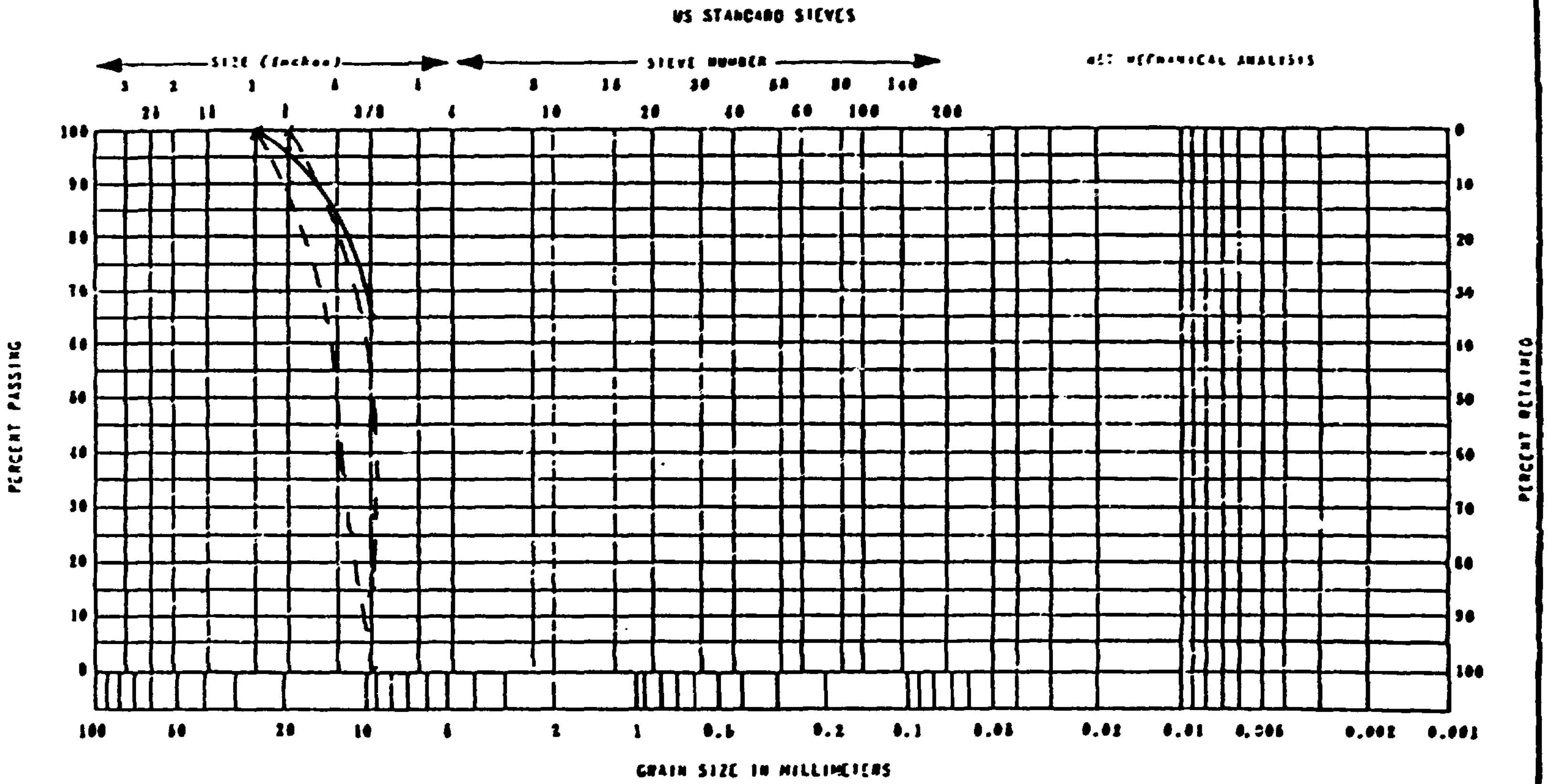
Figure A-17. Number 6 Stone Specifications and Sieve Analysis, Sample 3B

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE 12-31-87

PROJECT
NORTH FIELD NUMBER 6 STONE, SIEVE ANALYSIS AND WASH 200 DATA



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS
	3C						* 3/8 INCH OUT OF SPECIFICATIONS
							TOTAL SAMPLE WEIGHT 13,137 gm
							----- SPECIFICATION BOUNDARY
TECHNICIAN (Signature)			PLOTTED BY (Signature) Jo Ann Varnadore/Jim Evans				——— ACTUAL GRAIN SIZE

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GPO 831100

Figure A-18. Number 6 Stone Specifications and Sieve Analysis, Sample 3C

APPENDIX B

REPAIR PROFILES

This appendix is comprised of plots of the elevation profiles taken before and after crater formation, and periodically during aircraft trafficking. Also included are plots showing the change in pavement elevation caused by rolling the upheaved pavement before breaking out the upheaval.

Figures B-1 and B-2 illustrate the centerline profiles of each crater, compared to the original pavement surface. Profile elevations are plotted in feet relative to a benchmark elevation of 10 feet.

Figures B-3 through B-14 are profiles taken of Repair 1 during aircraft trafficking. Figures B-15 through B-26 are profiles taken of Repair 2 during aircraft trafficking.

Profile lines were established as shown in Figure 21 (Section II). Plots of each profile line are presented from the leftmost profile line to the rightmost line looking west along the repair. The first plot for each profile line shows "normalized"* mat surface elevations before and after proofrolling and after the 14th aircraft trafficking pass. The second plot for each profile line shows "normalized" mat surface elevations periodically for the remainder of trafficking. Profile lines L3 amd R3 (see Figure 21) received no trafficking and, hence, are not plotted for trafficking passes greater than 40.

Figures B-27 through B-35 are profiles showing the change upheaval caused by compressing the pavement with a 10-ton vibratory roller before breaking out upheaval.

* Normalization was performed by calculating elevations relative to an imaginary baseline defined by the beginning and ending profile points.

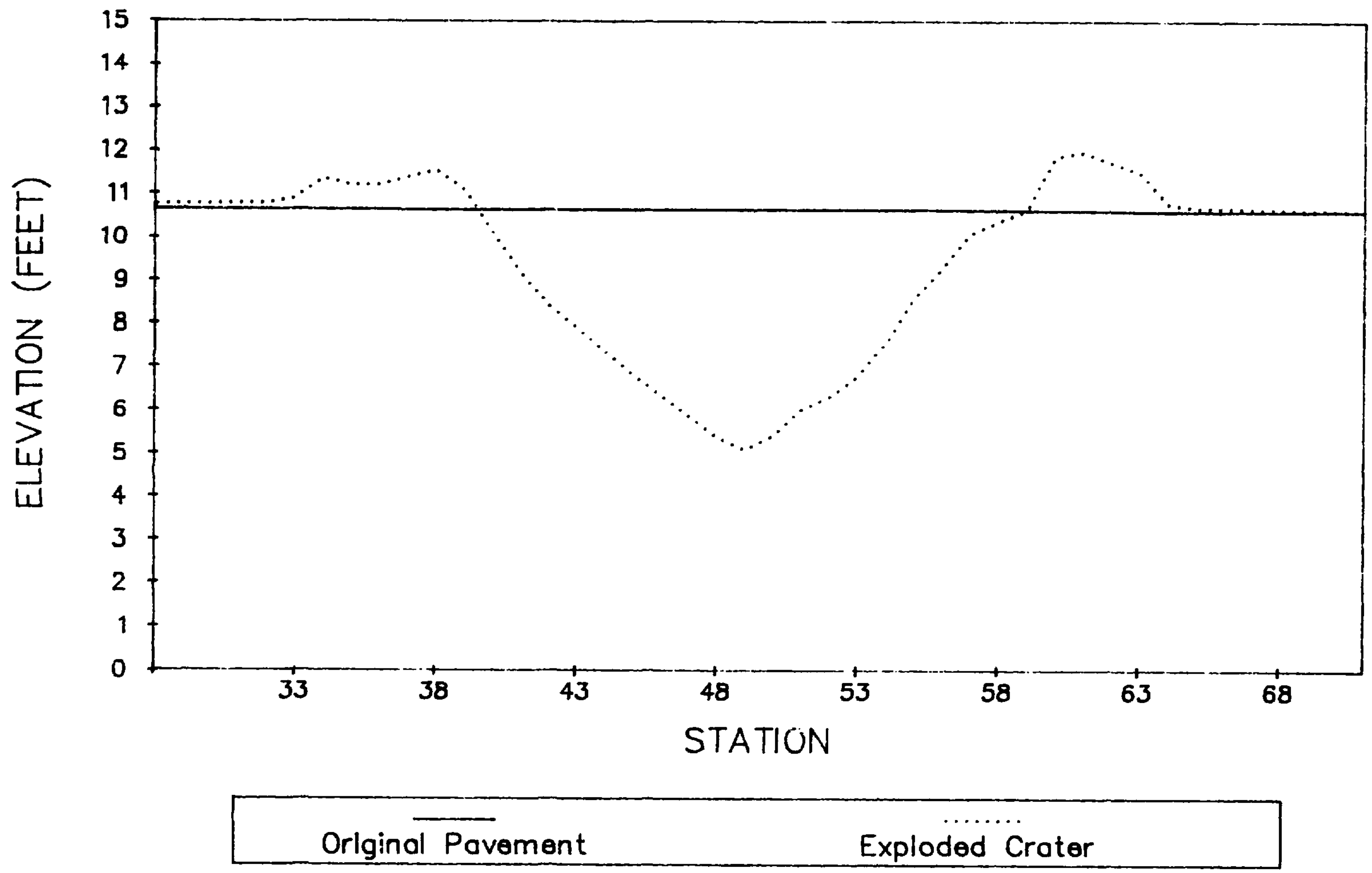


Figure B-1. Repair 1 Crater Depth

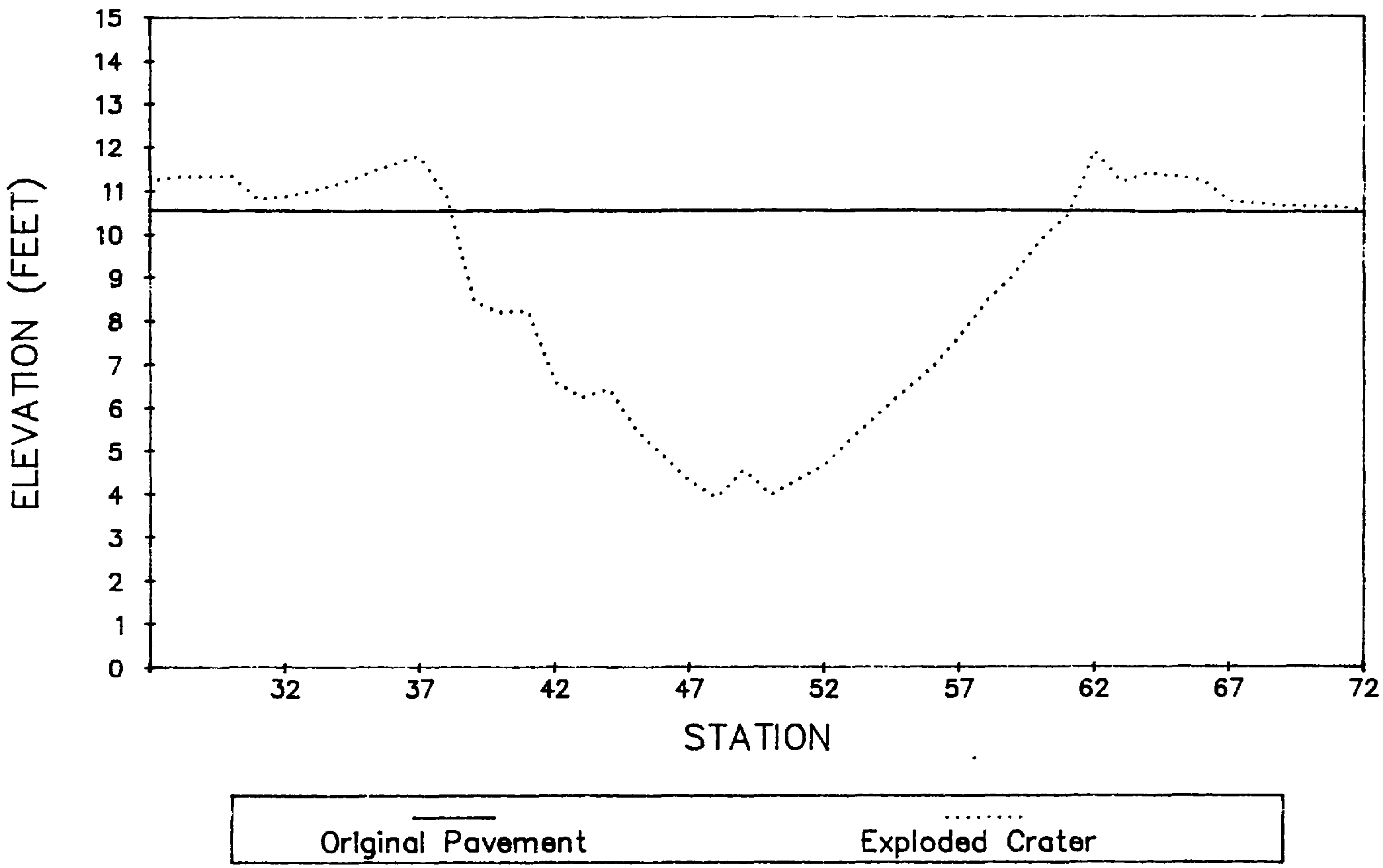


Figure B-2. Repair 2 Crater Depth

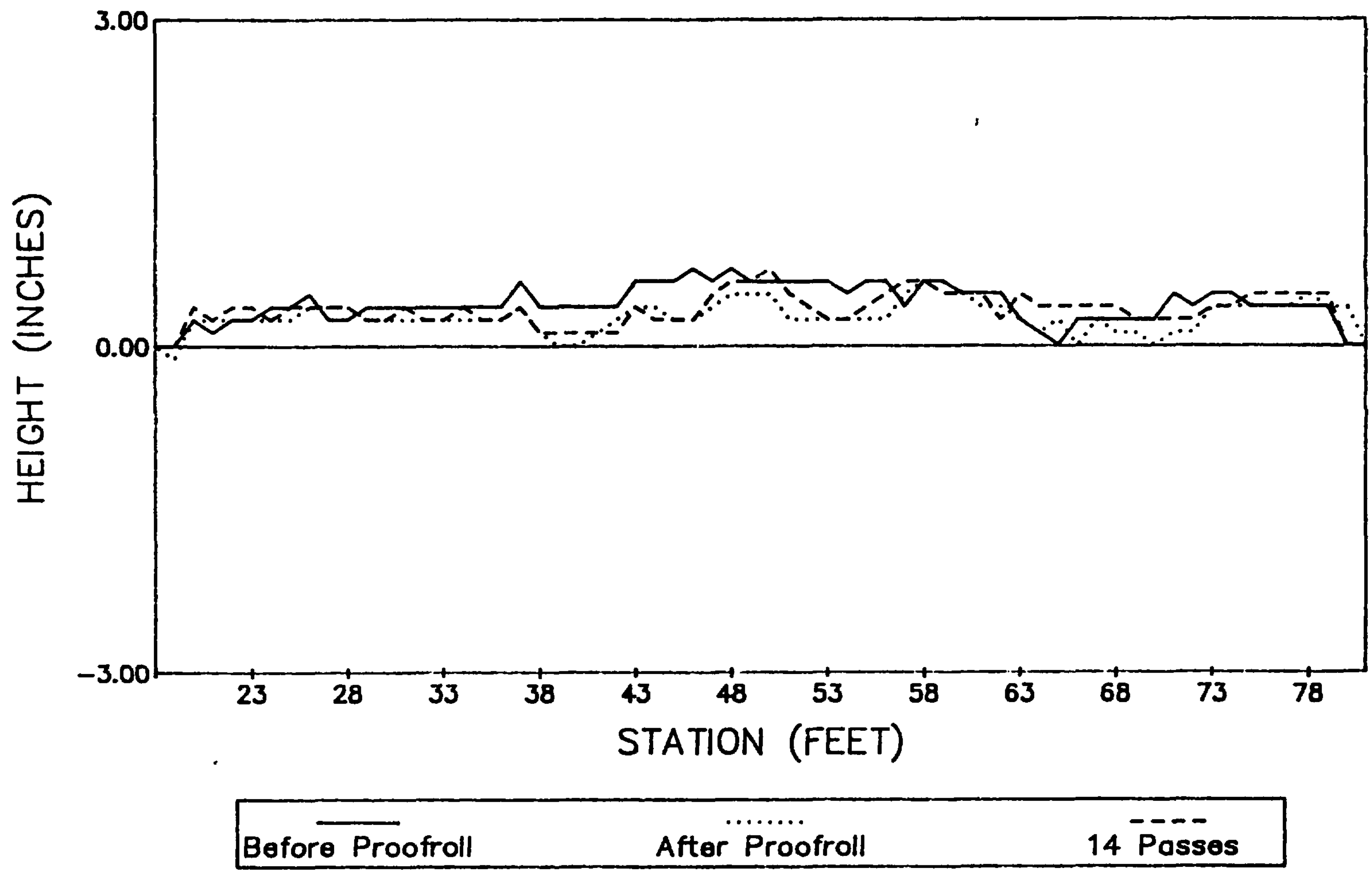


Figure B-3. Repair 1 After Proofrolling and 14 Aircraft Passes, 18 Feet North of Centerline (Profile R3)

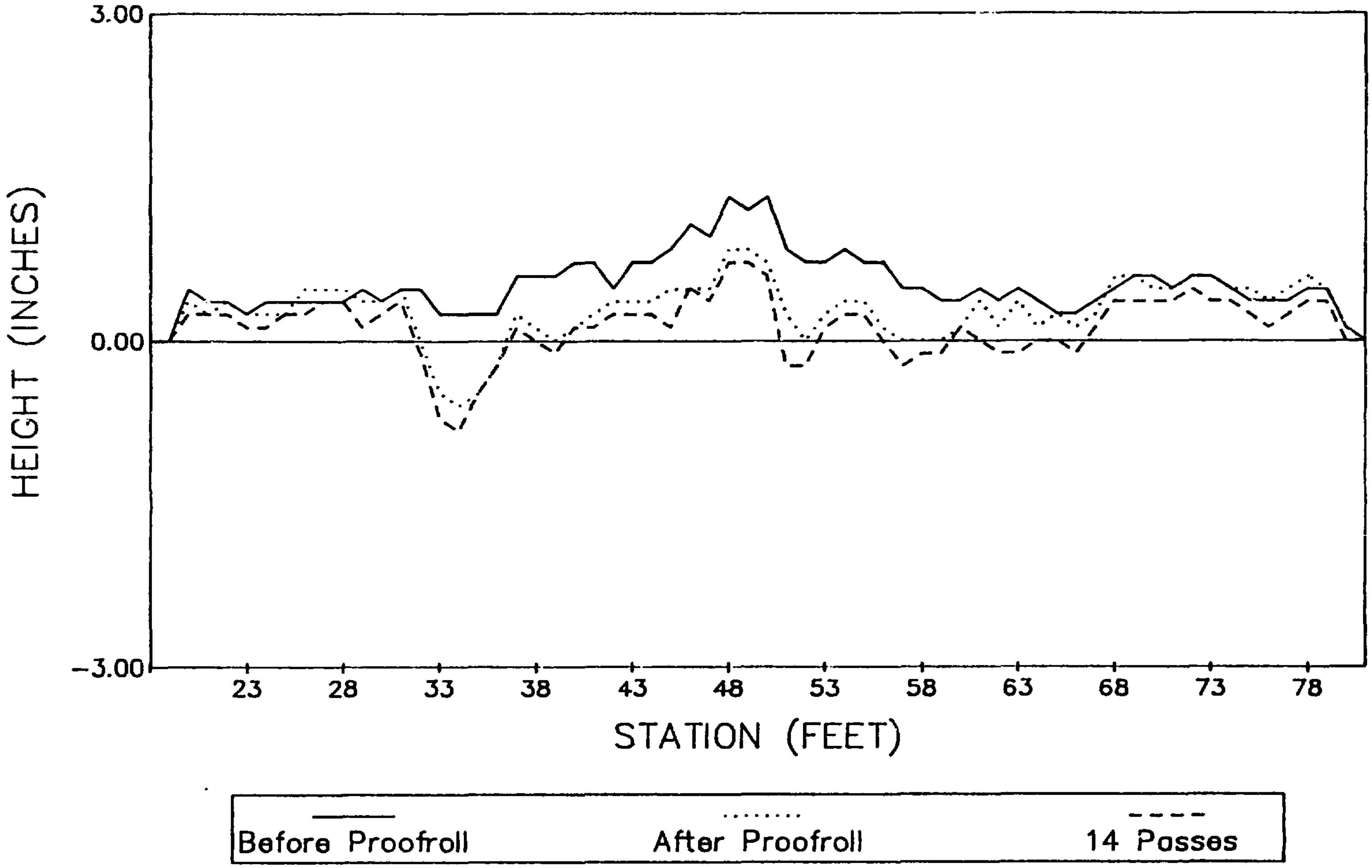


Figure B-4. Repair 1 After Proofrolling and 14 Aircraft Passes, 12 Feet North of Centerline (Profile R2)

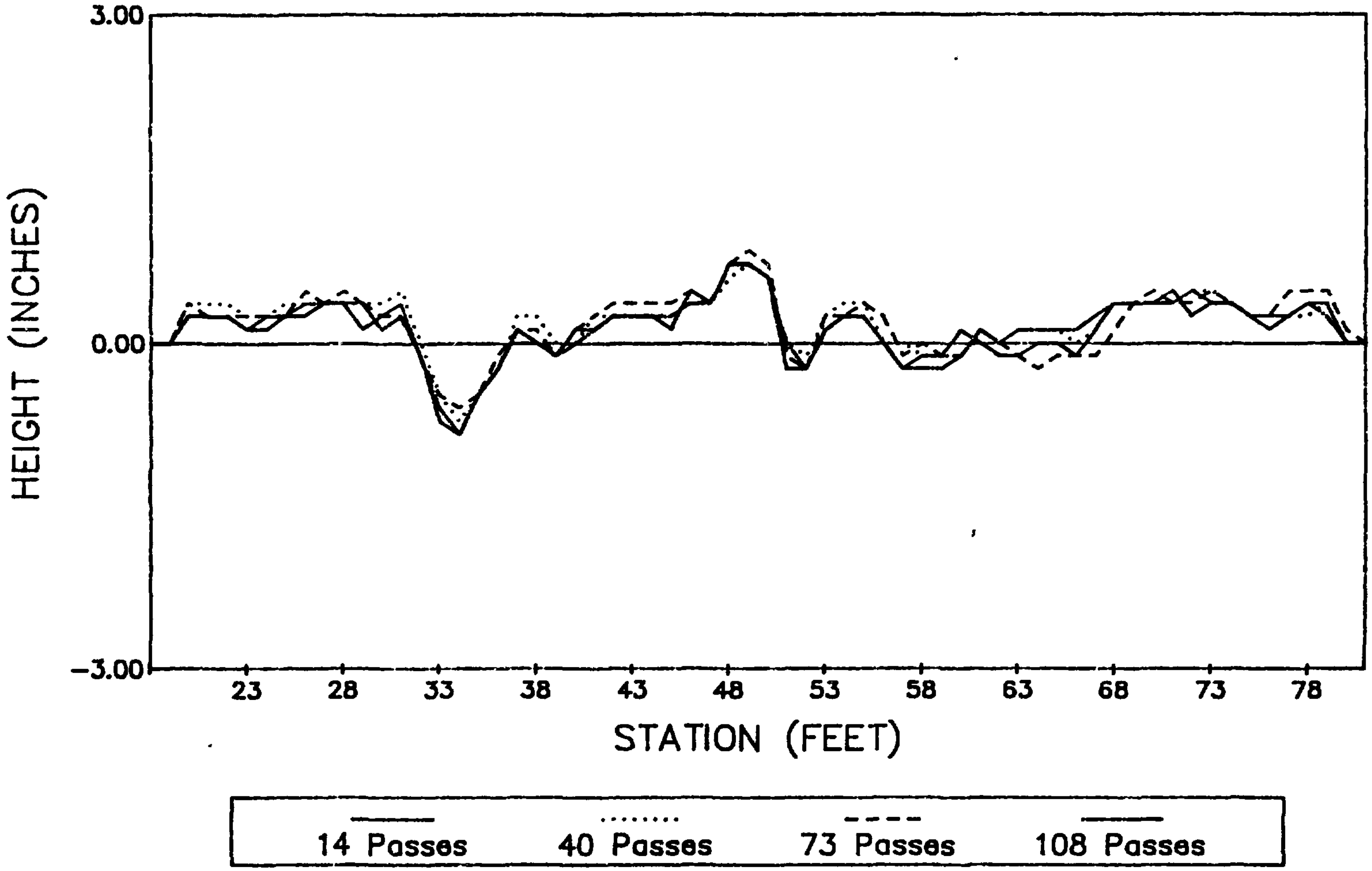


Figure B-5. Repair 1 After Aircraft Trafficking, 12 Feet North of Centerline (Profile R2)

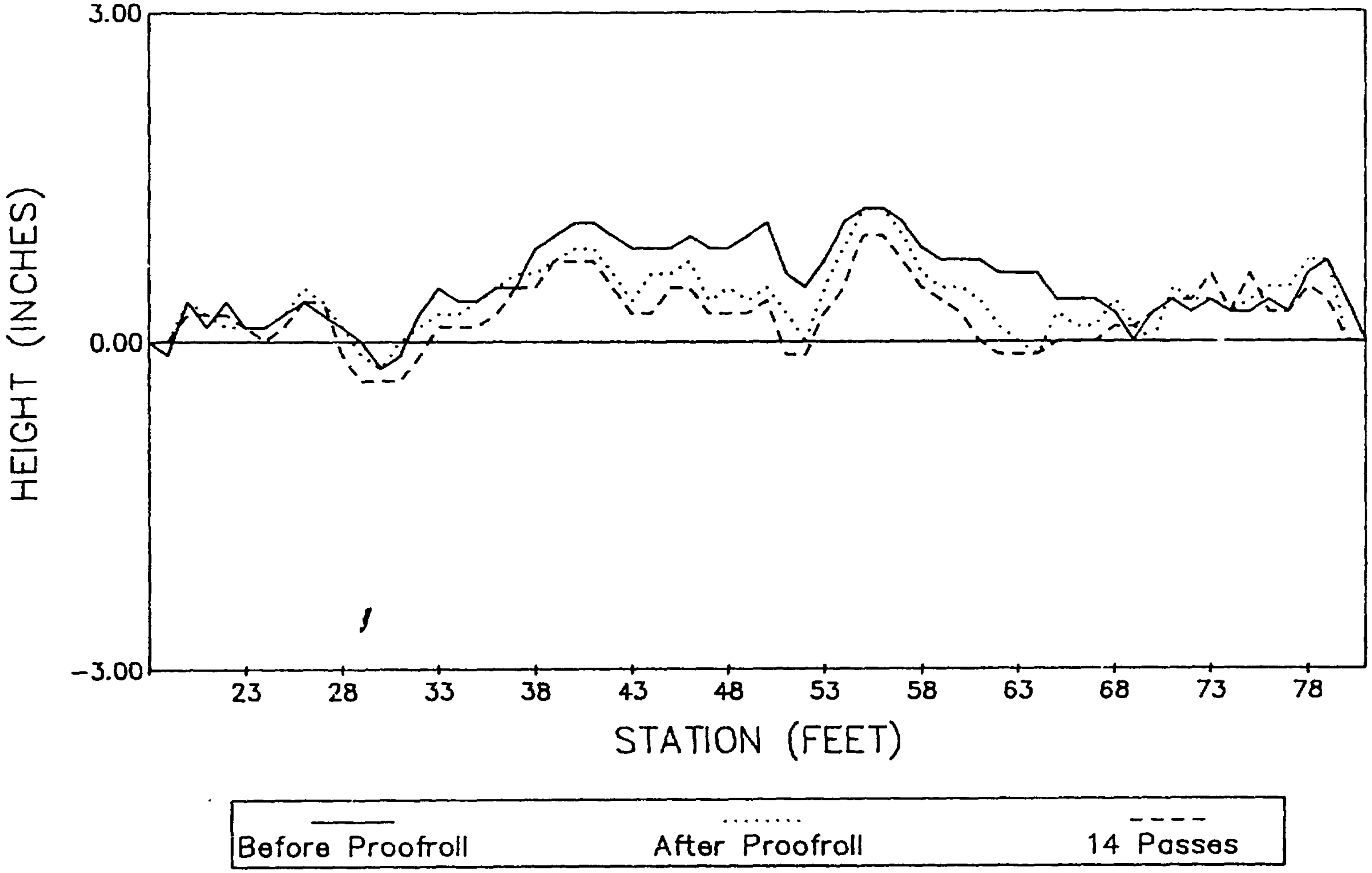


Figure B-6. Repair 1 Degradation After Proofrolling and 14 Aircraft Passes, 6 Feet North of Centerline

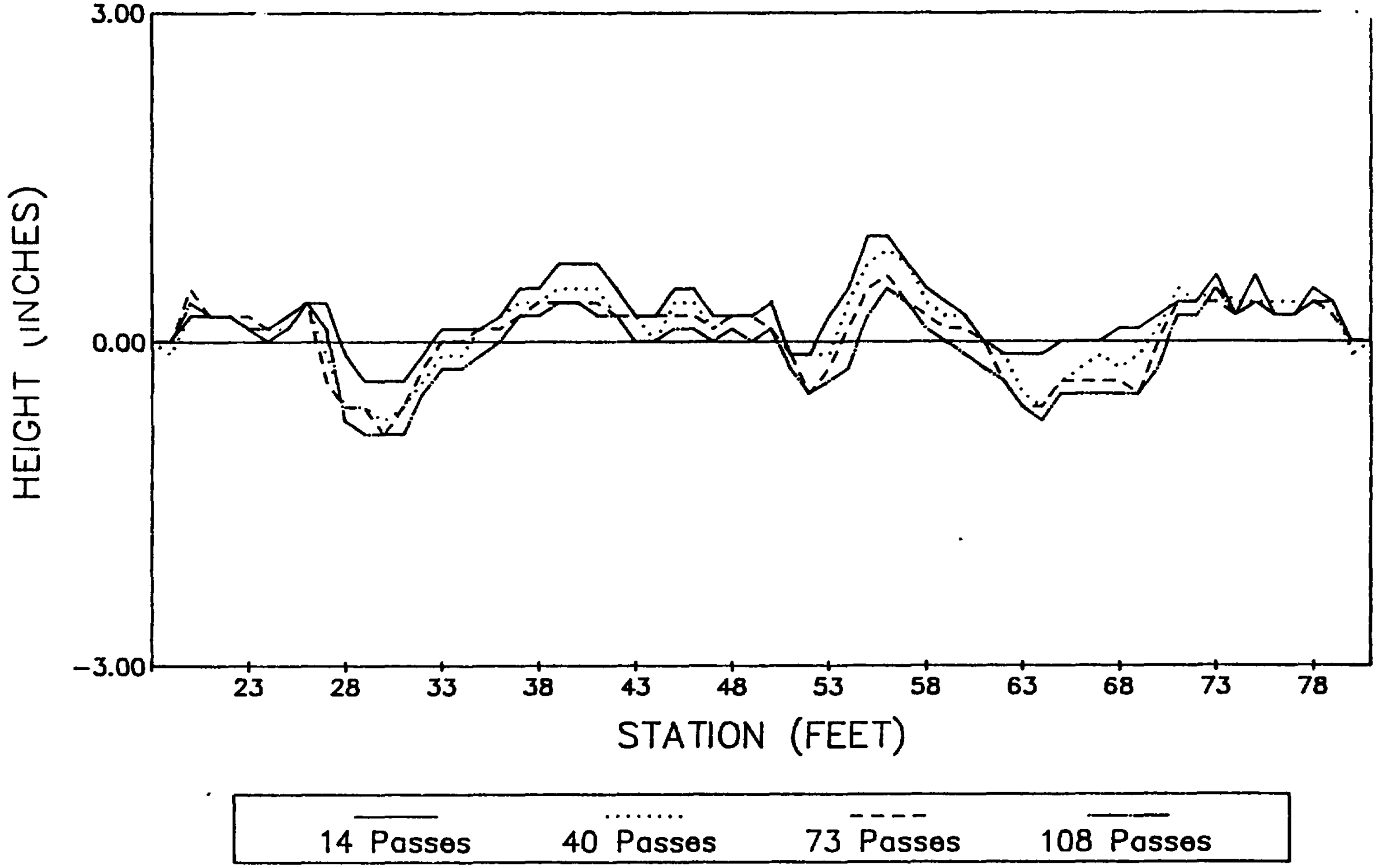


Figure B-7. Repair 1 After Aircraft Trafficking, 6 Feet North of Centerline (Profile R1)

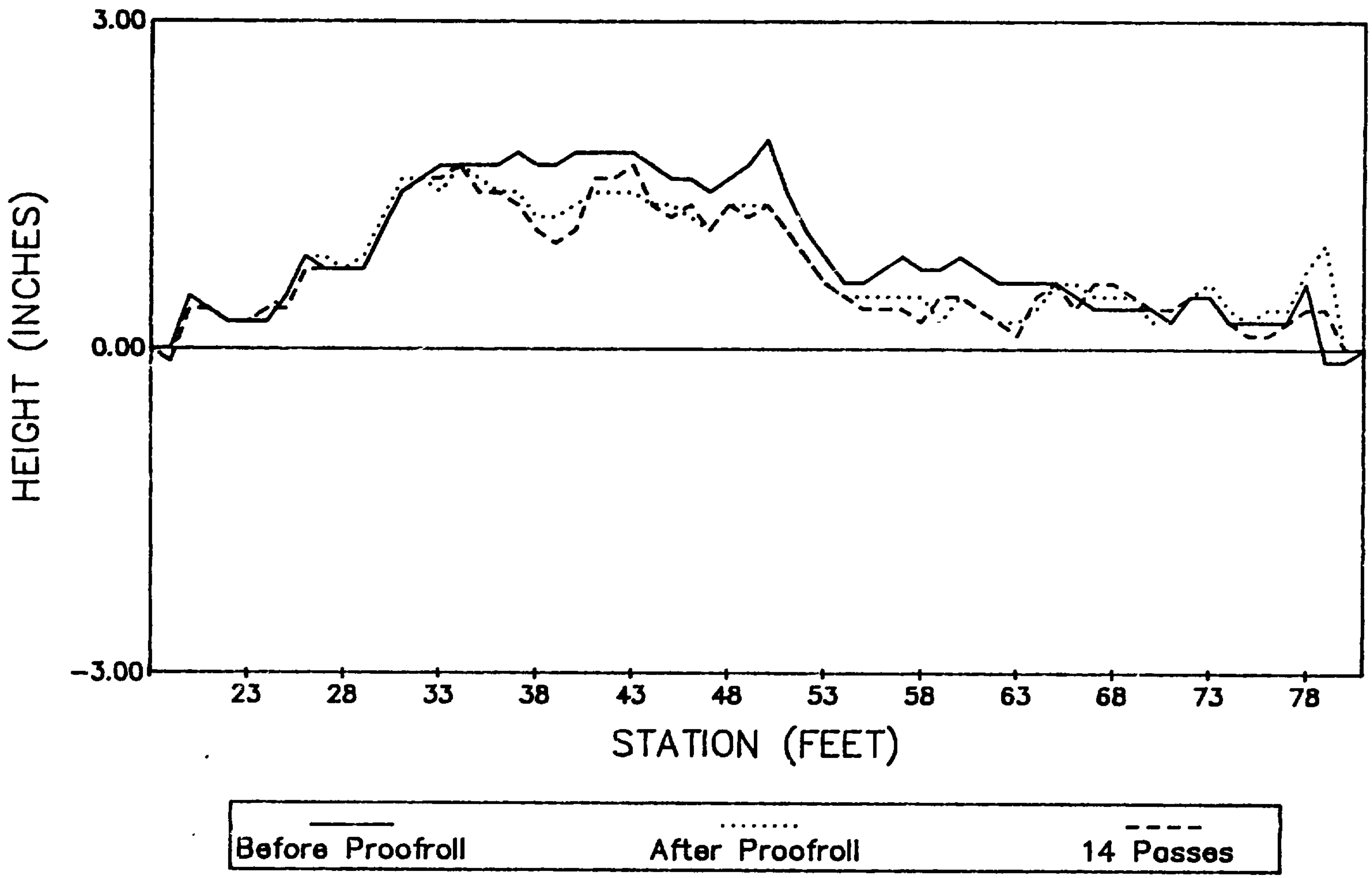


Figure B-8. Repair 1 After Proofroiling and 14 Aircraft Passes, Centerline

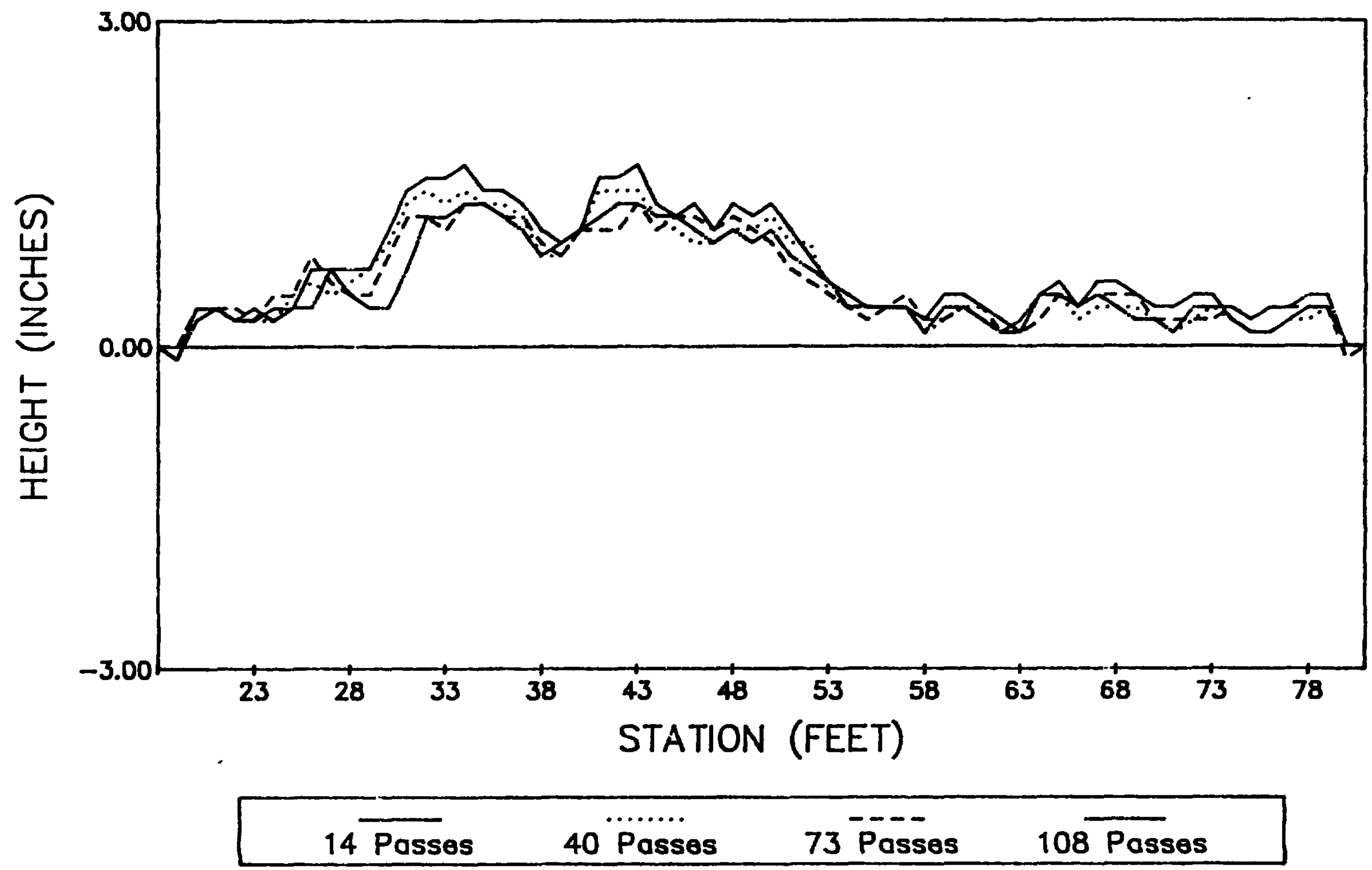


Figure B-9. Repair 1 After Aircraft Trafficking, Centerline

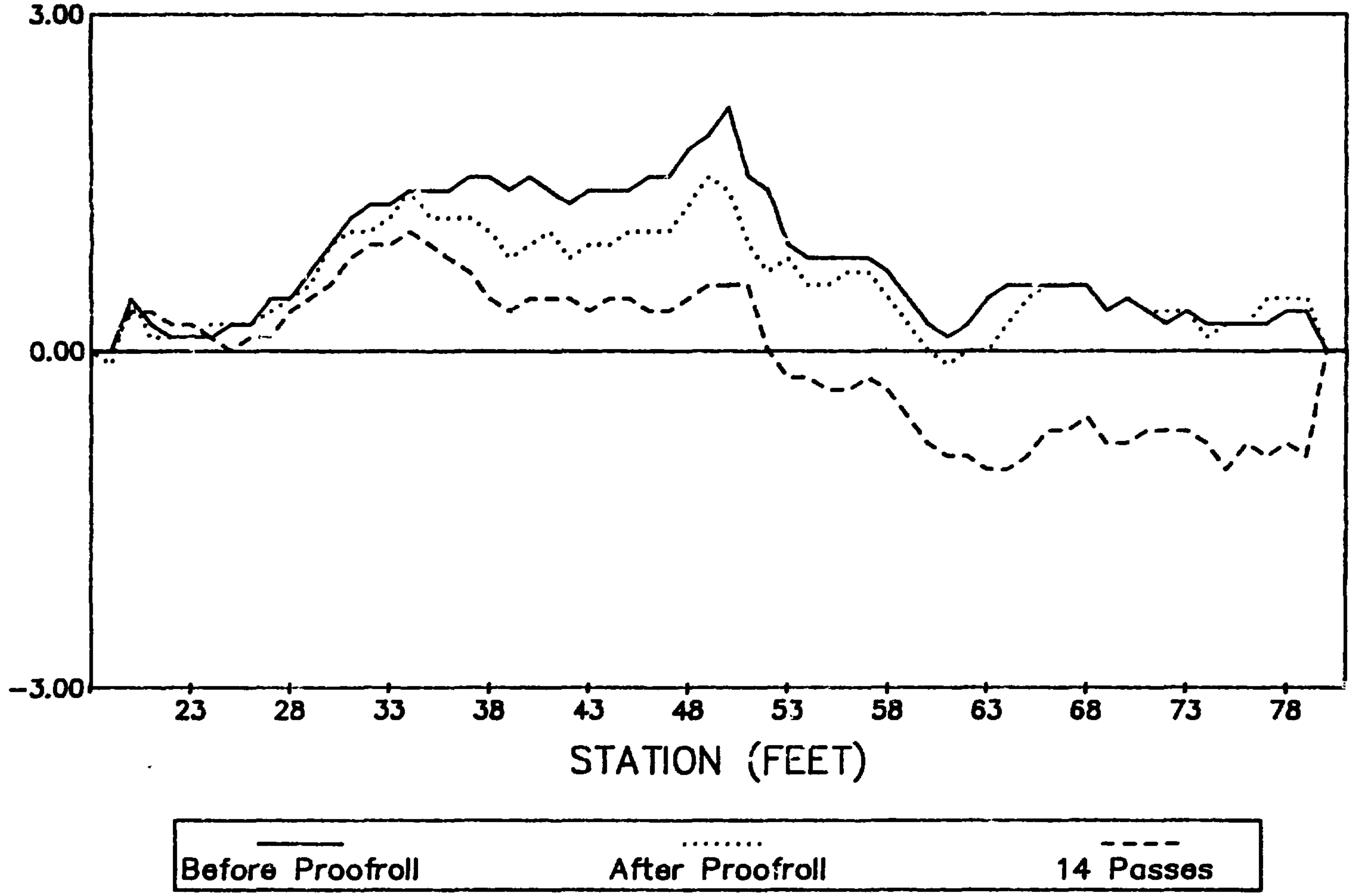


Figure B-10. Repair 1 After Proofrolling and 14 Aircraft Passes, 6 Feet South of Centerline (Profile L1)

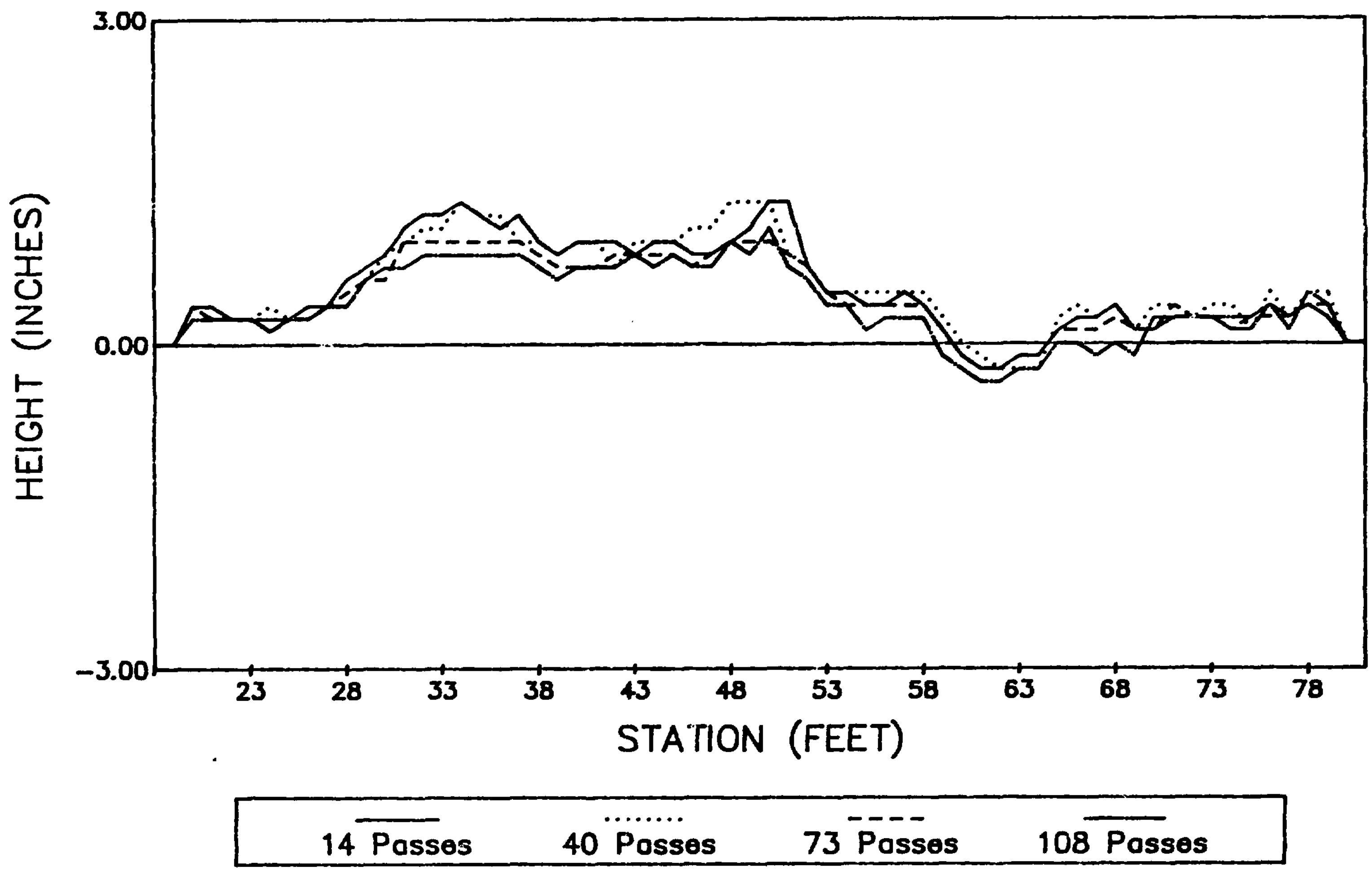


Figure B-11. Repair 1 After Aircraft Trafficking, 6 Feet South of Centerline (Profile L1)

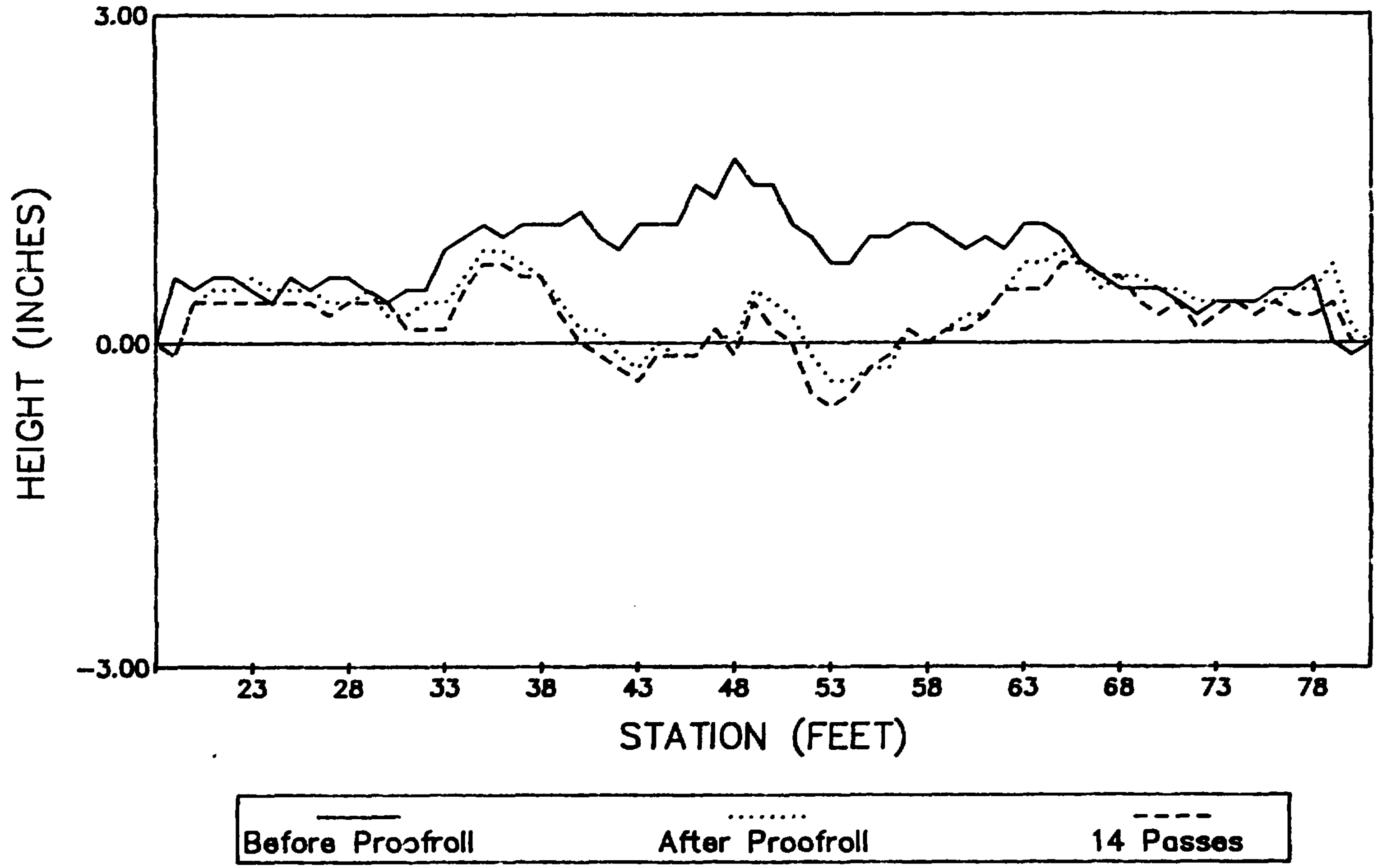


Figure B-12. Repair 1 After Proofrolling and 14 Aircraft Passes, 12 Feet South of Centerline (Profile L2)

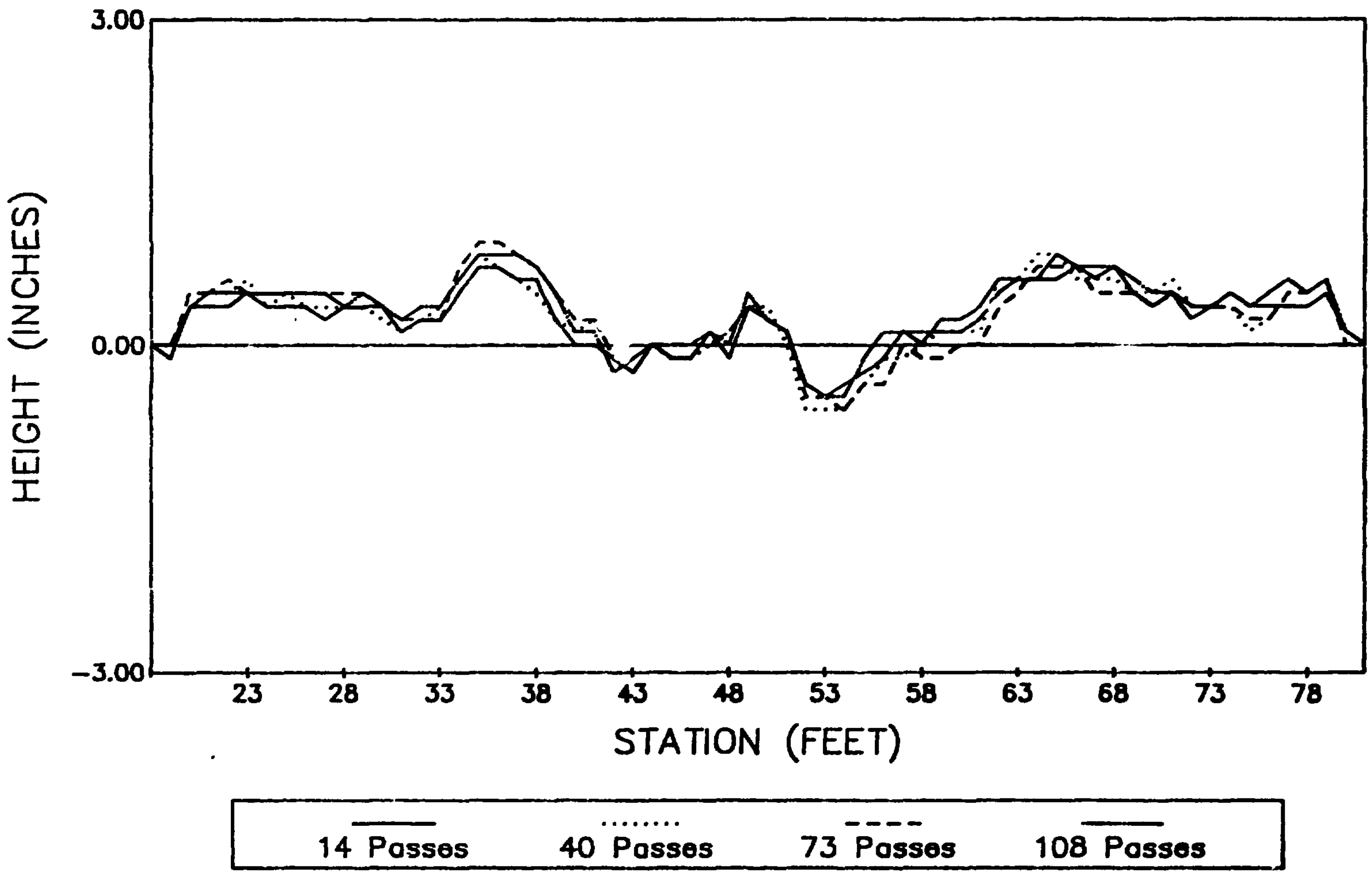


Figure B-13. Repair 1 After Aircraft Trafficking, 12 Feet South of Centerline (Profile L2)

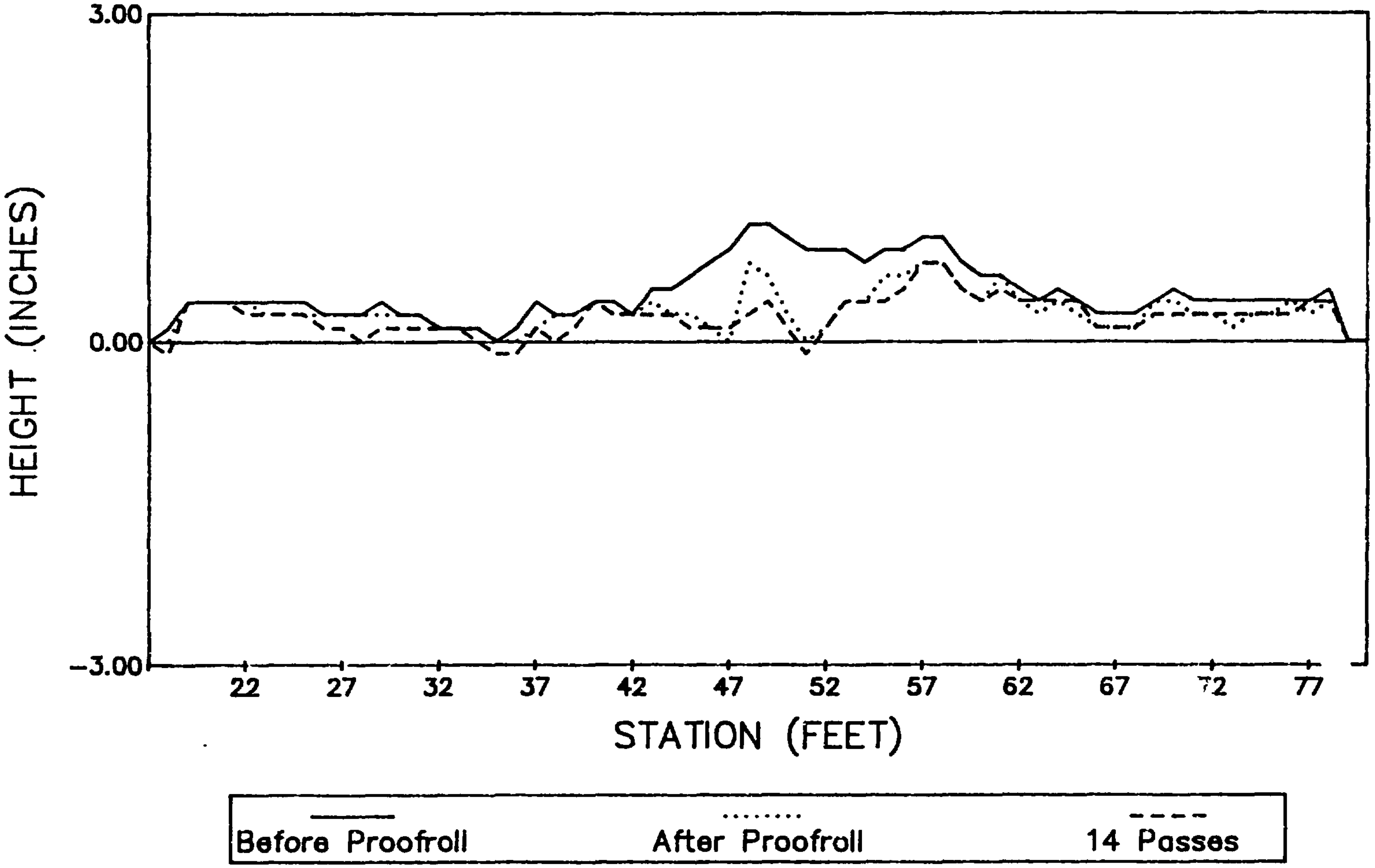


Figure B-14. Repair 1 After Proofrolling and 14 Aircraft Passes, 18 Feet South of Centerline (Profile L3)

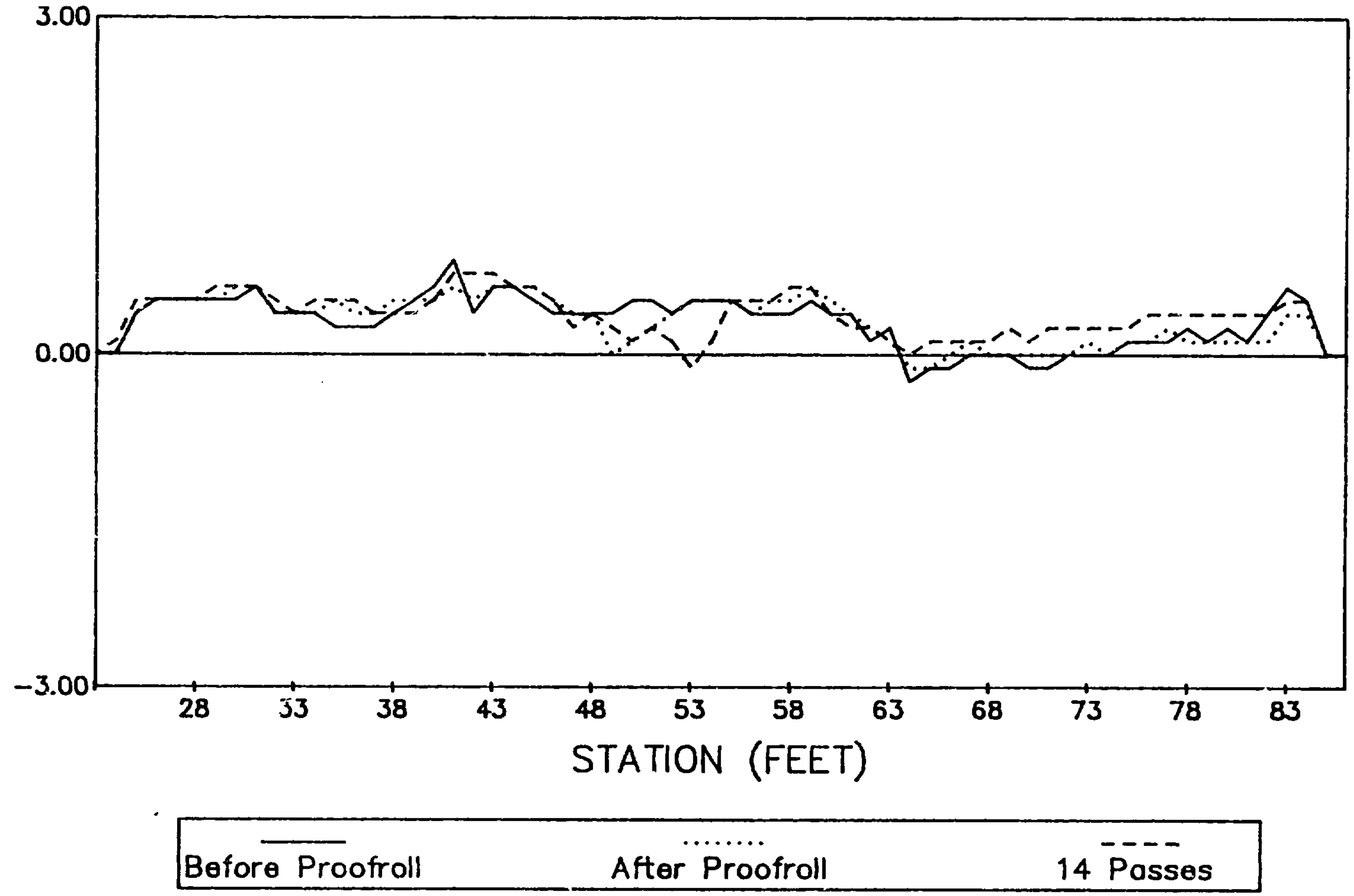


Figure B-15. Repair 2 After Proofrolling and 14 Aircraft Passes, 18 Feet North of Centerline (Profile R3)

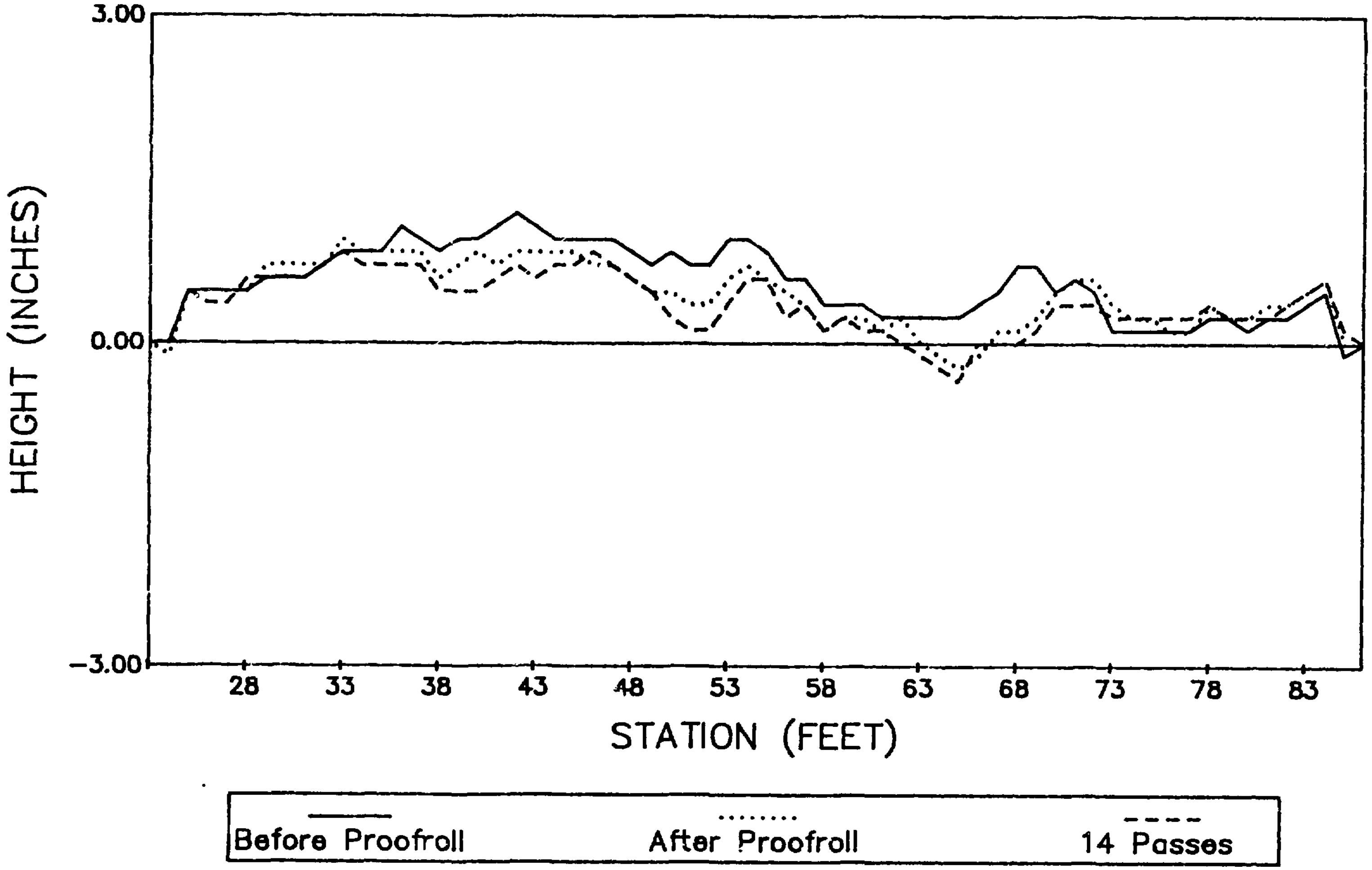


Figure B-16. Repair 2 After Proofrolling and 14 Aircraft Passes, 12 Feet North of Centerline (Profile R2)

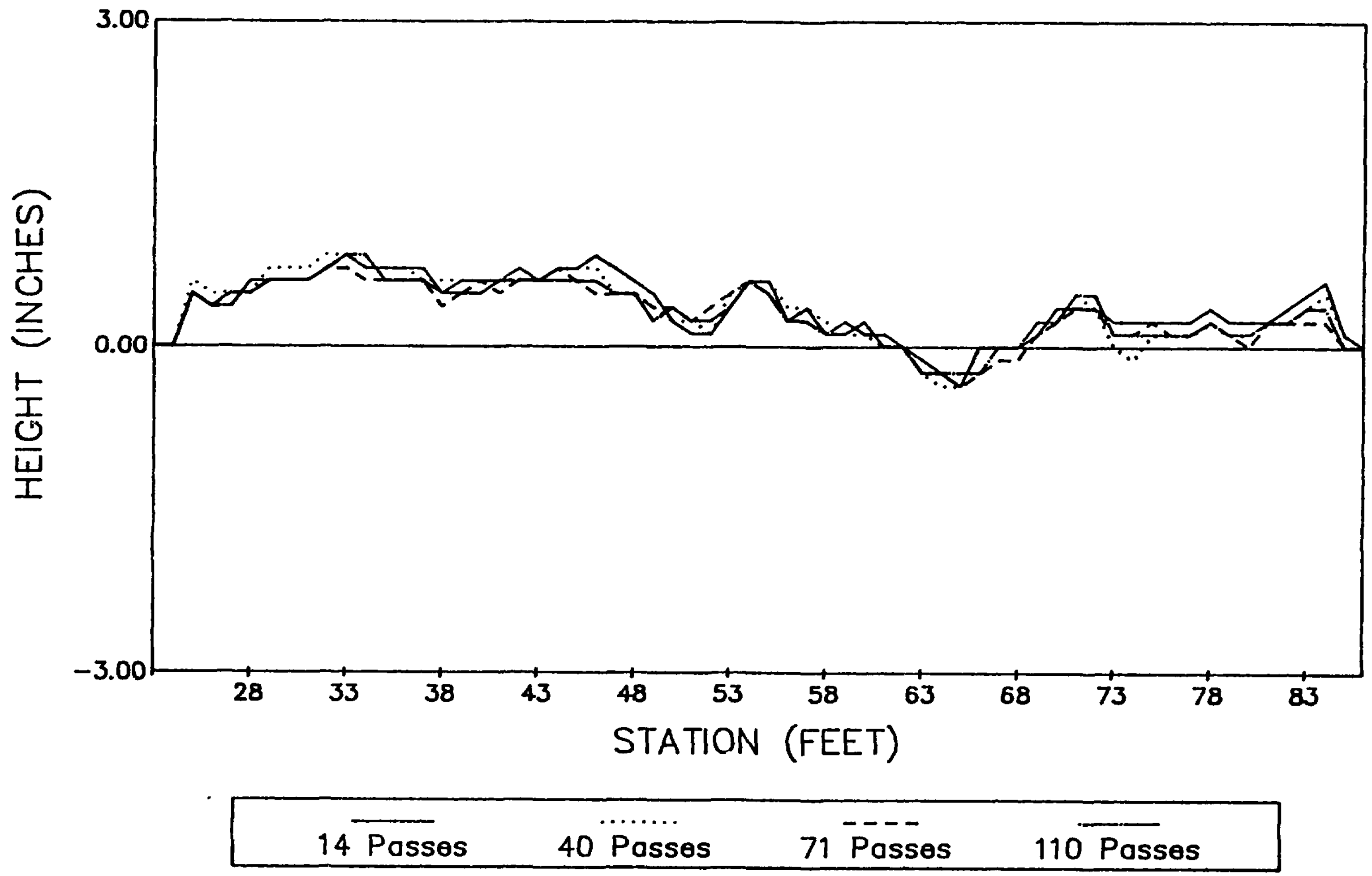


Figure B-17. Repair 2 After Aircraft Trafficking, 12 Feet North of Centerline (Profile R2)

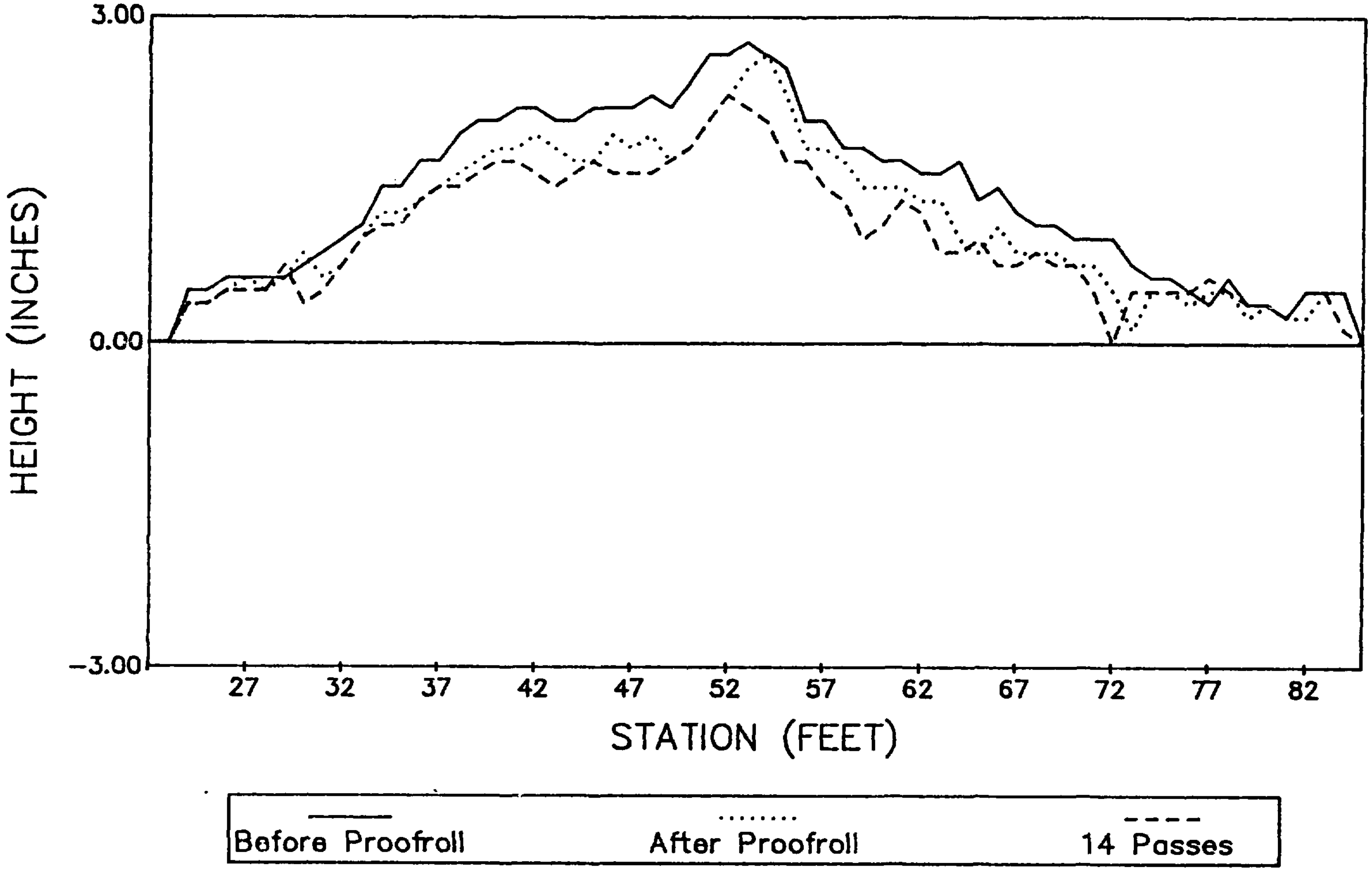


Figure B-18. Repair 2 After Proofrolling and 14 Aircraft Passes, 6 Feet North of Centerline (Profile R1)

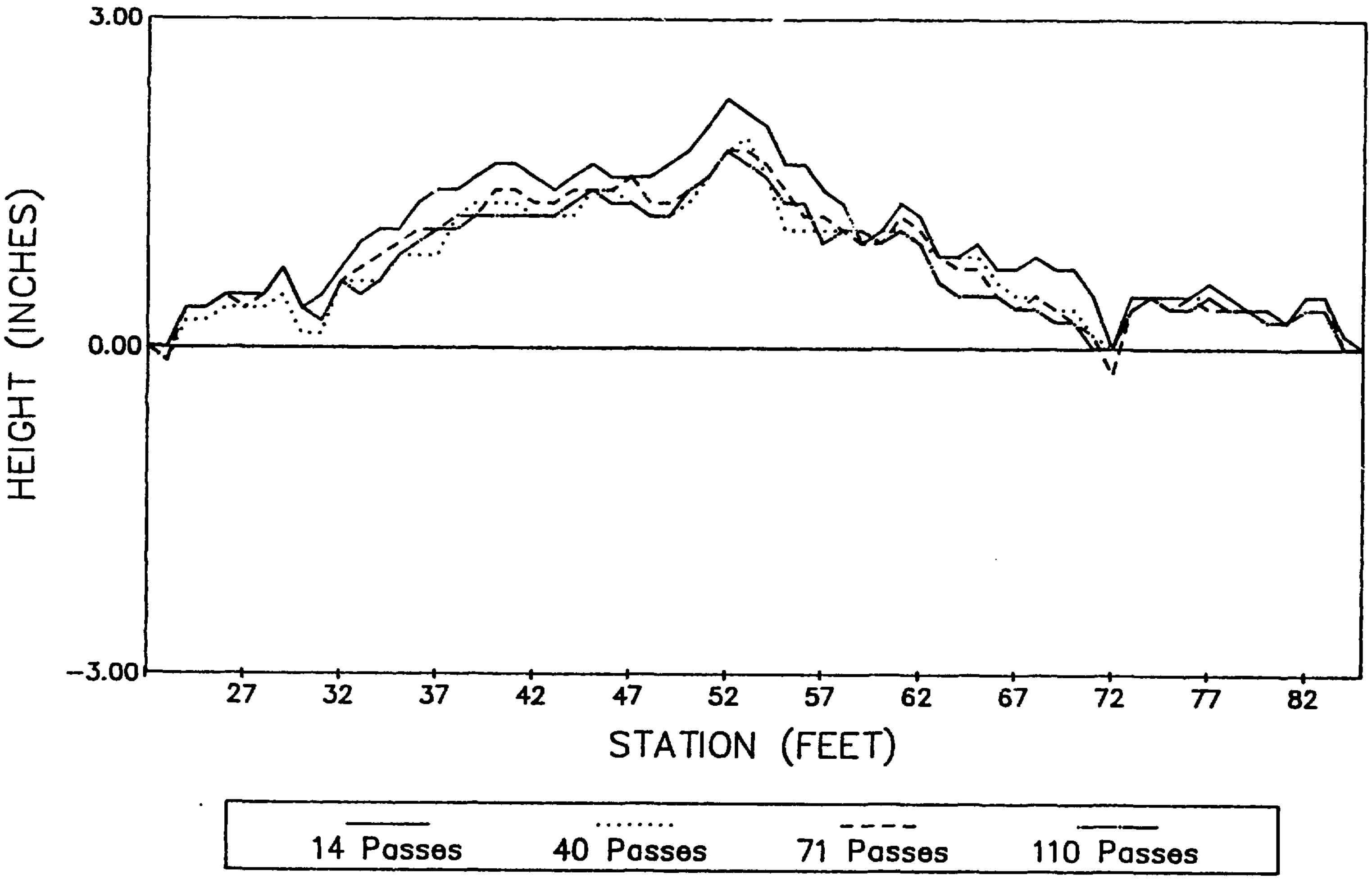


Figure B-19. Repair 2 After Aircraft Trafficking, 6 Feet North of Centerline (Profile R1)

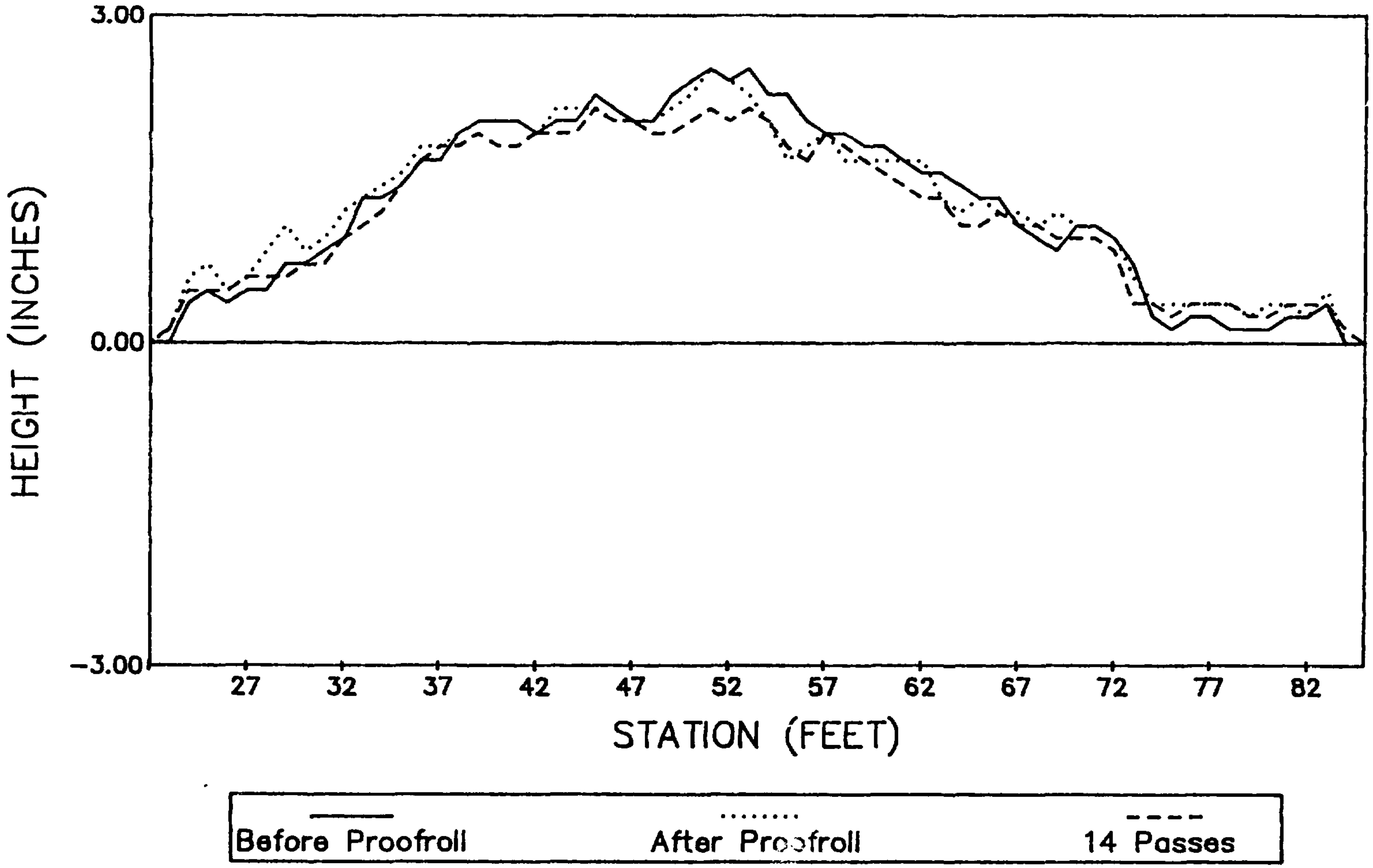


Figure B-20. Repair 2 After Proofrolling and 14 Aircraft Passes, Centerline

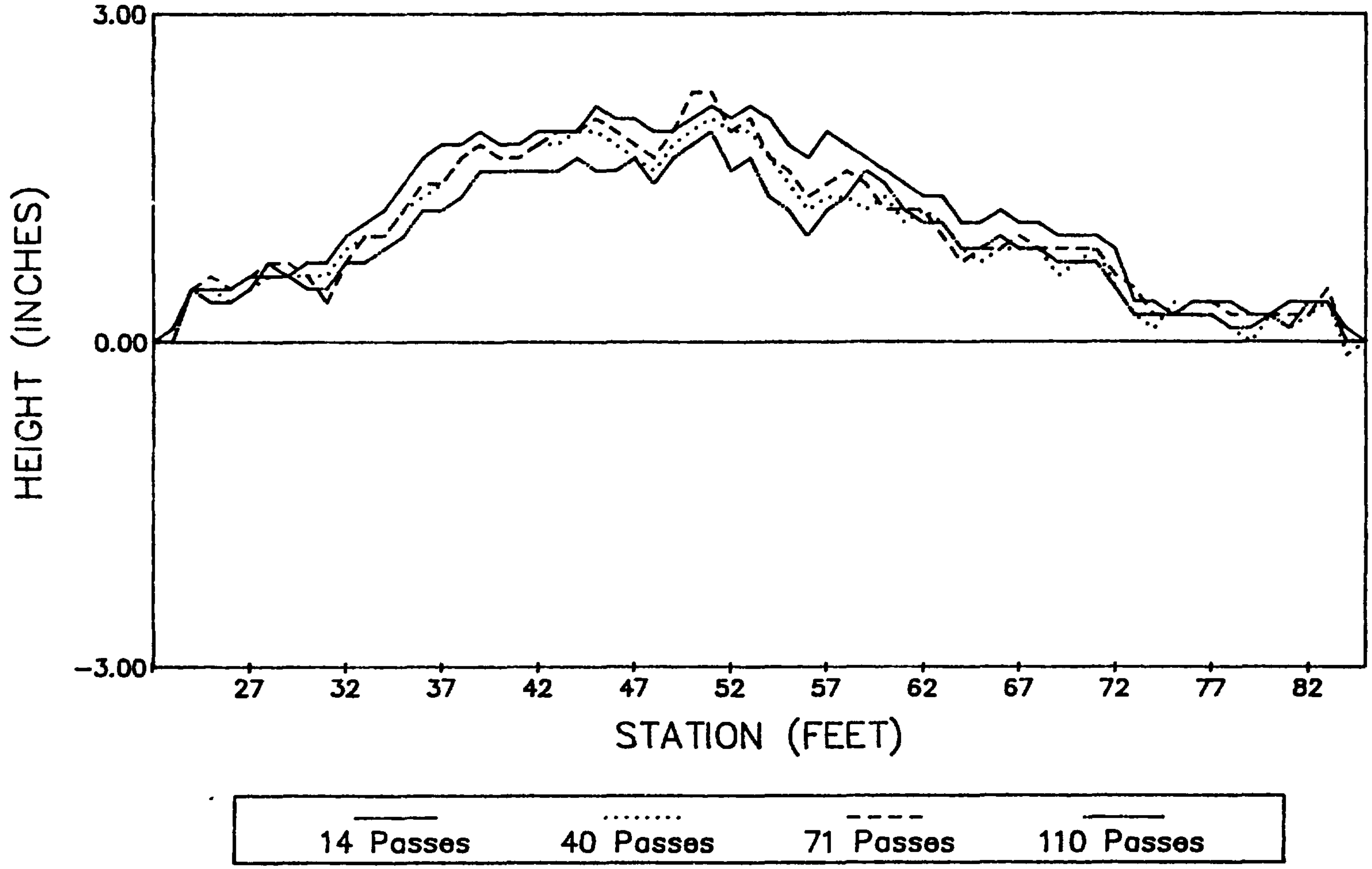


Figure B-21. Repair 2 After Aircraft Trafficking, Centerline

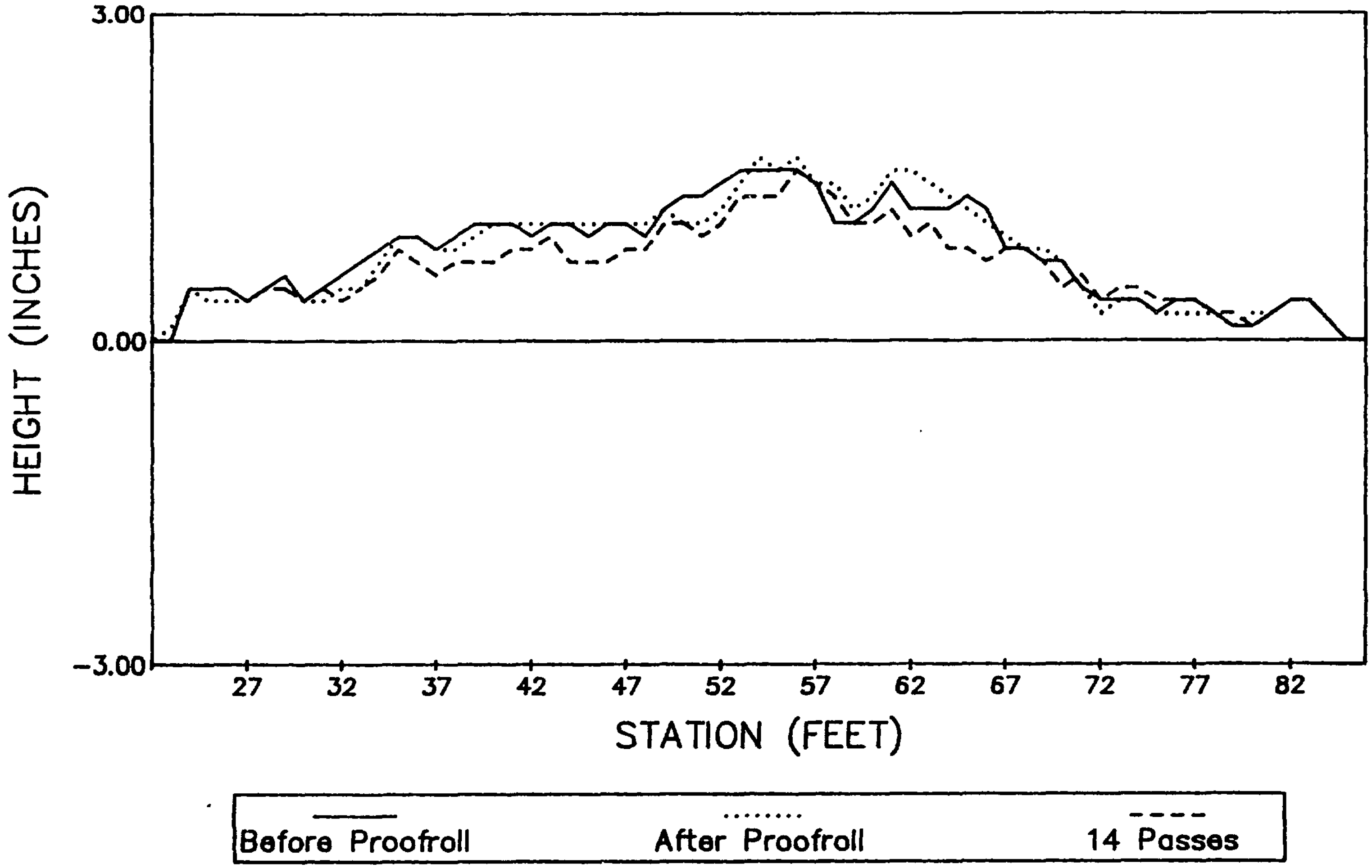


Figure B-22. Repair 2 After Proofrolling and 14 Aircraft Passes, 6 Feet South of Centerline (Profile L1)

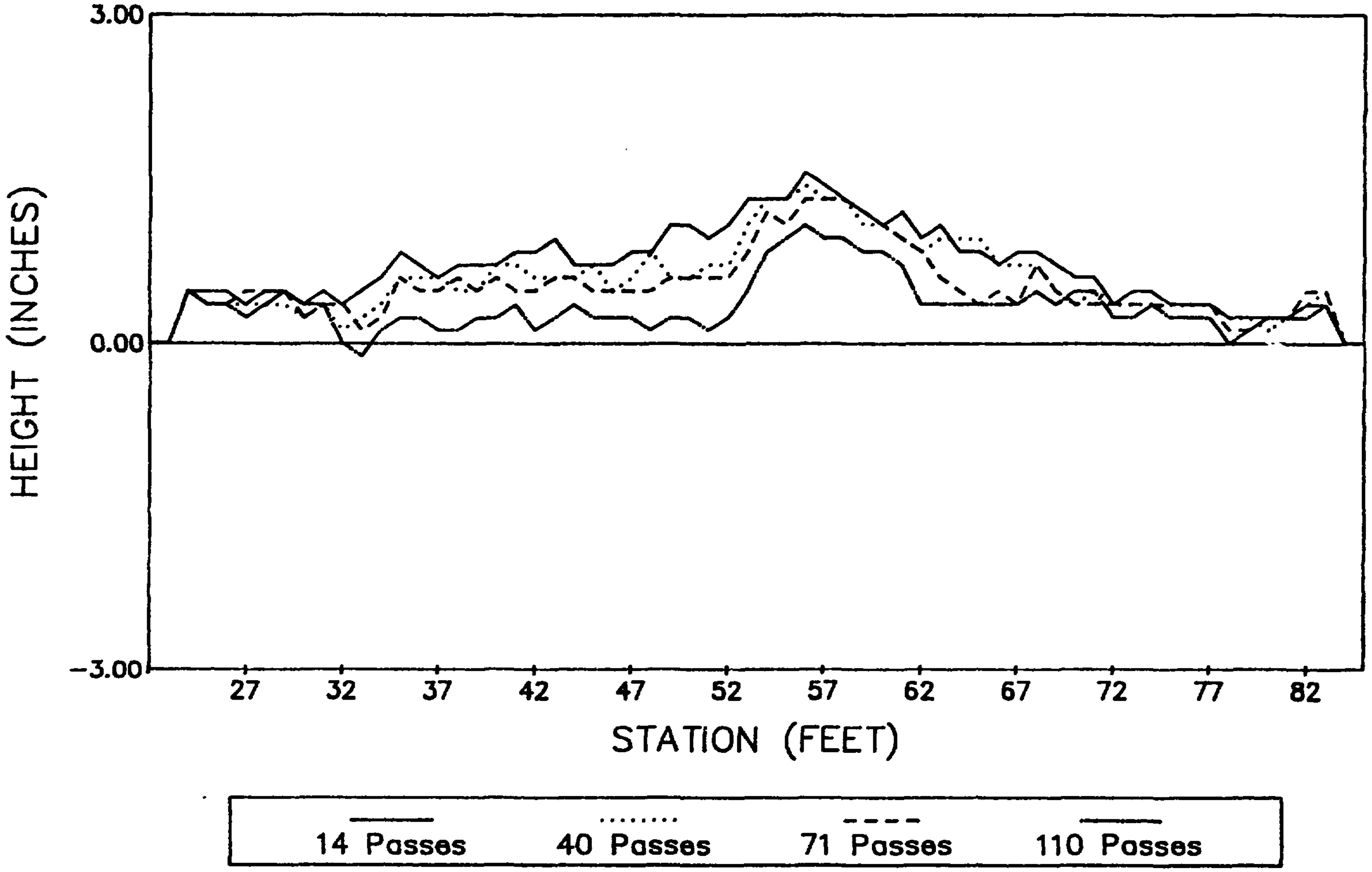


Figure B-23. Repair 2 After Aircraft Trafficking, 6 Feet South of Centerline (Profile L1)

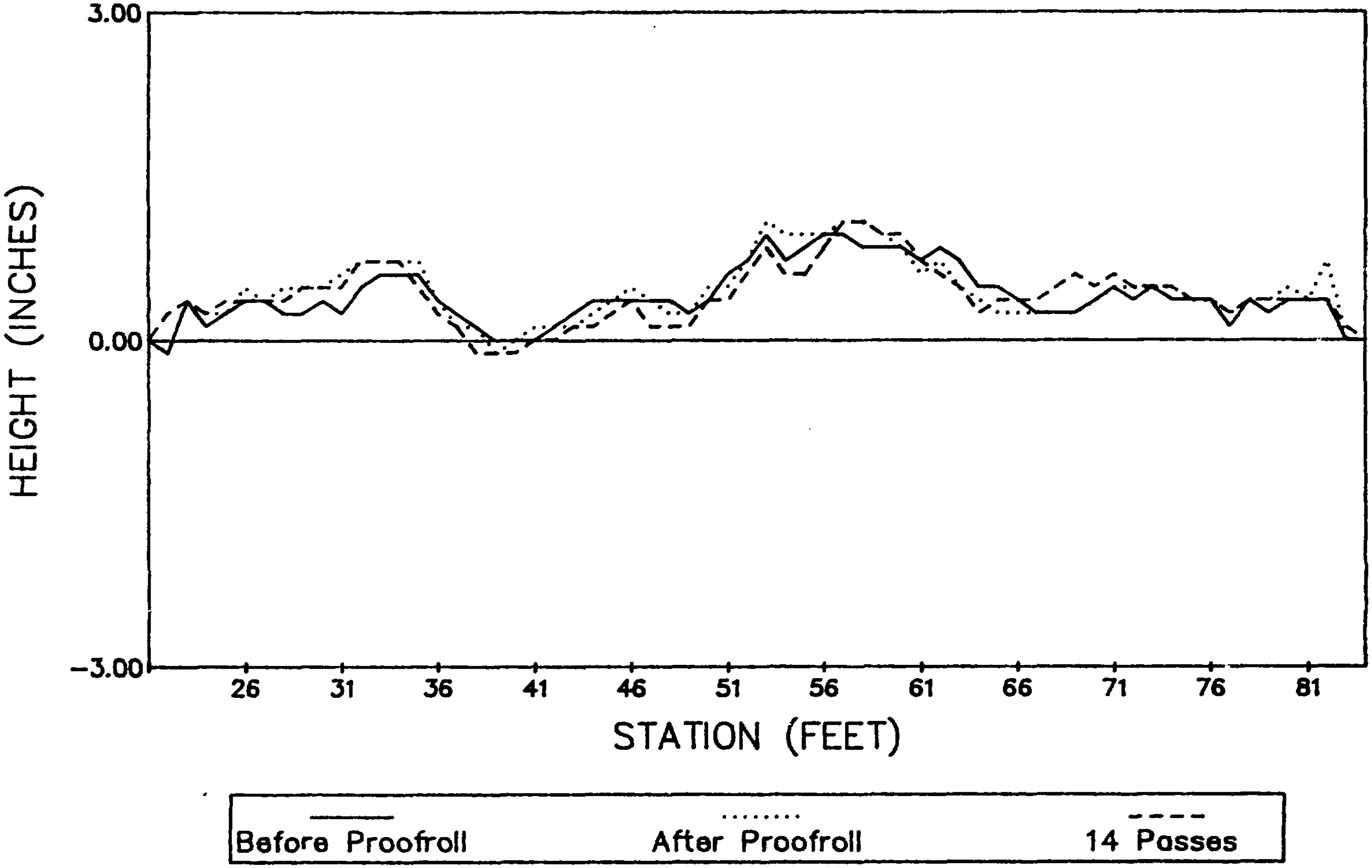


Figure B-24. Repair 2 After Proofrolling and 14 Aircraft Passes, 12 Feet South of Centerline (Profile L2)

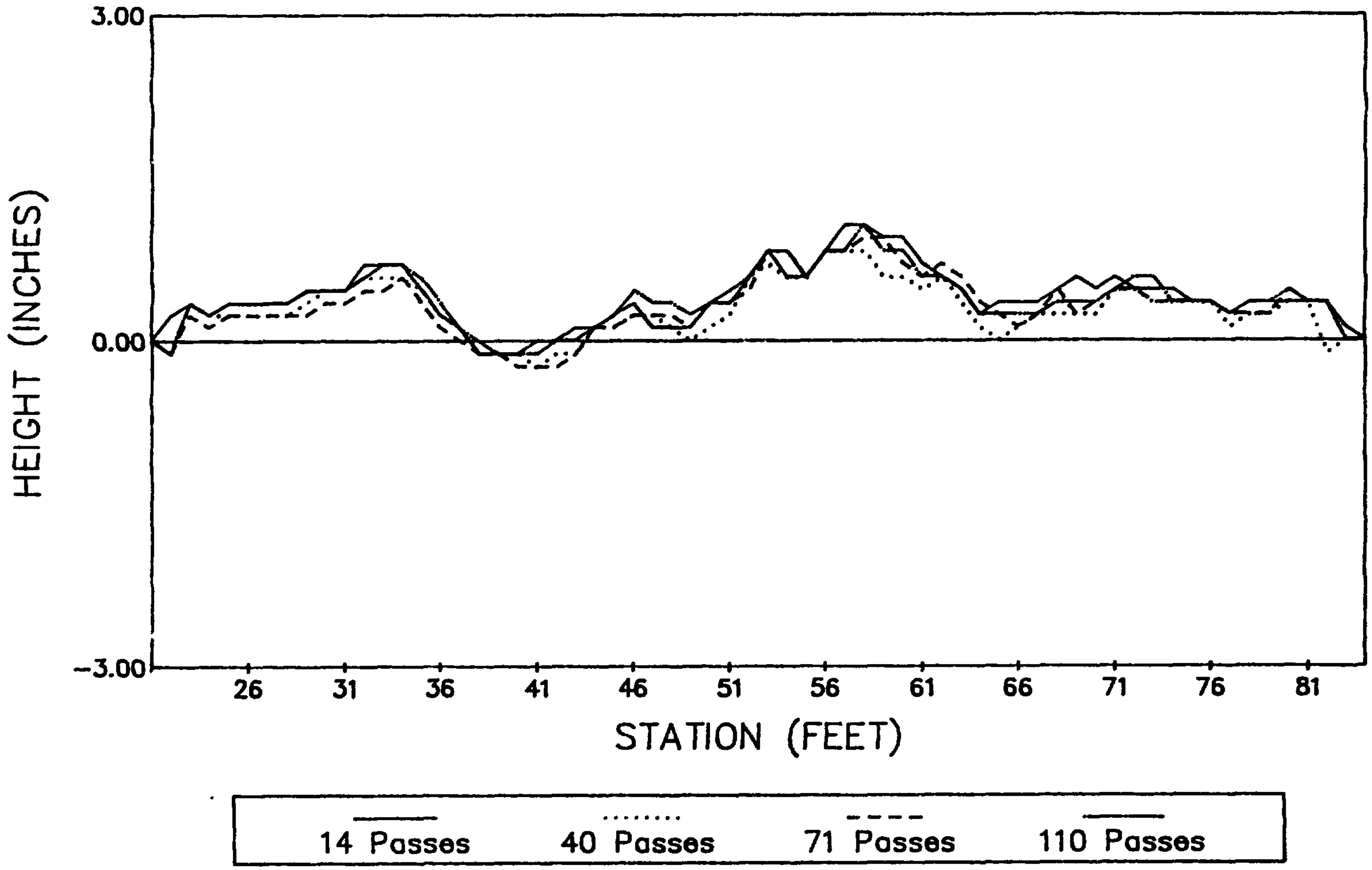


Figure B-25. Repair 2 After Aircraft Trafficking, 12 Feet South of Centerline (Profile L2)

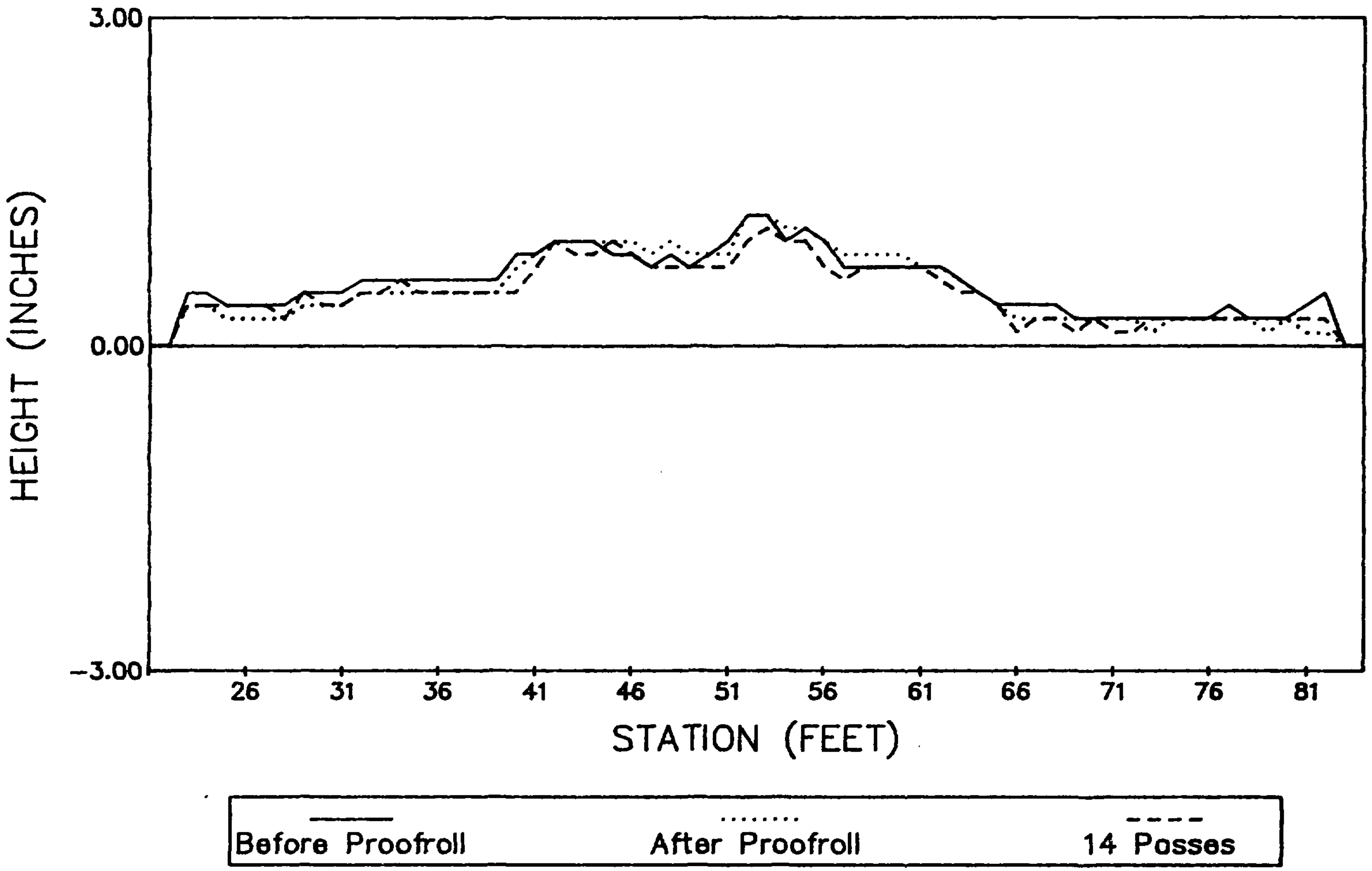


Figure B-26. Repair 2 After Proofrolling and 14 Aircraft Passes, 18 Feet South of Centerline (Profile L3)

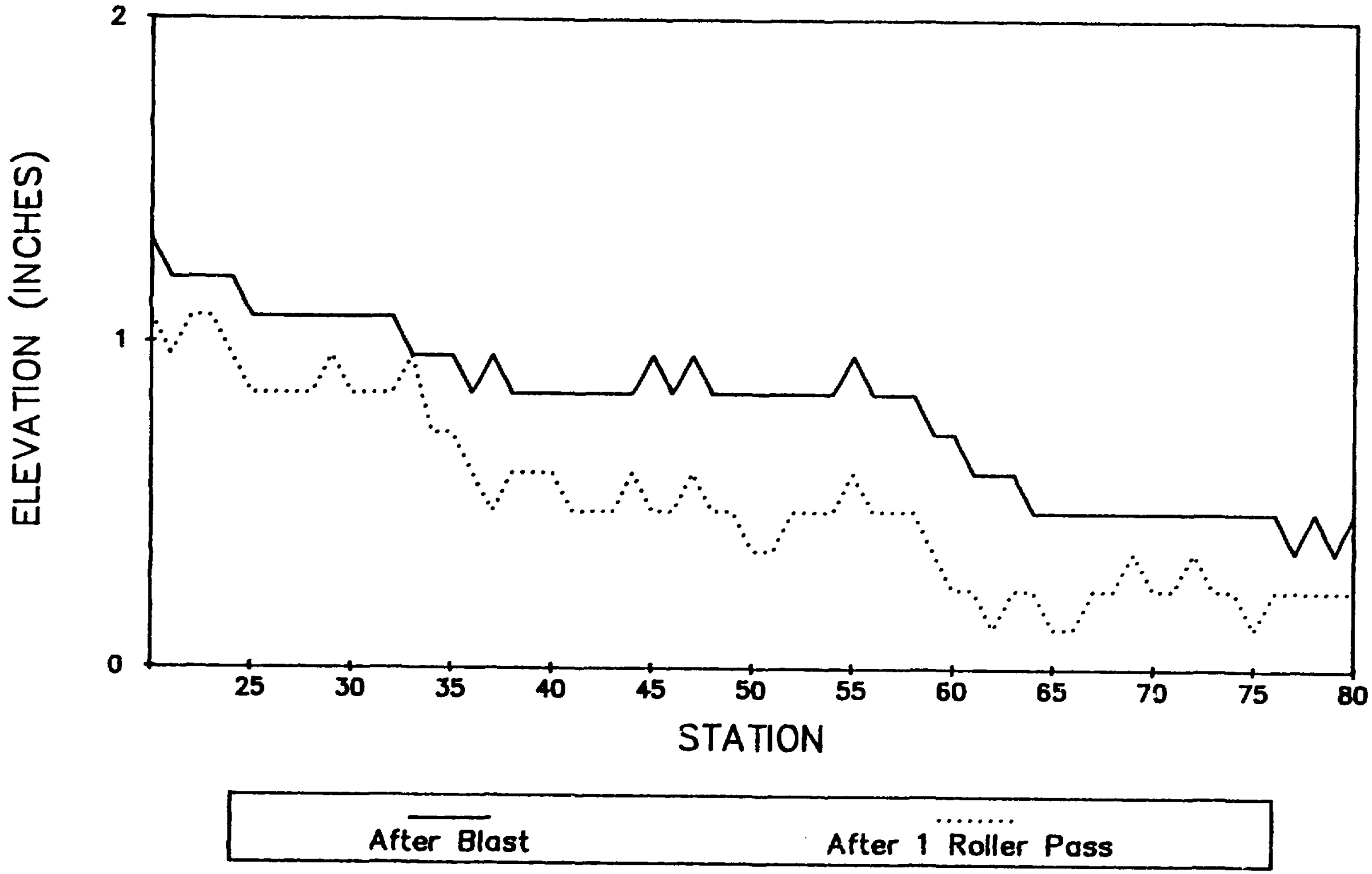


Figure B-27. Line L4 Before and After One Roller Pass over Upheaval

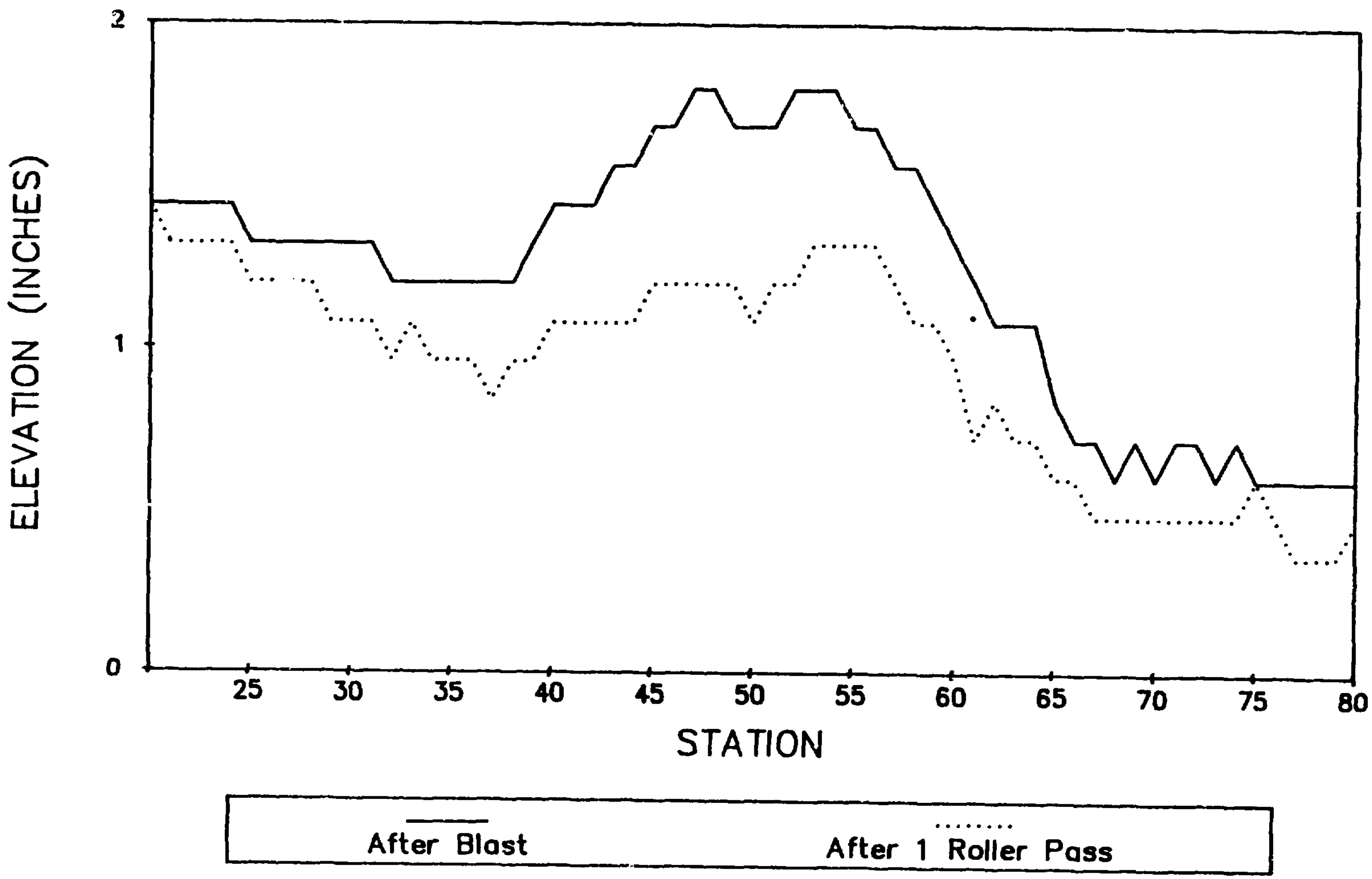


Figure B-28. Line L3 Before and After One Roller Pass over Upheaval

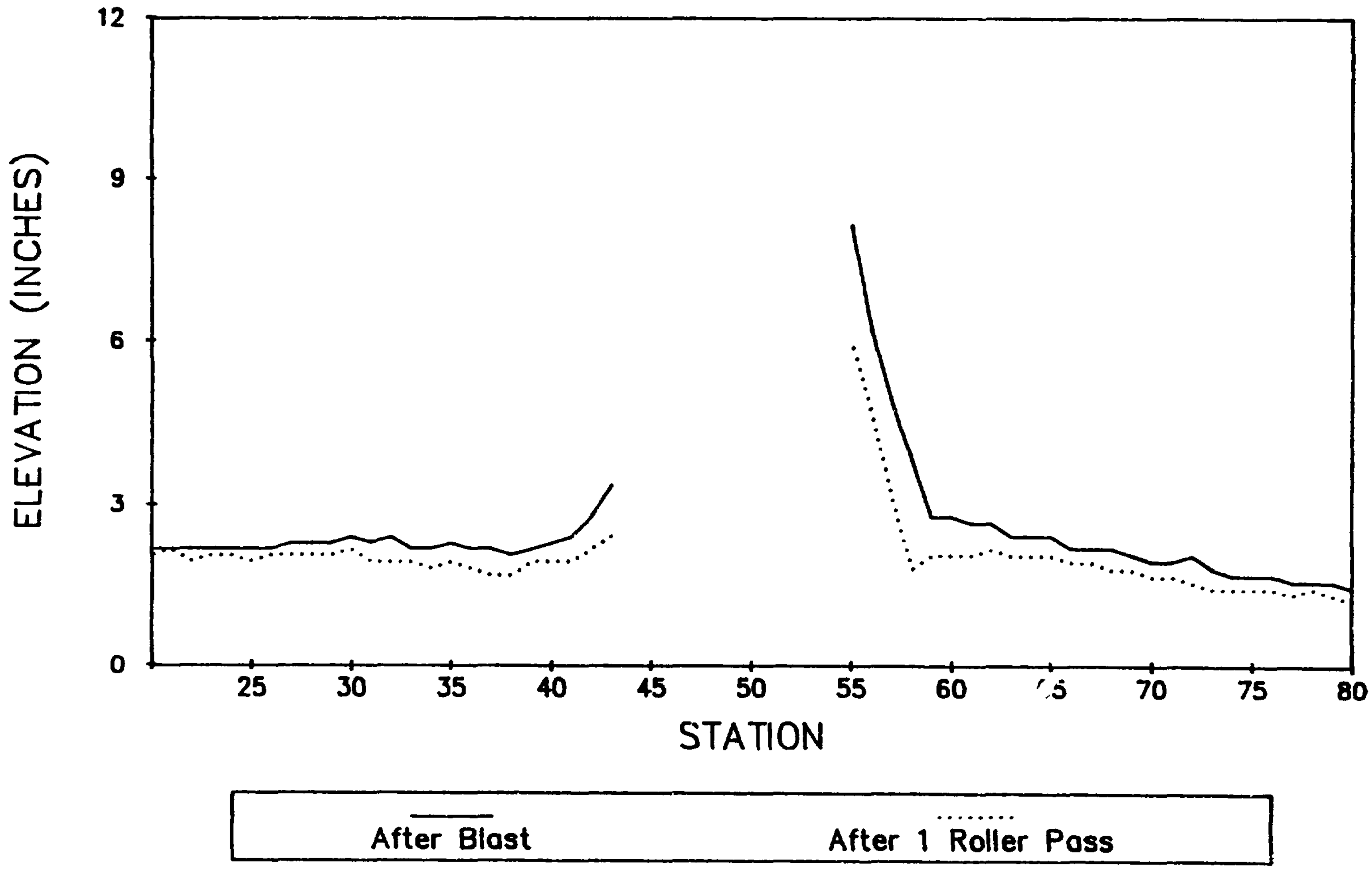


Figure B-29. Line L2 Before and After One Roller Pass over Upheaval

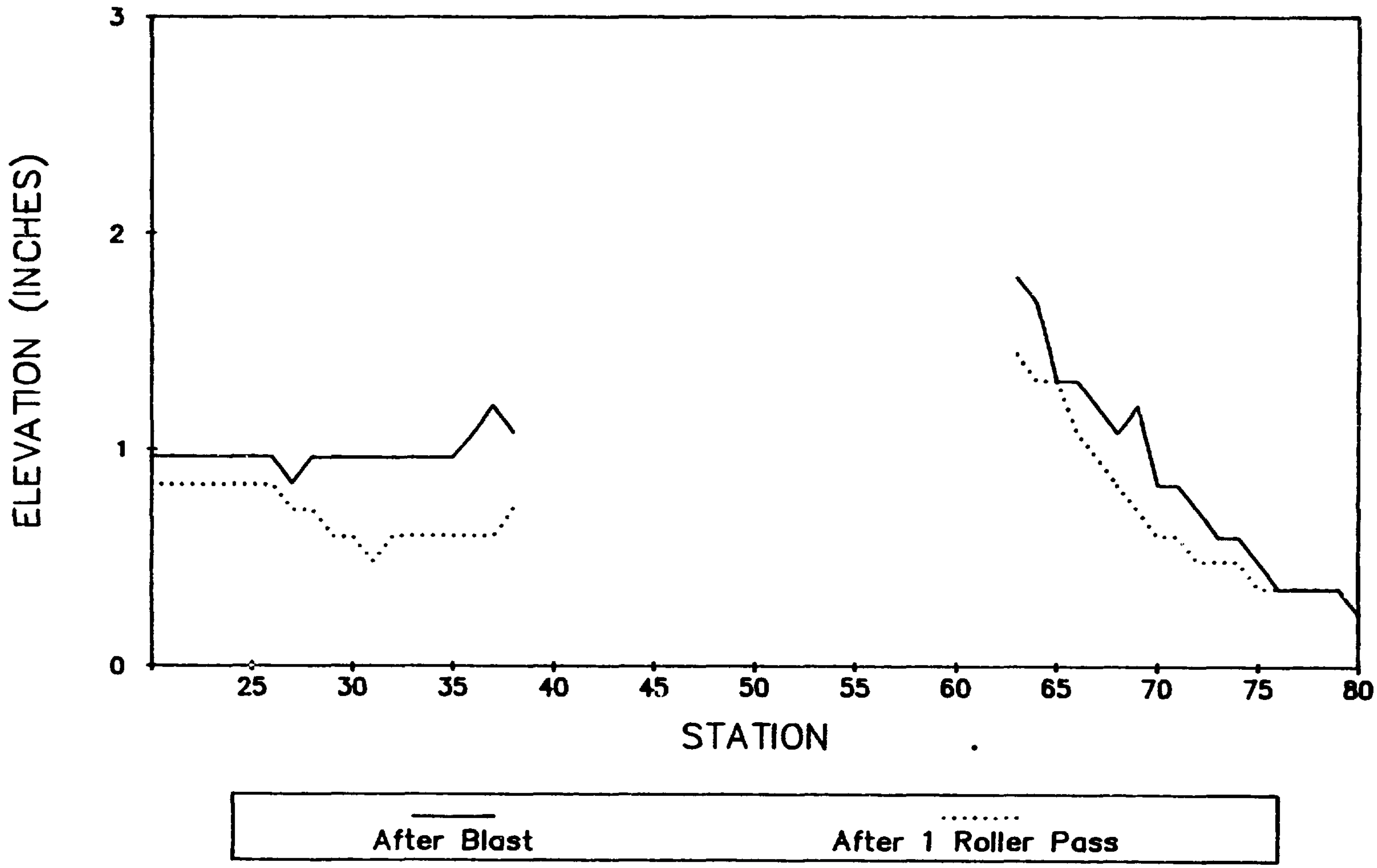


Figure B-30. Line L1 Before and After One Roller Pass over Upheaval

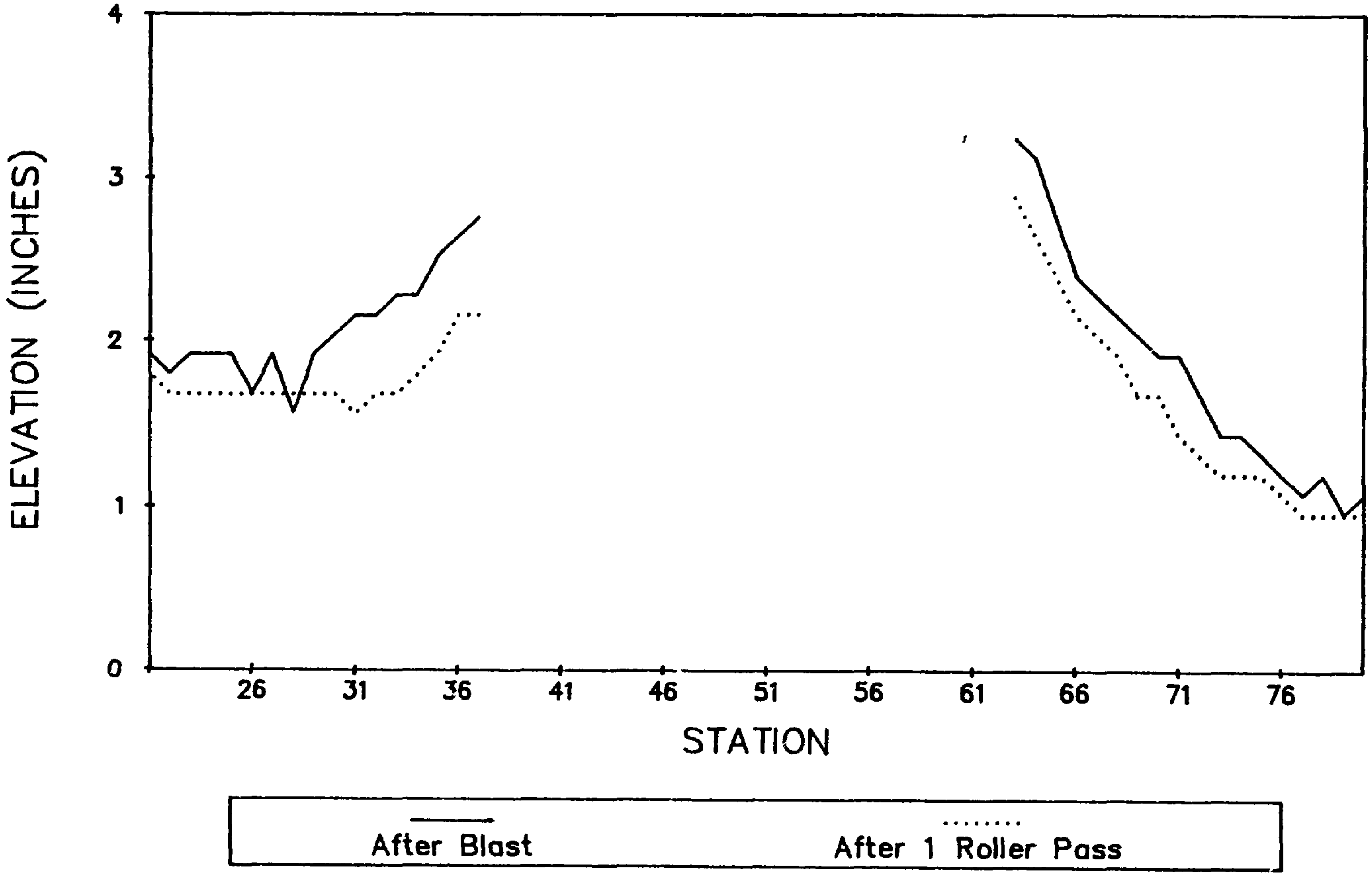


Figure B-31. Centerline Profile Before and After One Roller Pass over Upheaval

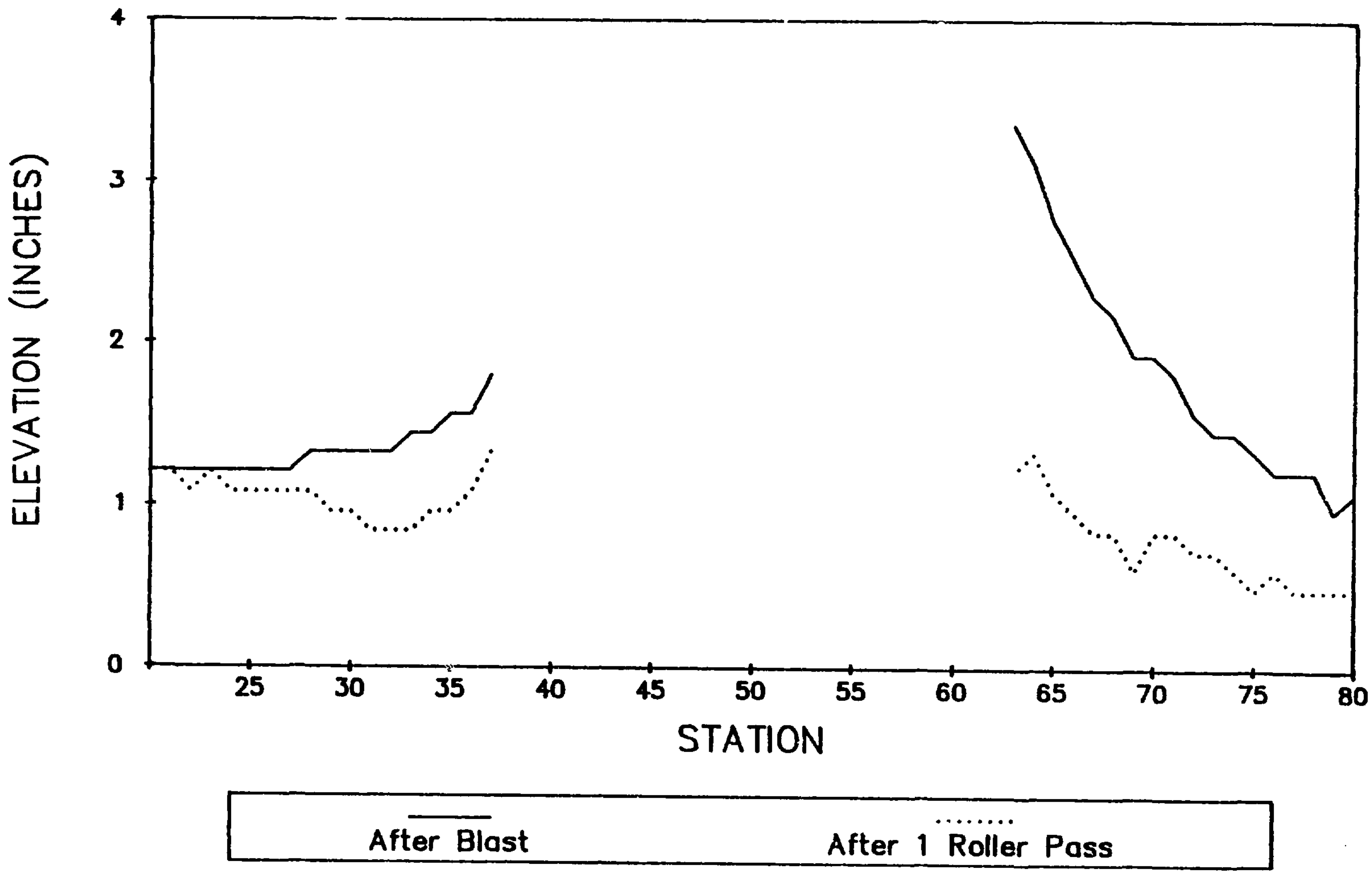


Figure B-32. Line R1 Before and After One Roller Pass over Upheaval

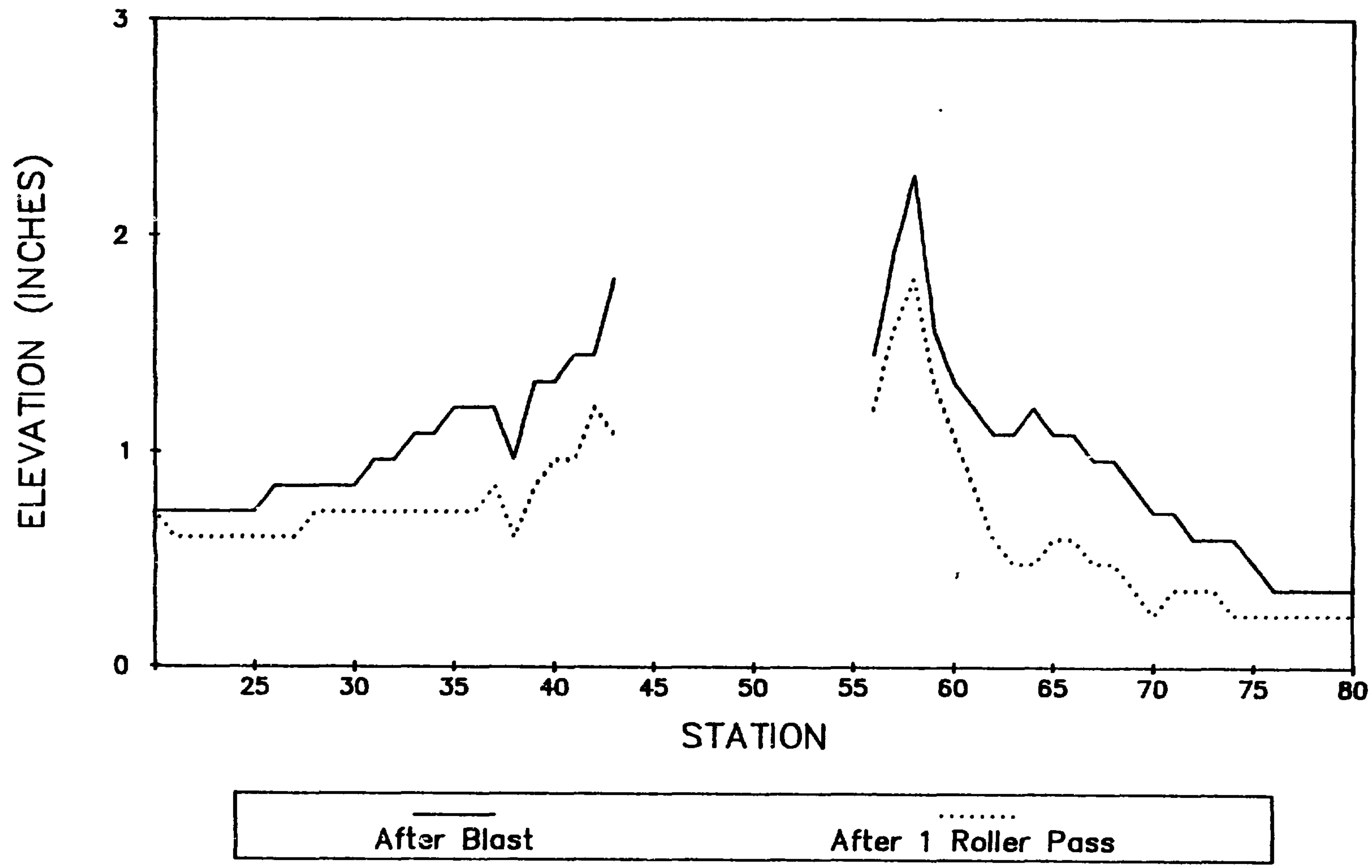


Figure B-33. Line R2 Before and After One Roller Pass over Upheaval

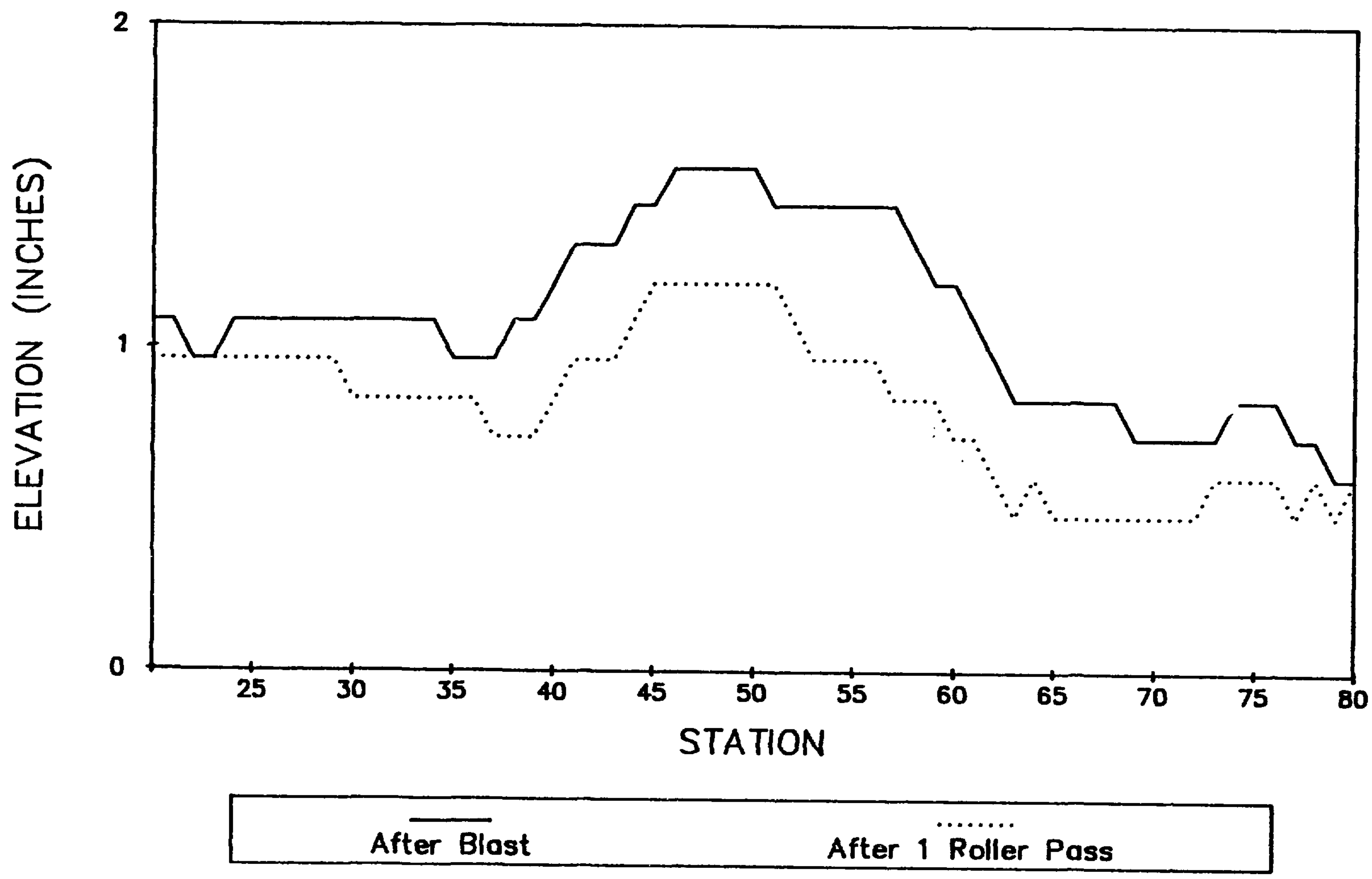


Figure B-34. Line R3 Before and After One Roller Pass over Upheaval

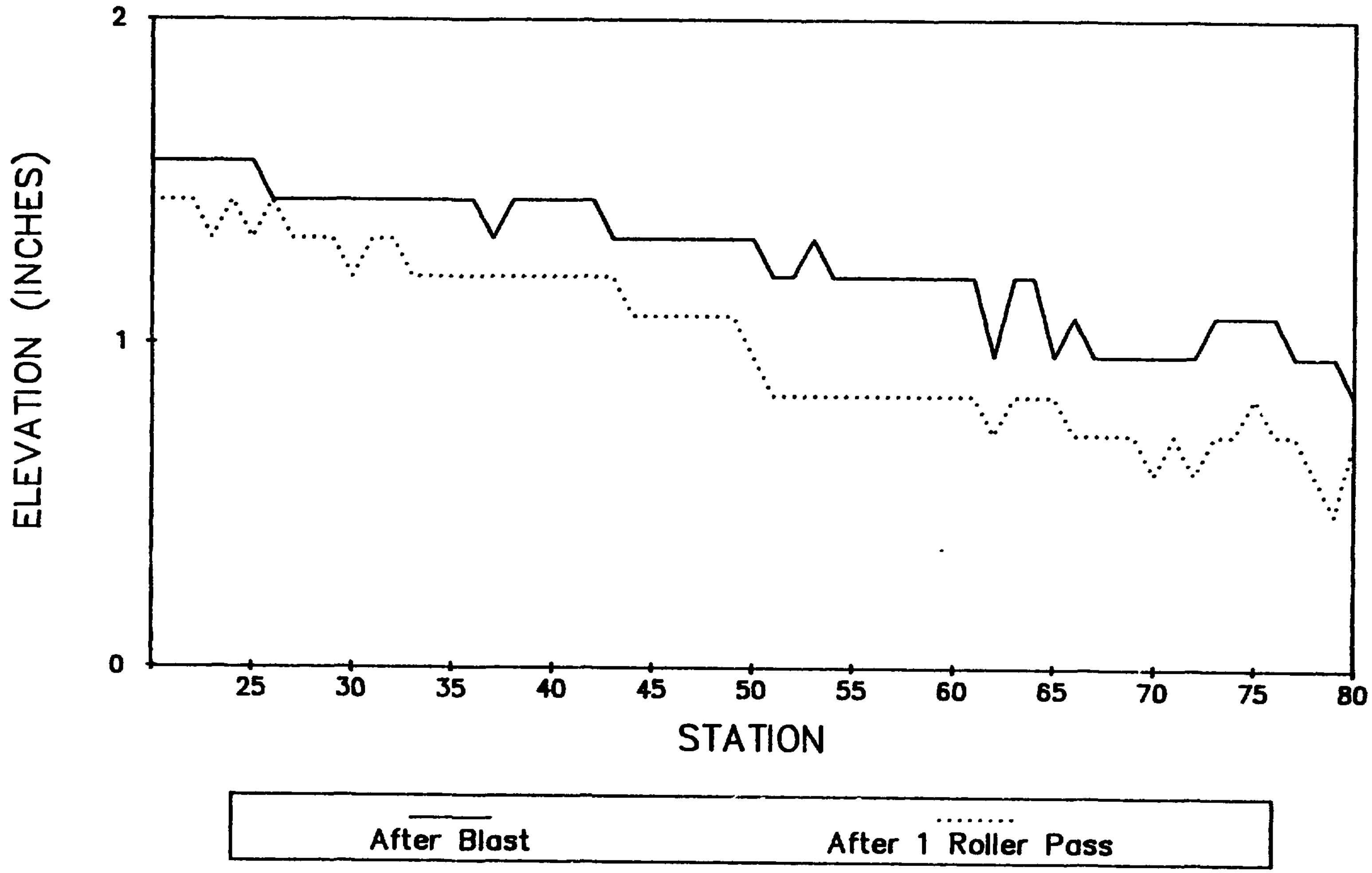


Figure B-35. Line R4 Before and After One Roller Pass over Upheaval

APPENDIX C

DEBRIS DENSITY STUDY

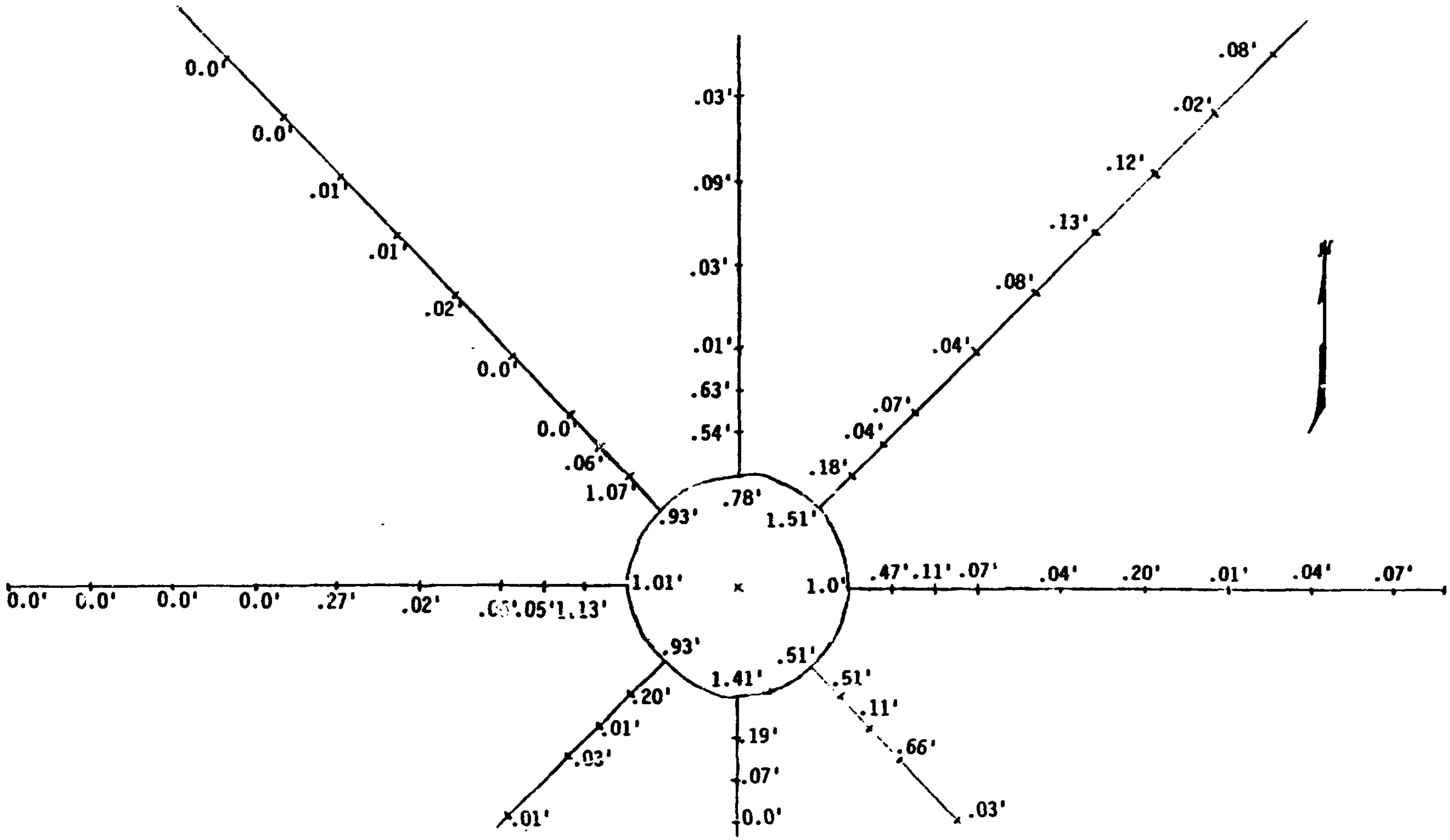
After the explosive formation of the test craters at North Field, large amounts of soil and concrete ejecta littered the pavement surrounding the craters. Figure C-1 illustrates the typical debris field surrounding a crater following the explosion. In addition to the structural data collected on both craters. Test personnel collected data and samples of crater ejecta in an effort to determine size, depth, and distribution of debris following crater formation to support future debris clearance studies.

Test technicians took debris surface elevation profiles on eight radial lines extending from each crater's center to determine debris field depth around each crater. Four of these radials were aligned along the cardinal headings and the remaining four bisected these lines. On each radial, elevation measurements were recorded 5, 10, 15, and every 10 feet thereafter from the crater lip. These data then were compared with pavement surface elevations taken before crater formation. Figures C-2 and C-3 show the location of the radials around Craters 1 and 2, respectively. The figures also indicate debris thickness. Maximum debris depth of Crater 1 was 1.51 feet measured at the lip of the crater on the northeast radial. The maximum debris depth of Crater 2 was 1.4 feet measured at the crater lip on the northwest and west radials.

In addition, technicians collected debris samples at eight different locations along each radial. At each collection station, the teams placed a 4-square-foot wooden frame and swept up all debris contained within the frame. Figures C-4 and C-5 show in-place debris samples. A sieve analysis (ASTM C-136) was performed on each sample by Law Engineering Inc. Figures C-6 through C-34 contain the results of the sieve analysis. Outsized debris (debris over 3 inches in diameter, or in greatest dimension) was collected separately from debris enclosed within the frame. Tables C-1 through C-4 list the outsized debris found on each radial.

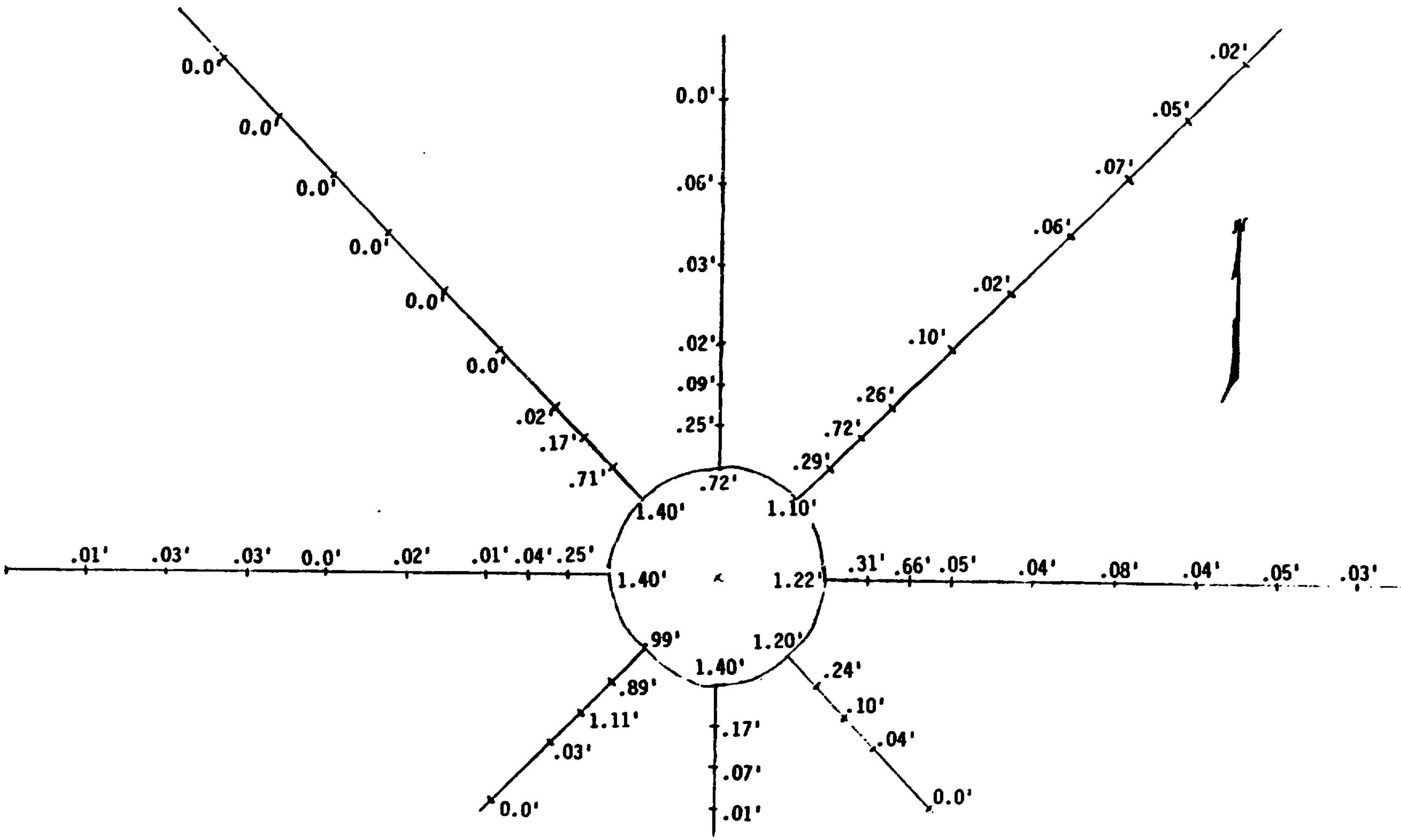
The largest pieces of debris ranged from 1 to 3 feet in length and were found within 5 feet of the crater lip on both craters.

Figure C-1. Debris Field Surrounding Crater 2



SCALE .5 Inch = 10 Feet

Figure C-2. Crater 1 Debris Thickness (In Feet)



SCALE .5 Inch = 1^ Feet

Figure C-3. Crater 2 Debris Thickness (In Feet)

Figure C-4. Debris Sample Near Crater Lip

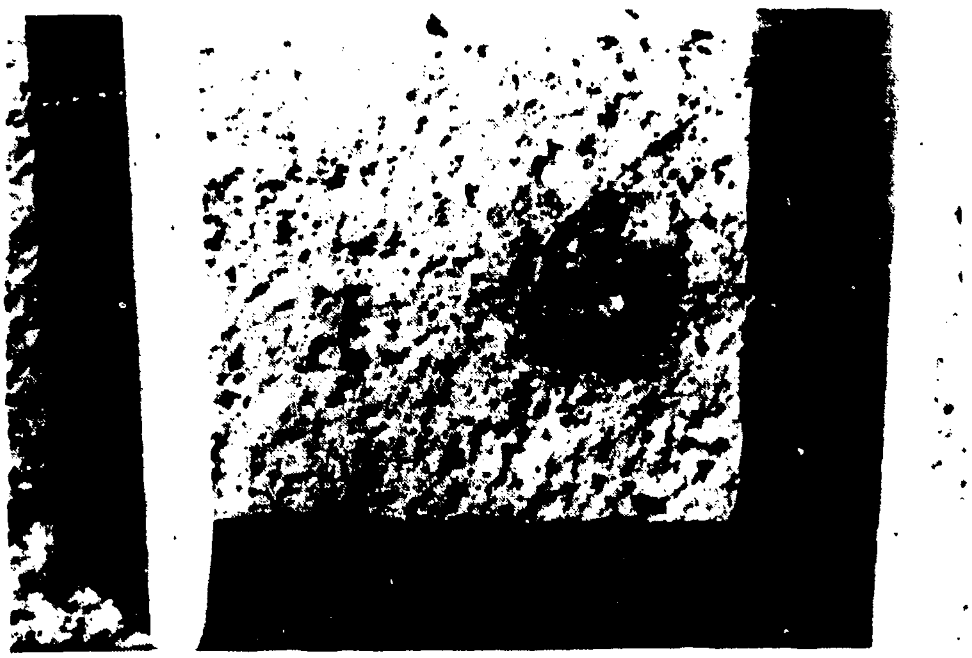


Figure C-5. Debris Sample Approximately 25 Feet from Crater Lip

TABLE C-1. DISTRIBUTION OF LARGER DEBRIS (IN INCHES) AROUND CRATER 1

DISTANCE FROM CRATER LIP (FEET)	RADIAL DIRECTION			
	West	Southwest	South	Southeast
5	24x12x6 CC	36x18x9 CC 12x12x8 CL	18x18x6 CC 12x4x3 CC 12x8x24 CC	24x24x8 CC 18x12x8 CC
10		24x24x5 CC 12x6x3 CL	8x4x2 CC	6x6x3 CL
15	6x8x8 CC		24x18x8 CC	24x18x6 CC
35	14x10x6 CC		12x4x12 CC	
45	3x2x4 CC			

CC-Concrete Chunk

CL-Clay Chunk

* No samples found at 25, 55, 65, and 75 feet along the West, Southwest, South, and Southeast radials.

TABLE C-2. DISTRIBUTION OF LARGER DEBRIS (IN INCHES) AROUND CRATER 1

DISTANCE FROM CRATER LIP (FEET)	RADIAL DIRECTION			
	East	Northeast	North	Northwest
5	24x12x8 CC	3x3x3 CL	36x24x6 CC 24x8x8 CL 36x24x10 CL	24x12x12 CC
10			15x24x6 CC 15x24x6 CC 3x4x1 CC	
15			3x5x3 CC 6x2x1 CC 4x2x5 CL	
45		2x1x2 CL		
55			2x5x1 CC	
65		2x4x2 CC		

CC-Concrete Chunks

CL-Clay Cnunks

* No samples found at 25,35, and 75 feet alonc the East, Northeast, North, and Northwest radials.

TABLE C-3. DISTRIBUTION OF LARGER DEBRIS (IN INCHES) AROUND CRATER 2

DISTANCE FROM CRATER LIP (FEET)	RADIAL DIRECTION			
	West	Southwest	South	Southeast
5	18x36x8 CC	36x24x9 CC 12x10x10 CL	36x48x9 CC	12x7x3 CC 12x24x7 CC
10	12x8x8 CC 6x4x3 CC	12x12x12 CL 8x4x2 CC	3x3x3 CL	
25	12x10x7 CC 6x3x3 CC			
35		5x3x2 CC		
75		3x8x3 CC		9x7x3 CC 4x3x6 CC
*				

CC-Concrete Chunks

CL-Clay Chunks

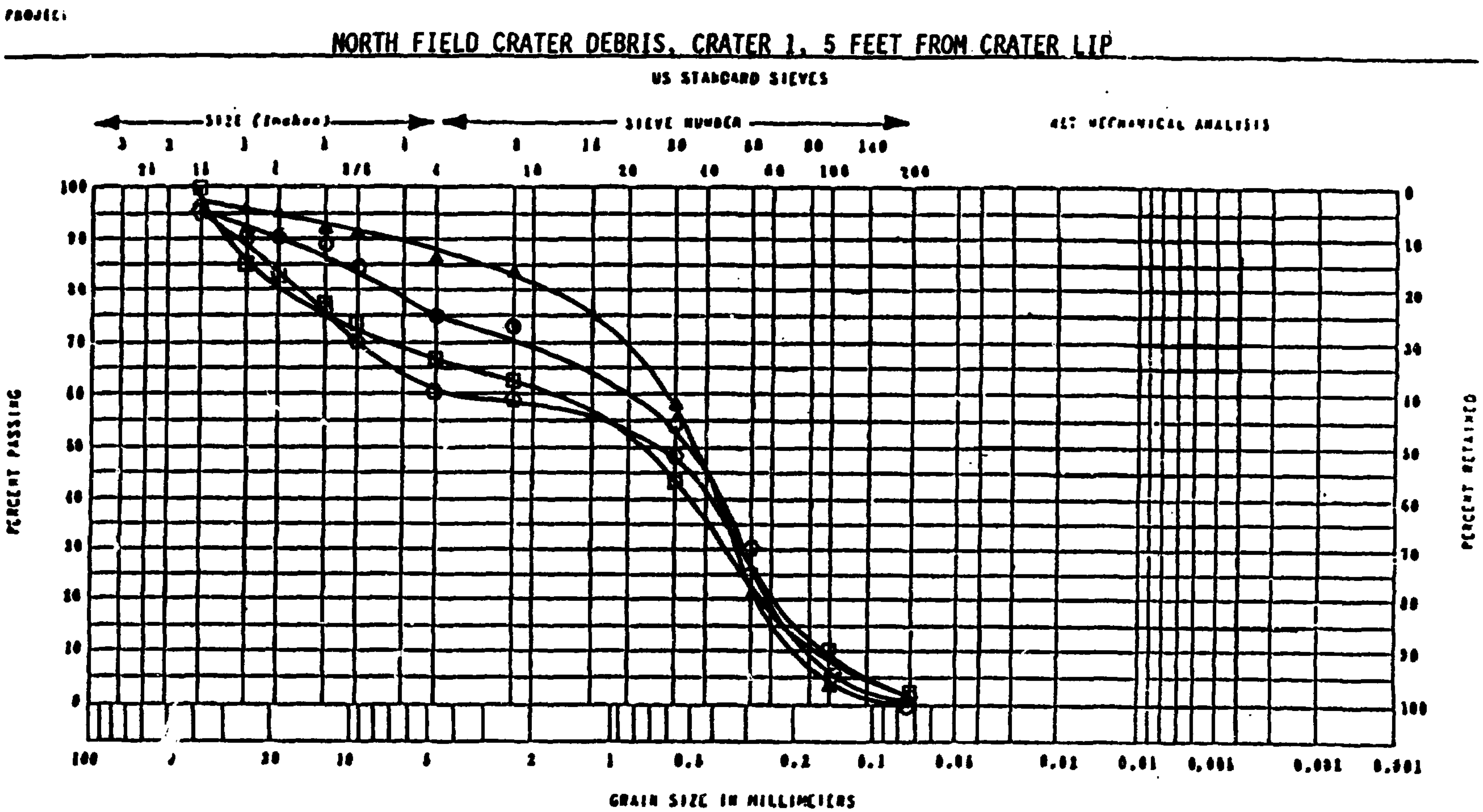
* No samples found at 15, 45, 55, and 65 feet along the West, Southwest, South, and Southeast radials.

TABLE C-4. DISTRIBUTION OF LARGER DEBRIS (IN INCHES) AROUND CRATER 2

DISTANCE FROM CRATER LIP (FEET)	RADIAL DIRECTION			
	East	Northeast	North	Northwest
5	6x3x3 CC 6x8x3 CC		12x12x12 CL 12x8x3 CC 5x5x3 CL 4x3x8 CC	24x24x8 CC
10	4x6x10 CC 36x18x4 CC	4x2x6 CC 2x2x2 CL 5x5x2 CC		
15	5x5x5x CL	24x12x12 CC 6x5x3 CC		6x3x2 CC 1x2x2 CC
25	8x5x3 CL 3x4x1 CL 2x2x1 CL	2x2x2 CL	3x3x3 CL	4x5x3 CL
35	2x3x1 CL 2x2x1 CL			
45	8x5x1 CC	3x4x3 CL 1x2x1 CL		
55		7x4x4 CL 3x3x2 CL		
65		8x6x6 CC		
75		12x12x12 CC		

CC-Concrete Chunks

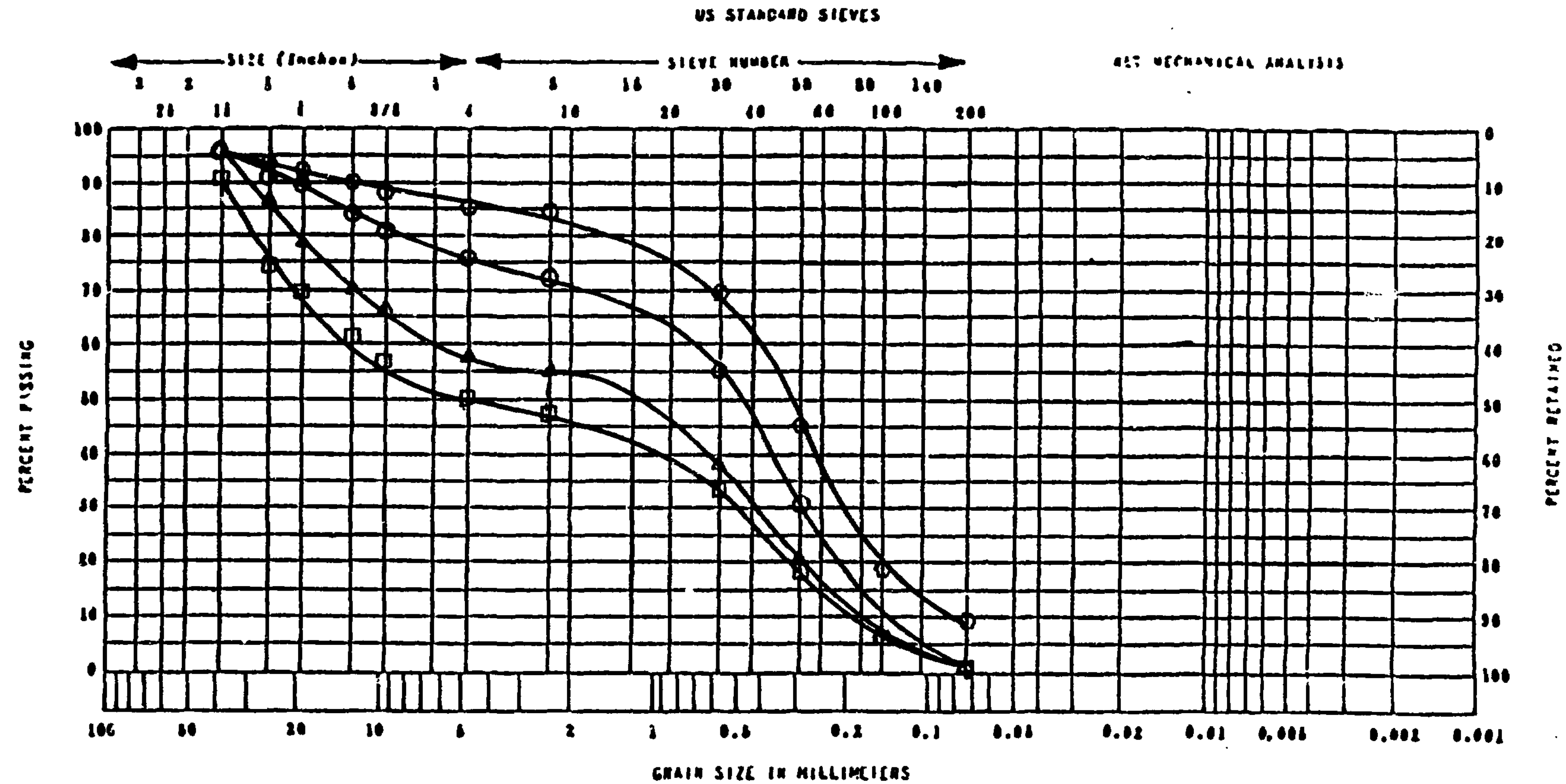
CL-Clay Chunks



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ *Southeast*	13,463	14,800
□ West	5,282	7,622
△ Northwest	7,847	8,150
⬡ East	5,253	7,083

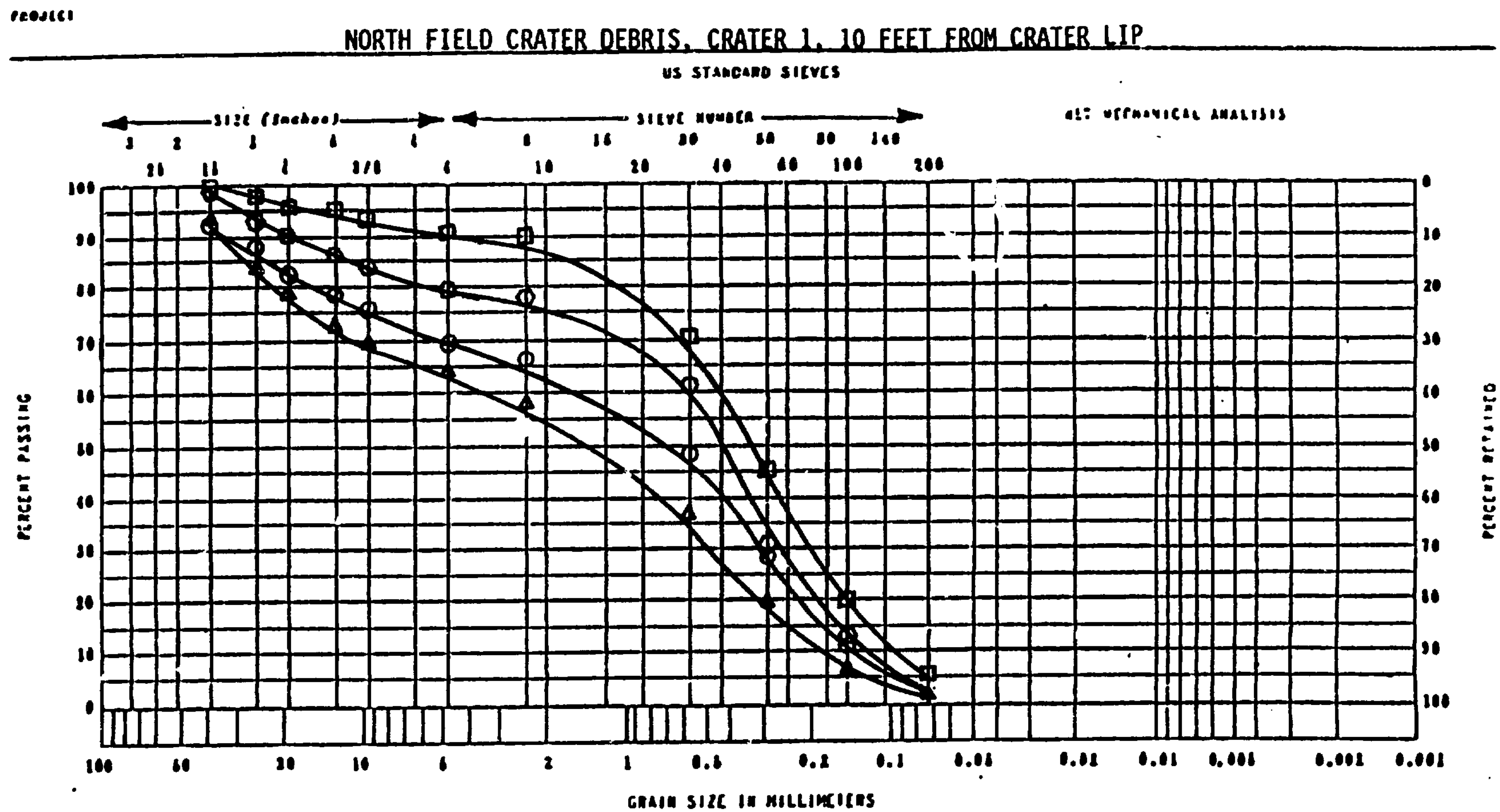
Figure C-6. Debris Density, Crater 1, 5 Feet, Southeast, West, Northeast, East Radials

NORTH FIELD CRATER DEBRIS, CRATER 1, 5 FEET FROM CRATER LIP



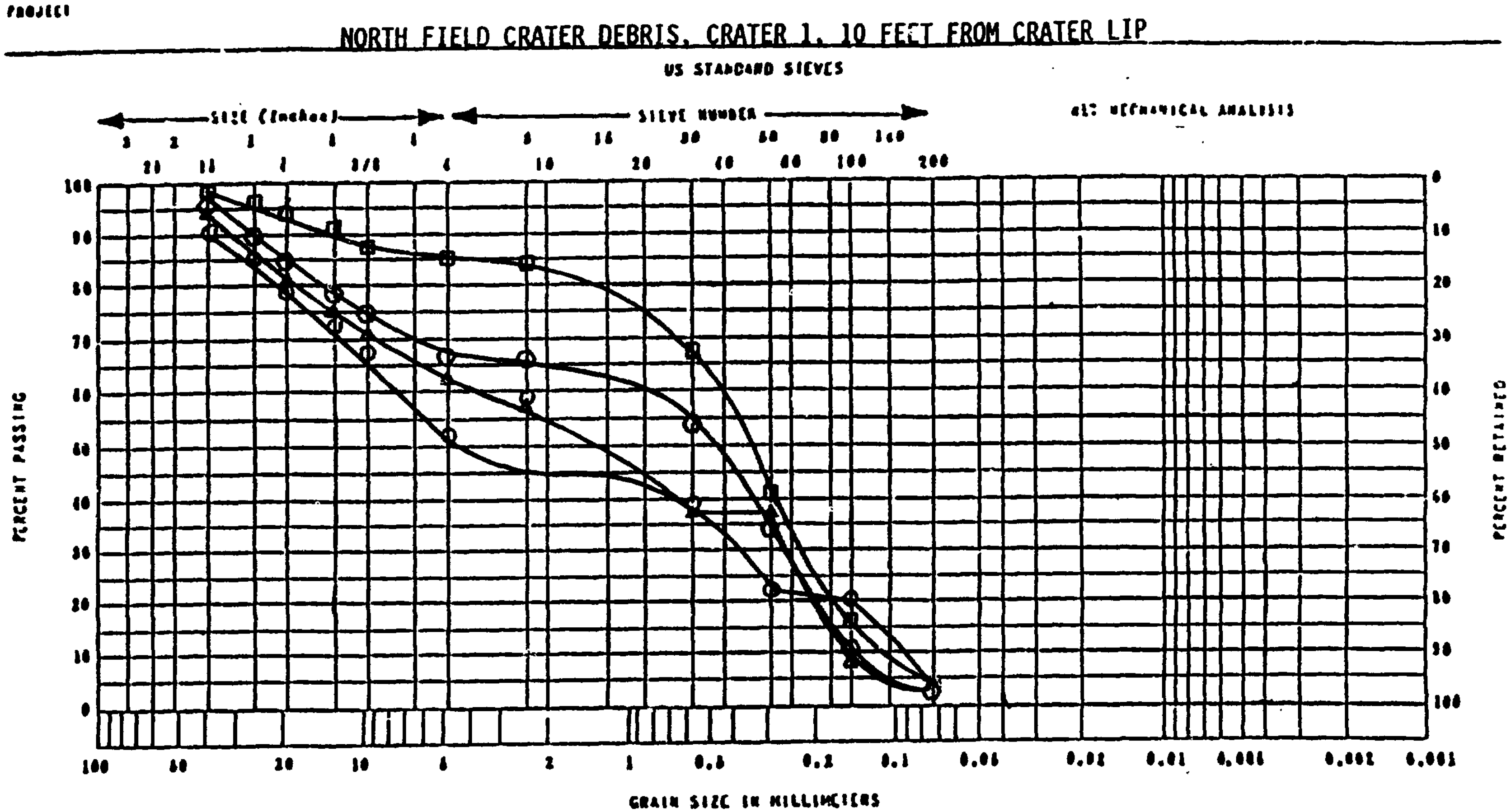
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ North	6,485	6,485
△ South	9,191	16,535
□ Southwest	8,788	10,485
⬡ Northeast	7,370	7,370

Figure C-7. Debris Density, Crater 1, 5 Feet, North, South, Southwest, and Northeast Radials



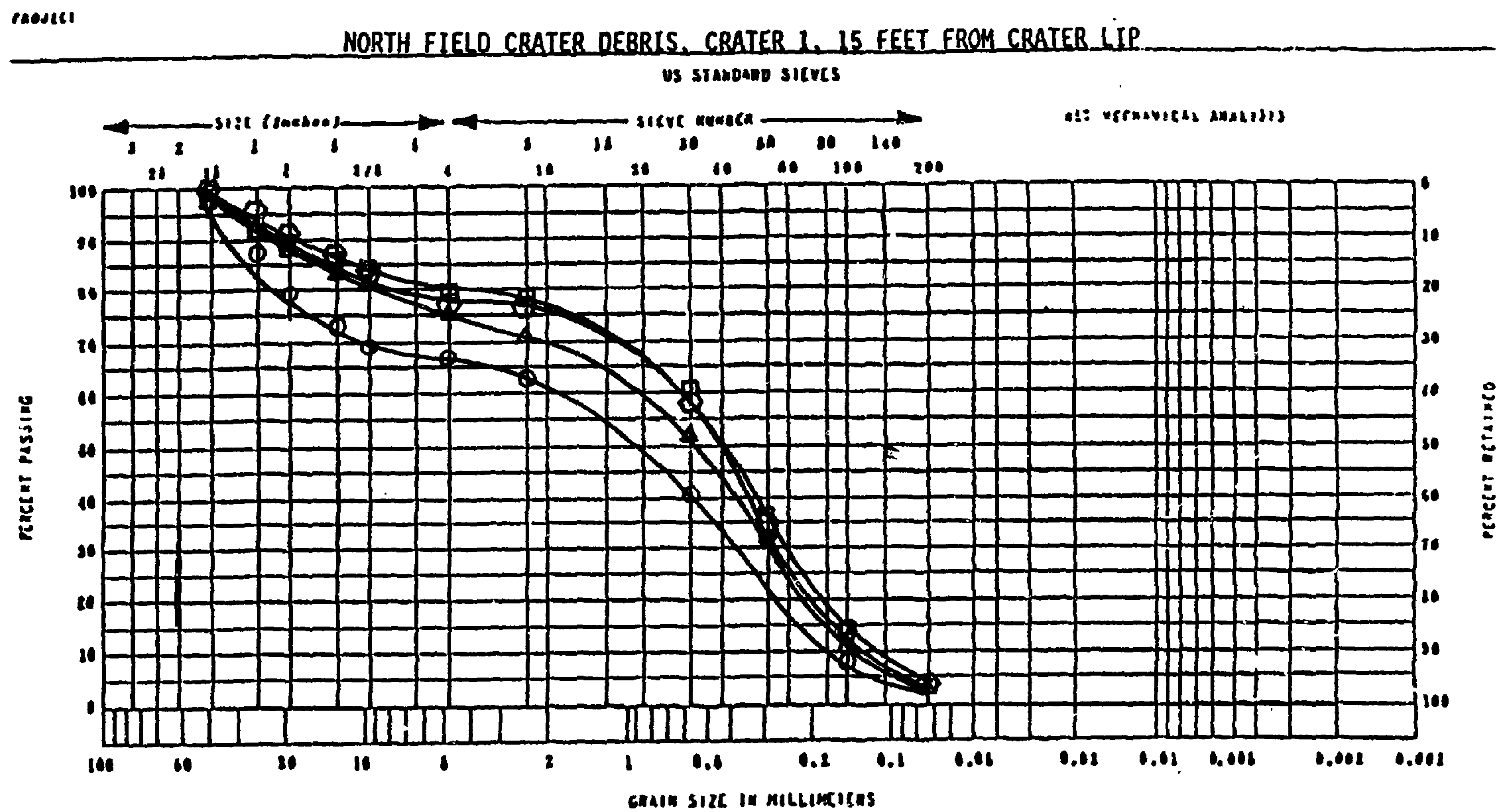
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northwest	3,318	3,640
□ Northeast	6,800	6,955
△ Southwest	2,235	2,555
⬡ North	5,723	5,723

Figure C-8. Debris Density, Crater 1, 10 Feet, Northwest, Northeast, Southwest, North Radials



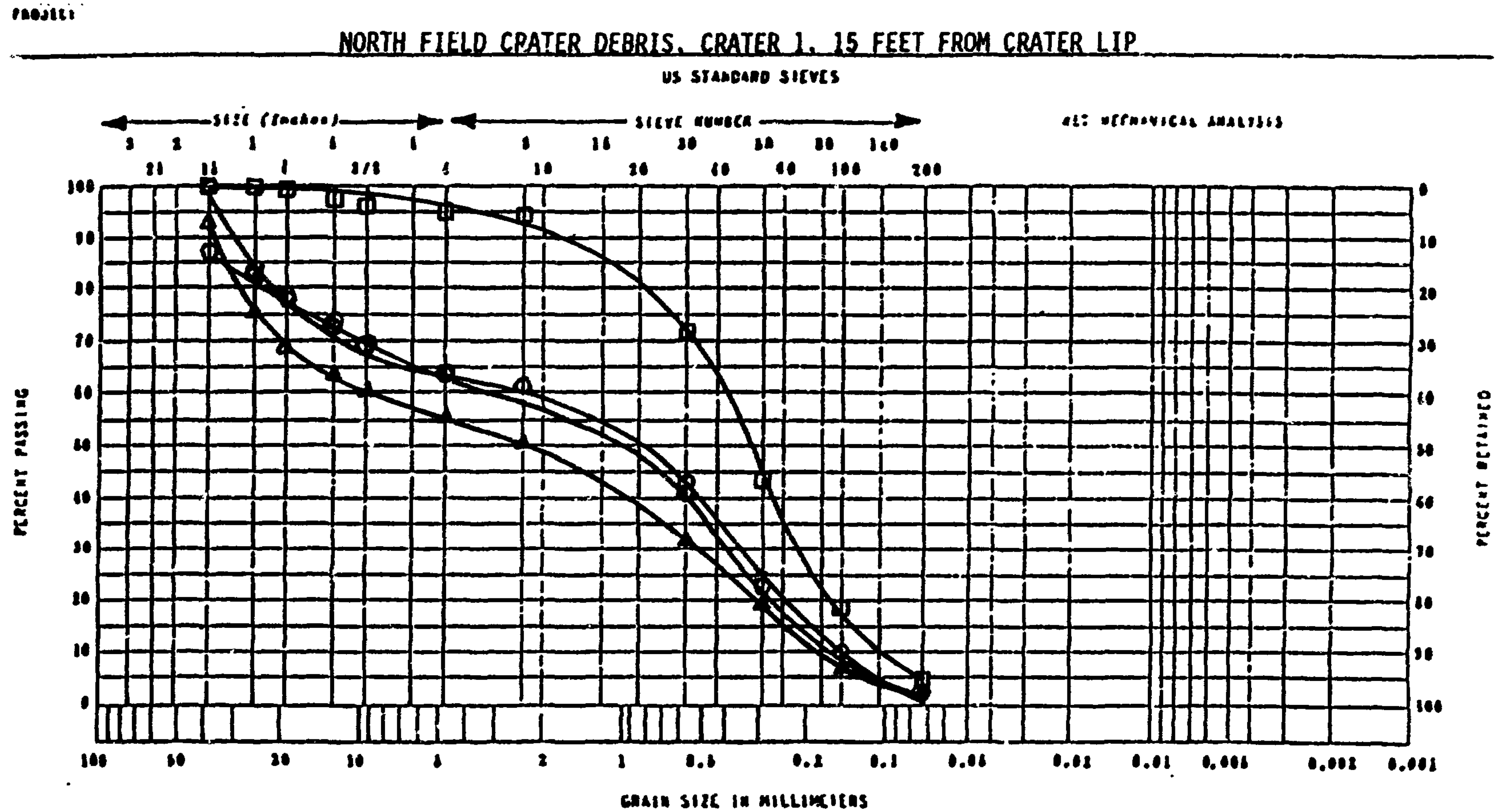
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ South	2,859	3,854
□ East	9,711	11,028
△ West	2,638	3,023
⬡ Southeast	6,938	8,890

Figure C-9. Debris Density, Crater 1, 10 Feet, South, East, West, and Southeast Radials



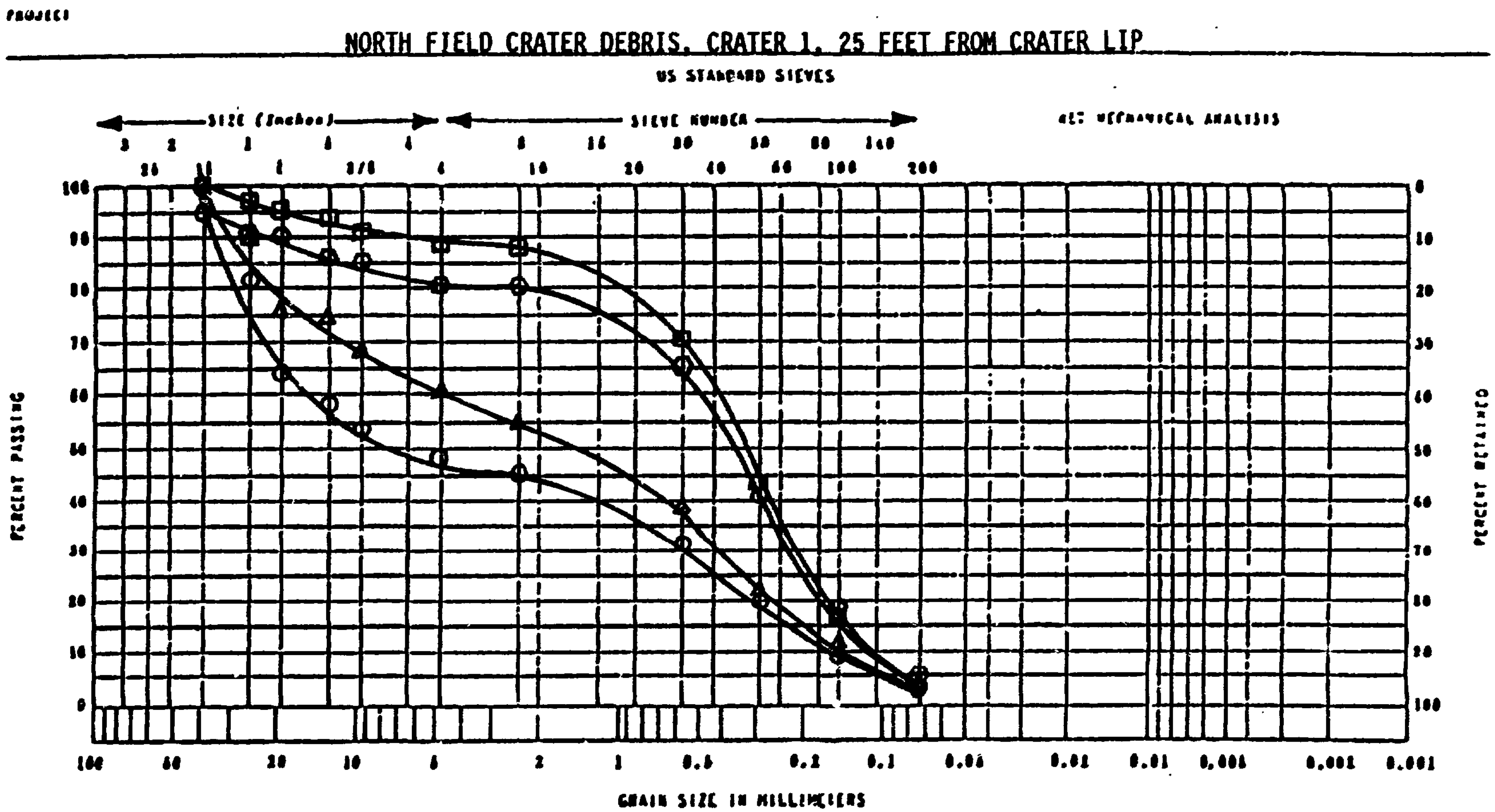
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ South	1,255	1,667
□ East	5,629	6,112
△ West	1,025	1,025
⬡ Southeast	4,925	4,925

Figure C-10. Debris Density, Crater 1, 15 Feet, South, East, West, and Southeast Radials



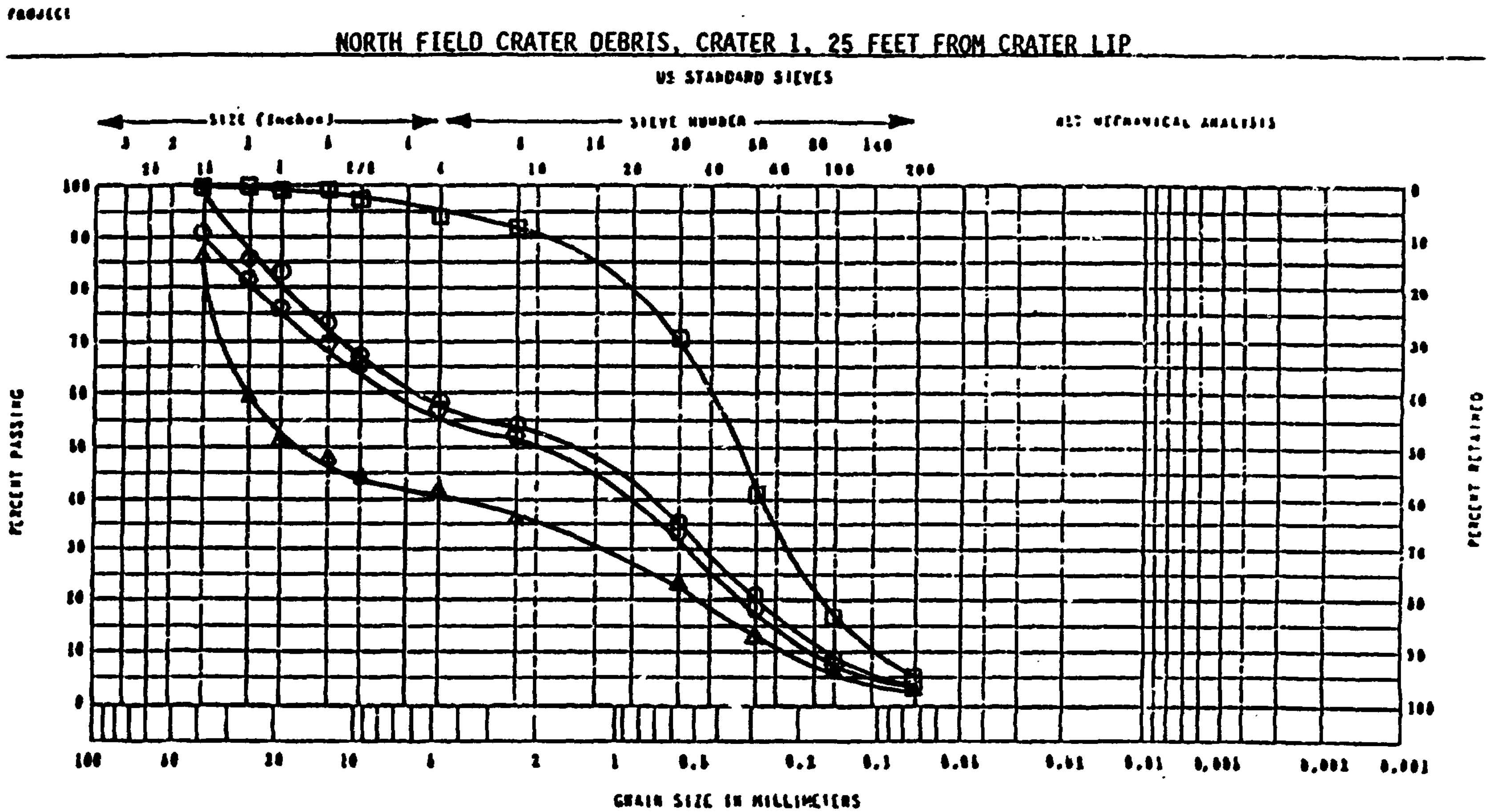
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
O Northwest	1,686	2,008
□ Northeast	5,848	5,848
△ Southwest	1,469	2,063
O North	1,762	1,933

Figure C-11. Debris Density, Crater 1, 15 Feet, Northwest, Northeast, Southwest, and South Radials



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ South	619	1,733
□ East	4,030	4,030
△ West	465	1,229
⬡ Southeast	3,554	4,000

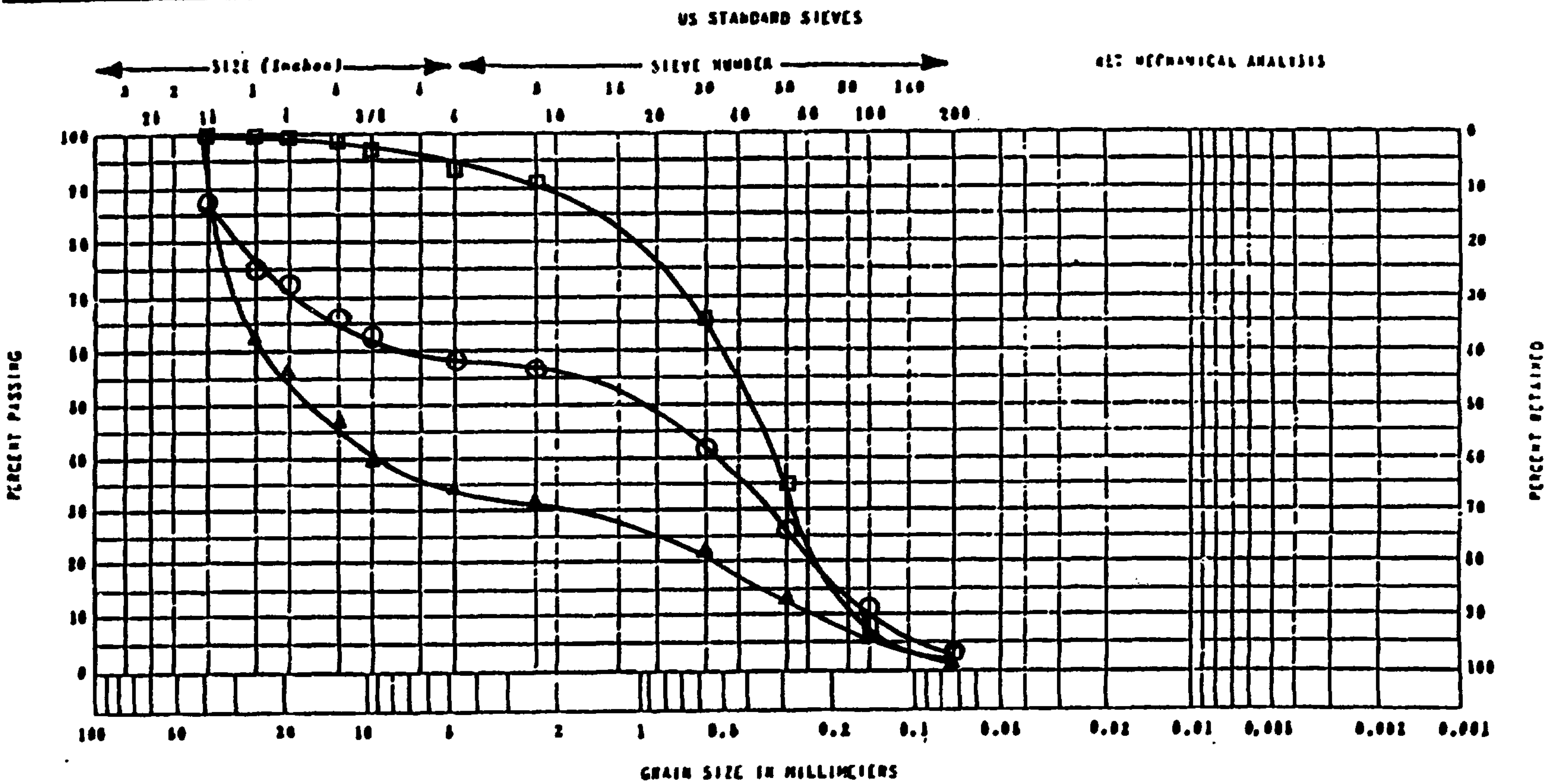
Figure C-12. Debris Density, Crater 1, 25 Feet, South, East, West, and Southeast Radials



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northwest	1,259	1,581
□ Northeast	3,212	3,212
△ Southwest	850	1,369
○ North	1,529	1,727

Figure C-13. Debris Density, Crater 1, 25 Feet, Northwest, Northeast, Southwest, and North Radials

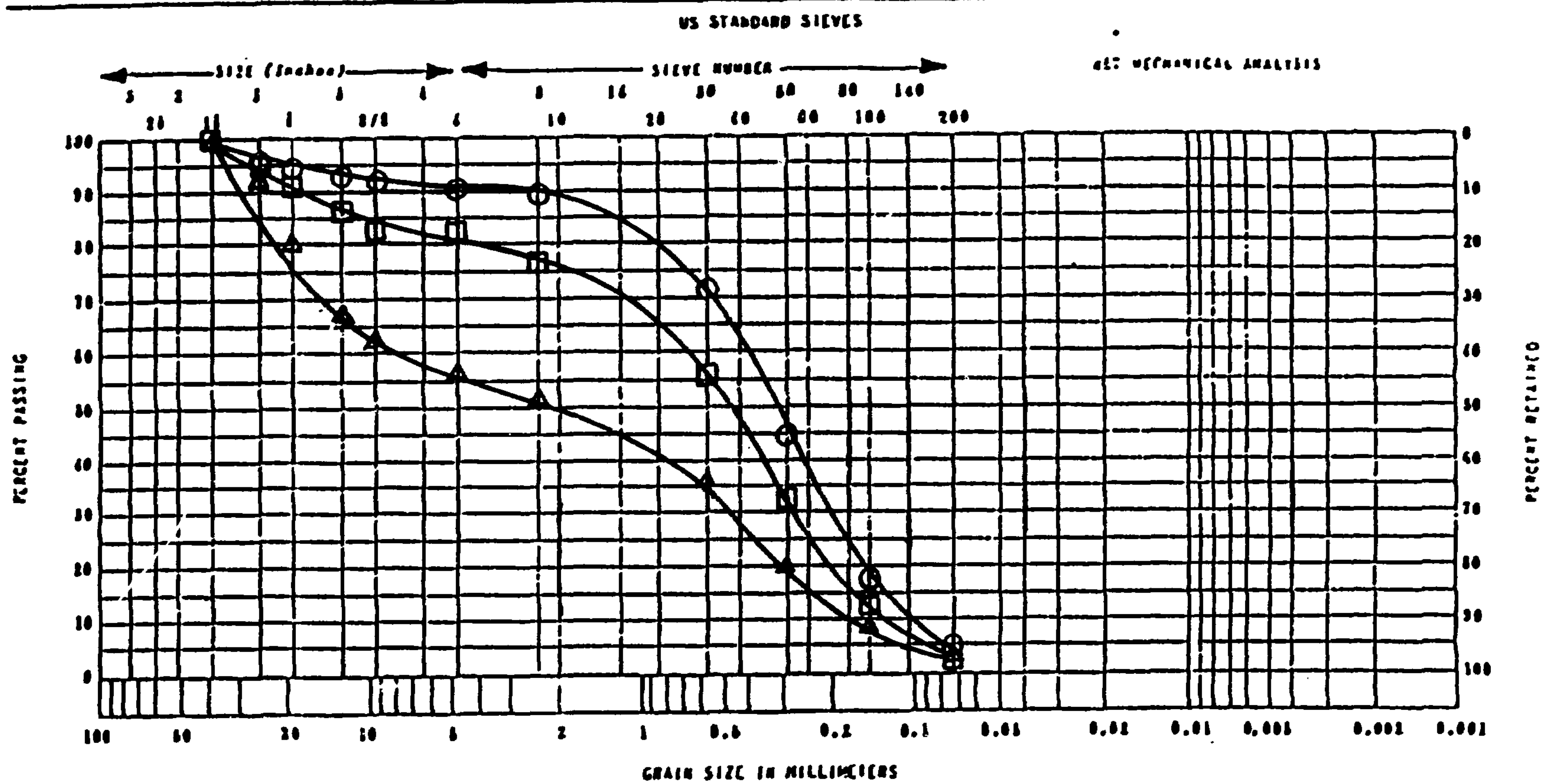
NORTH FIELD CRATER DEBRIS, CRATER 1, 35 FEET FROM CRATER LIP



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ North	5,412	5,412
△ South	470	470
□ Northeast	2,019	2,019

Figure C-14. Debris Density, Crater 1, 35 Feet, North, South, and Northeast Radials

NORTH FIELD CRATER DEBRIS, CRATER 1, 35 FEET FROM CRATER LIP



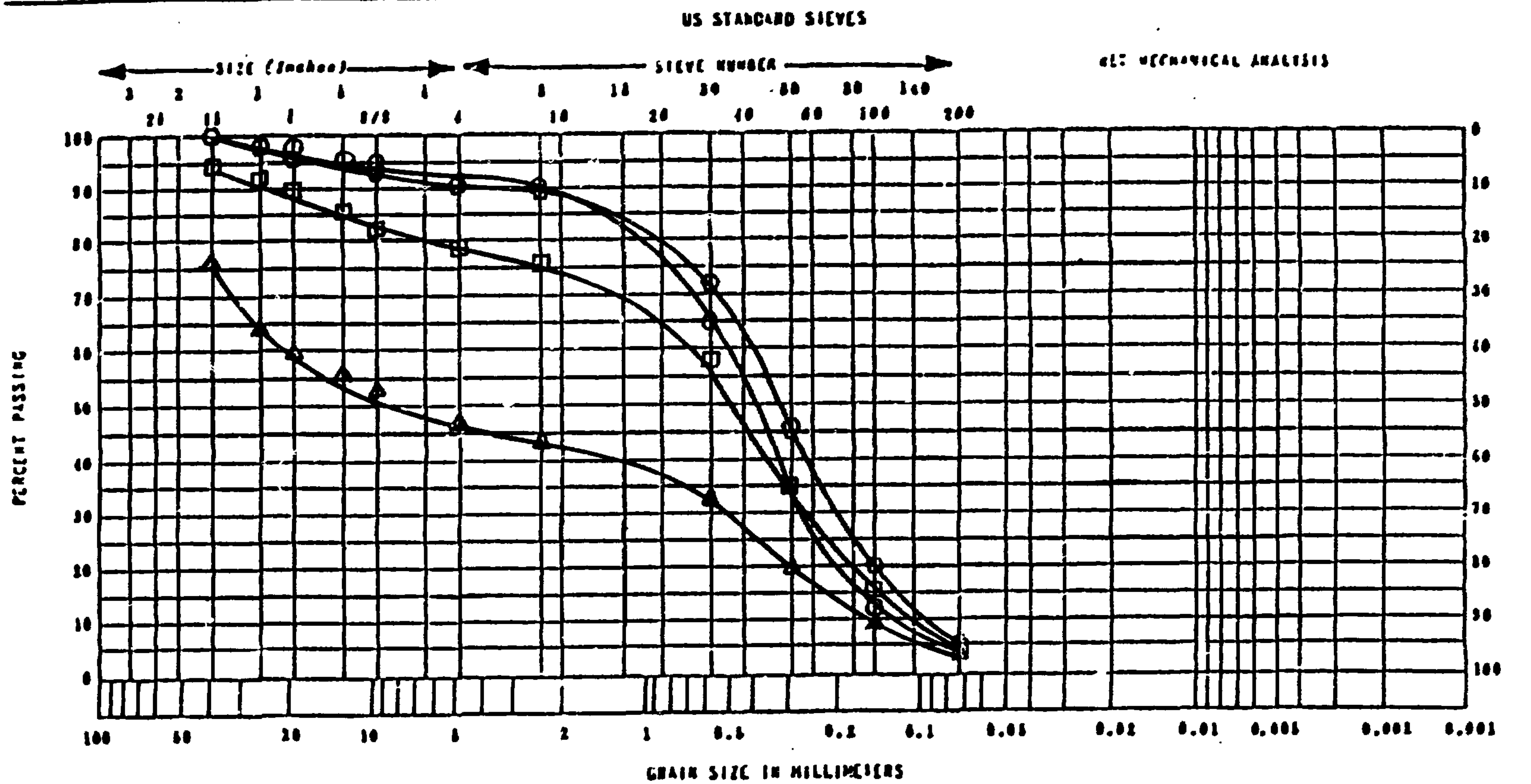
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Southeast	4,273	4,611
□ East	2,199	2,840
△ West	385	608

*No Sieve Analysis - SW, NW, Radials

Figure C-15. Debris Density, Crater 1, 35 Feet, Southeast, East, and West Radials

PROJECT

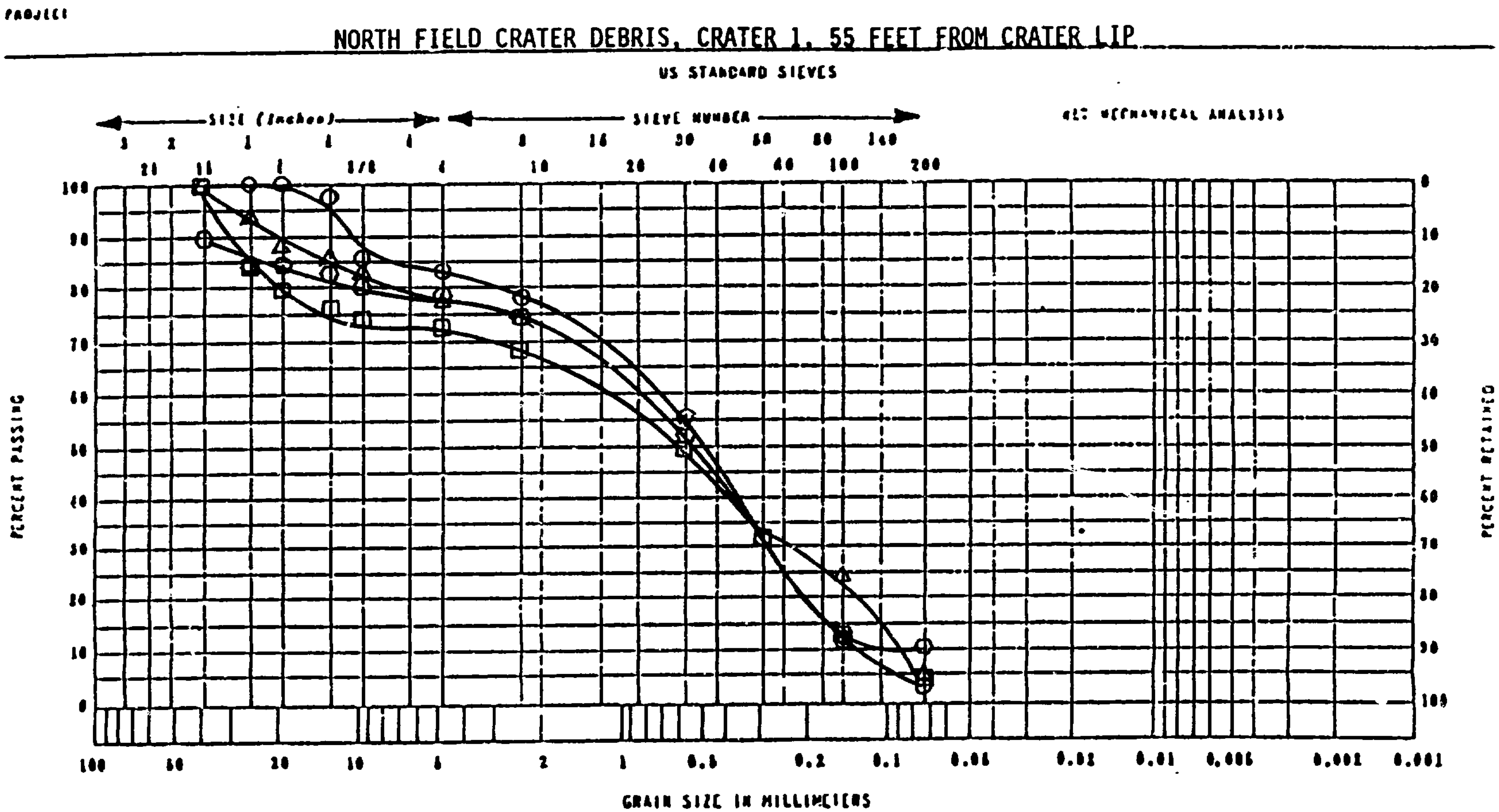
NORTH FIELD CRATER DEBRIS, CRATER 1, 45 FEET FROM CRATER LIP



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northeast	1,475	1,475
□ East	1,668	1,668
△ West	342	605
⬡ Southeast	1,770	1,925

*No Sieve Analysis - NW, SW, N, S, Radials

Figure C-16. Debris Density, Crater 1, 45 Feet, Northeast, East, West, and Southeast Radials

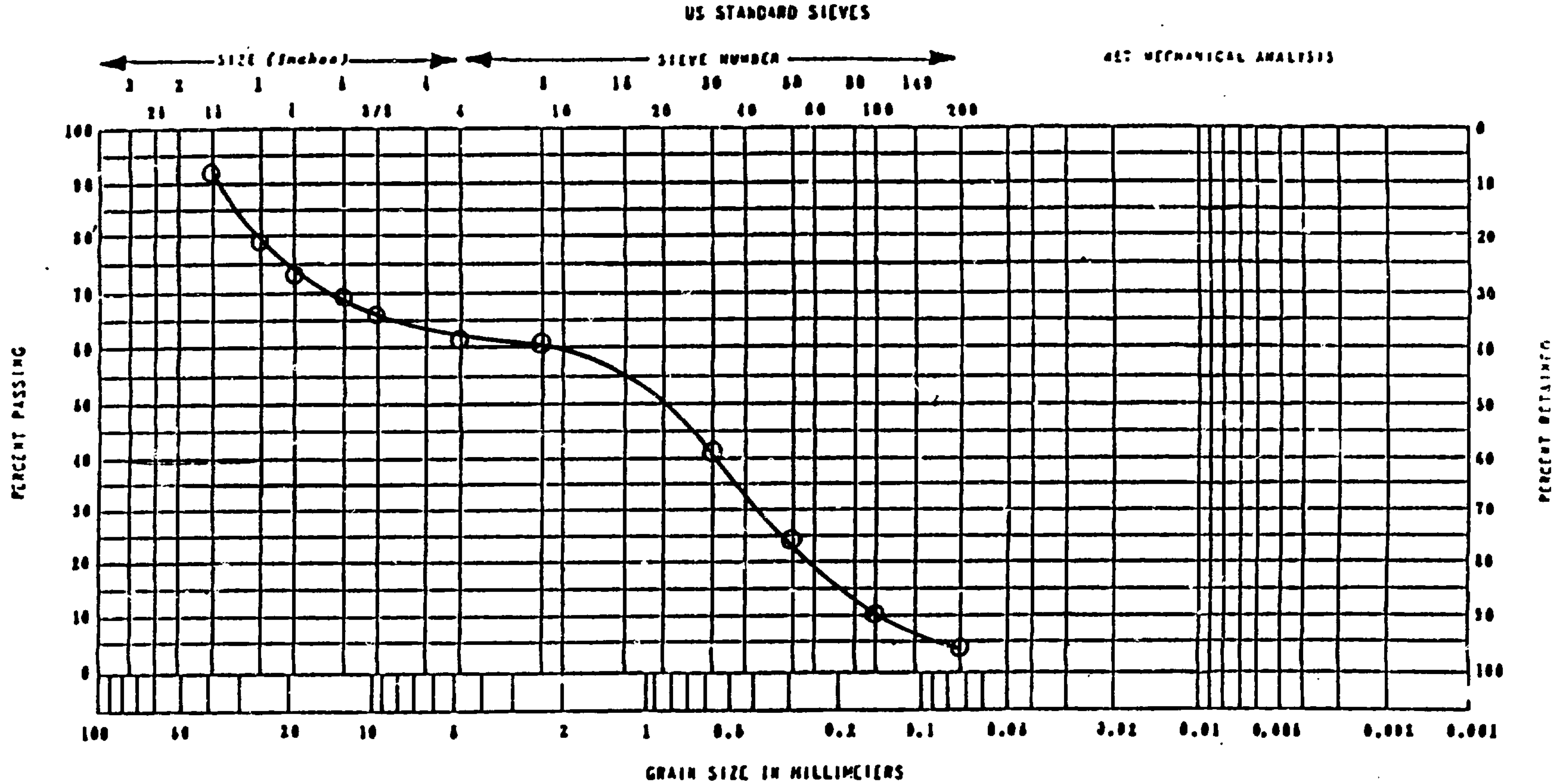


Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northwest	218	453
△ Southeast	1,014	1,724
□ Southwest	317.2	473.5
⬡ Northeast	1,003.5	1,003.5

Figure C-17. Debris Density, Crater 1, 55 Feet, Northwest, Southeast, Southwest, and Northeast Radials

PROJECT

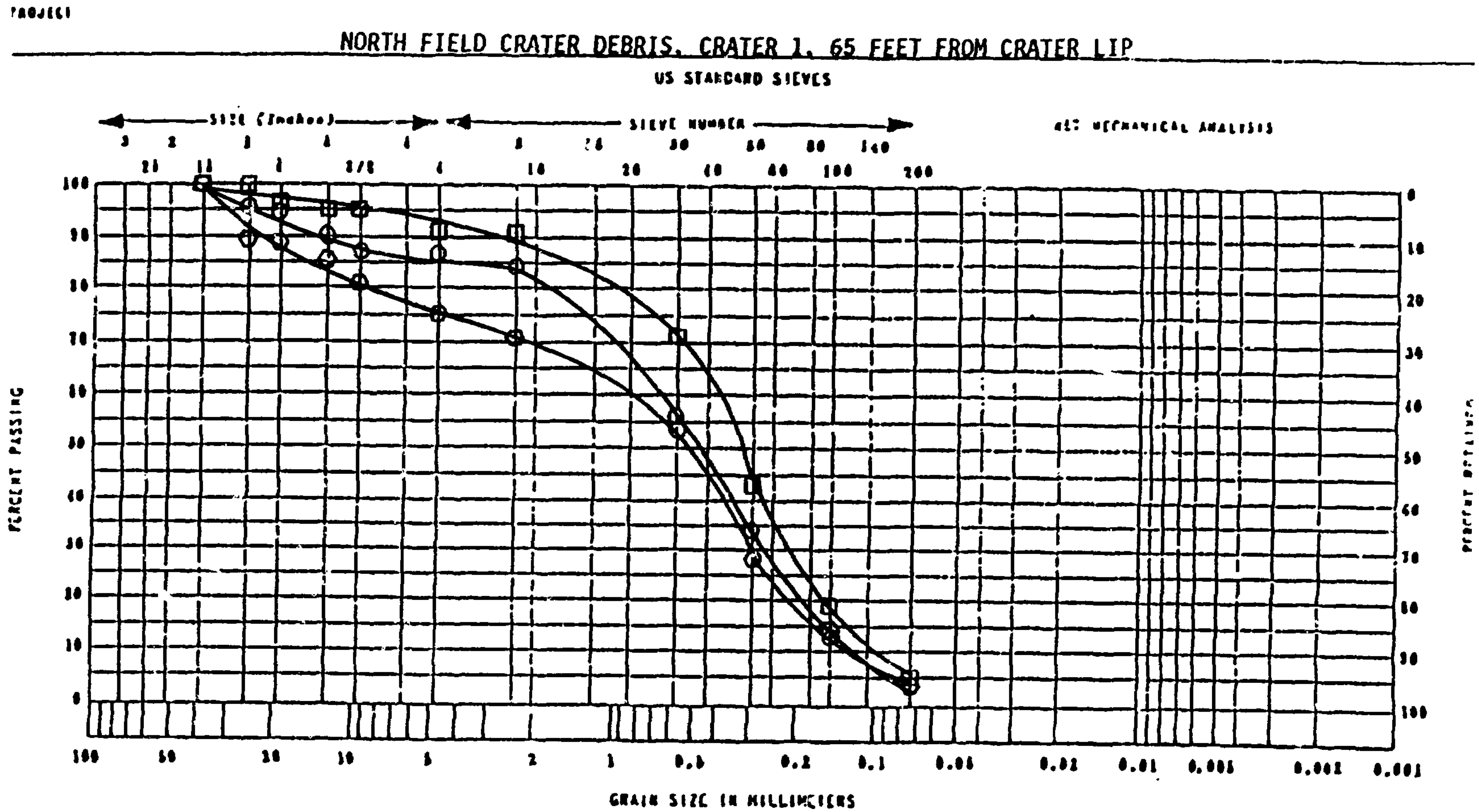
NORTH FIELD CRATER DEBRIS, CRATER 1, 55 FEET FROM CRATER LIP



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ East	2,207	3,402

*No Sieve Analysis - W, N, S Radials

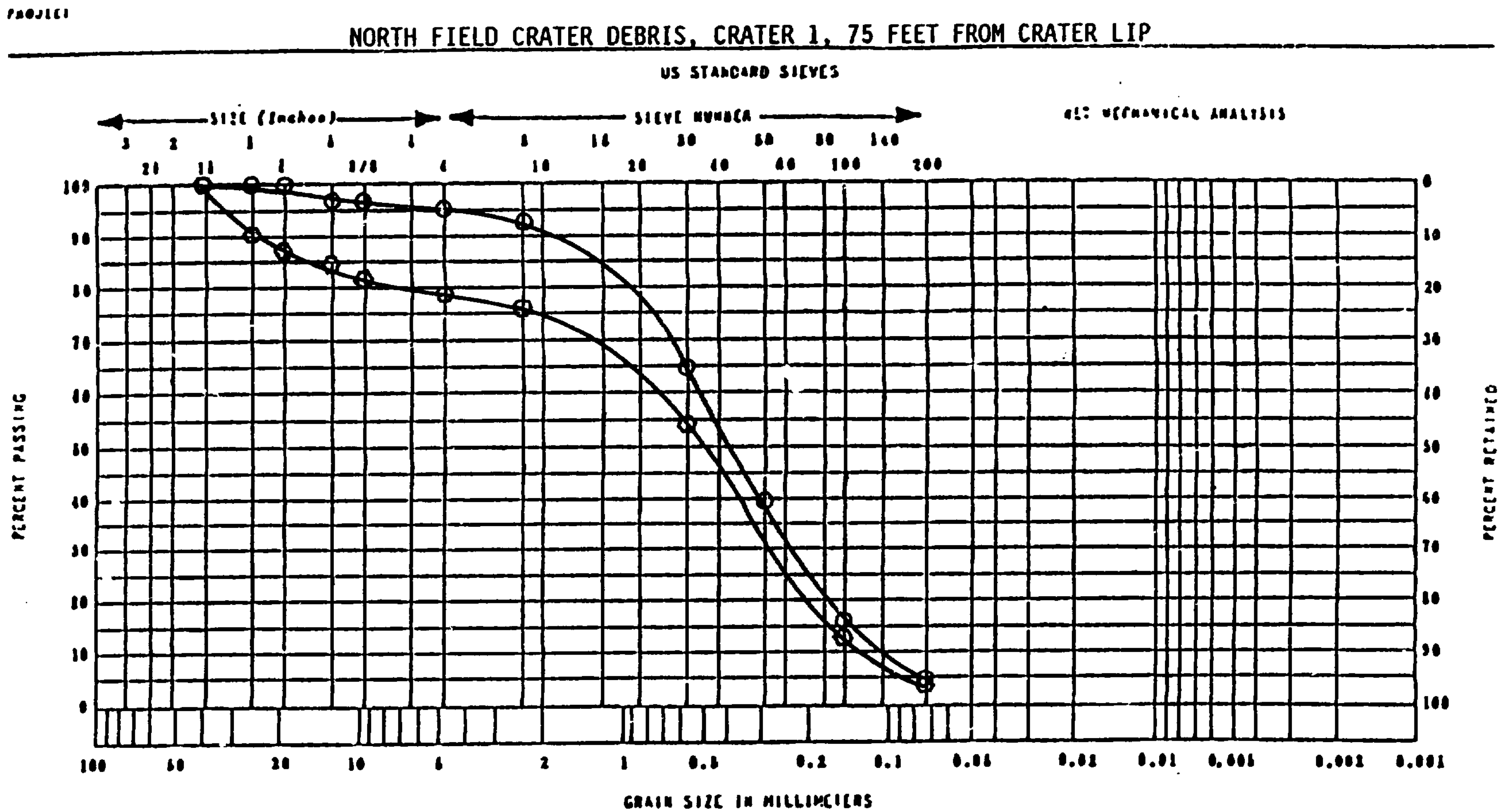
Figure C-18. Debris Density, Crater 1, 55 Feet, East Radial



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northeast	752.3	752.3
□ East	1,552.0	1,552.0
⬡ Southeast	380.0	380.0

*No Sieve Analysis - W, N, S, SW, NW Radials

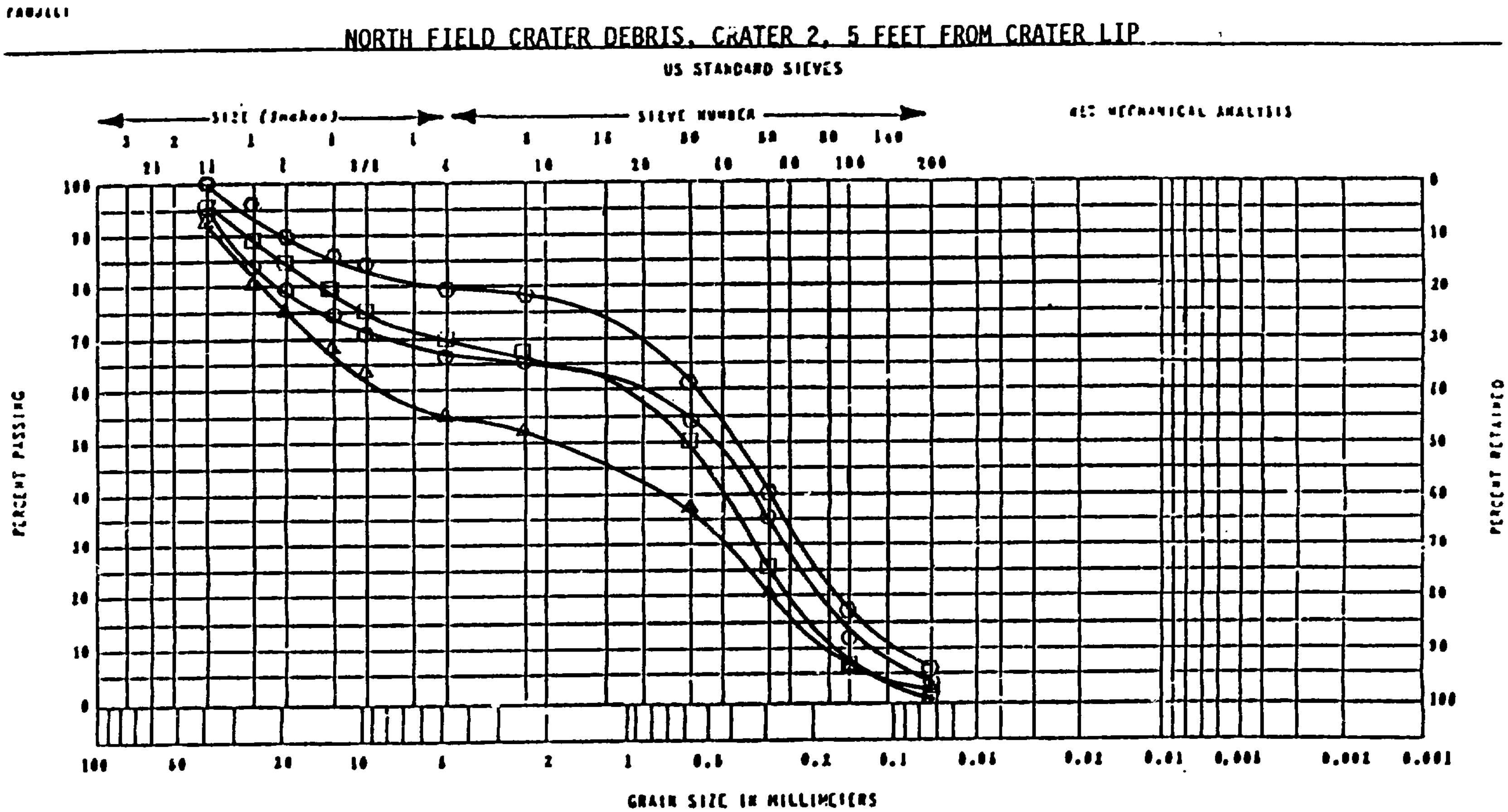
Figure C-19. Debris Density, Crater 1, 65 Feet, Northeast, East, Southeast Radials



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northeast	542.2	542.2
◌ East	1,412.0	1,822.0

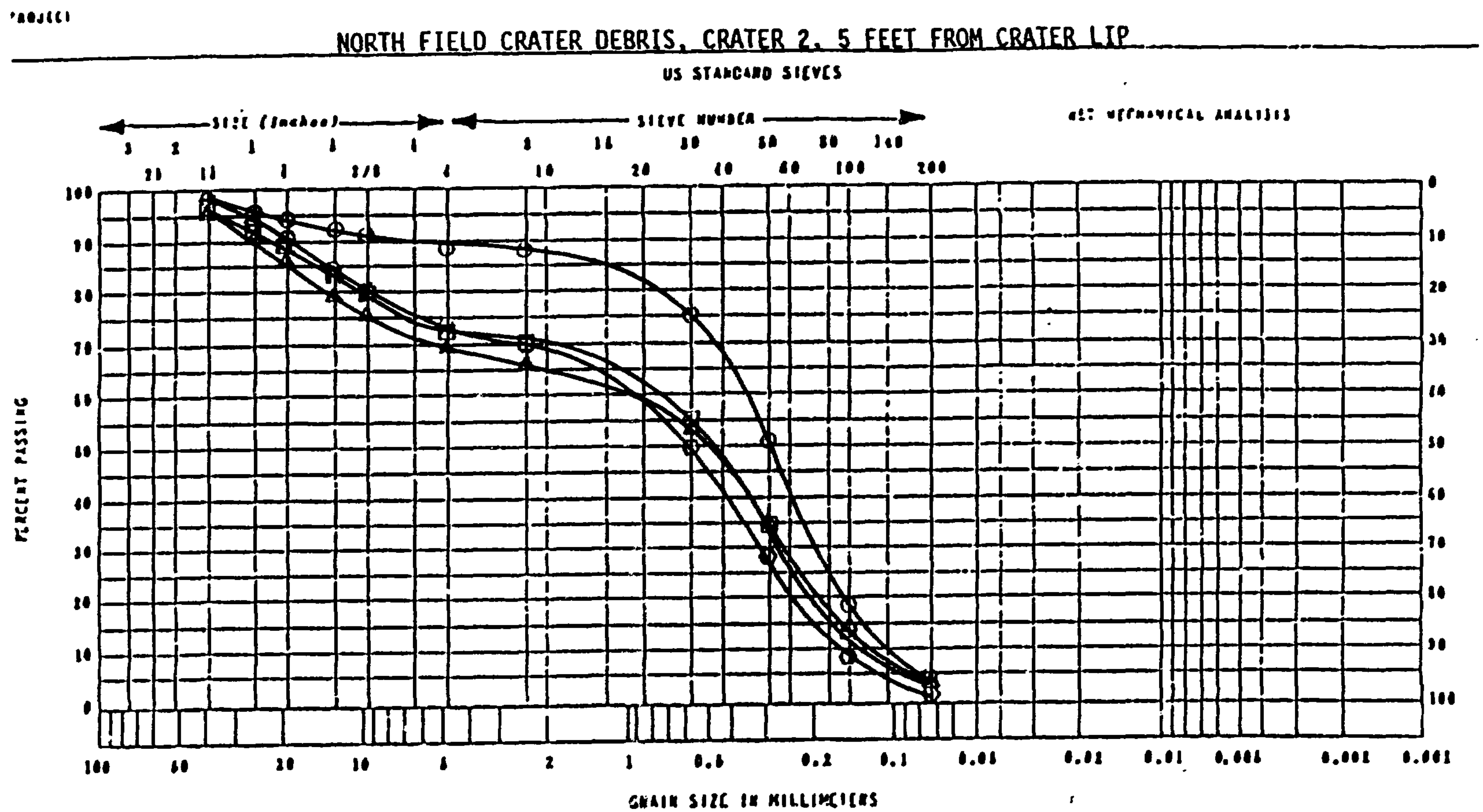
*No Sieve Analysis - W, N, S, SE, NW, SW Radials

Figure C-20. Debris Density, Crater 1, 75 Feet, Northeast and East Radials



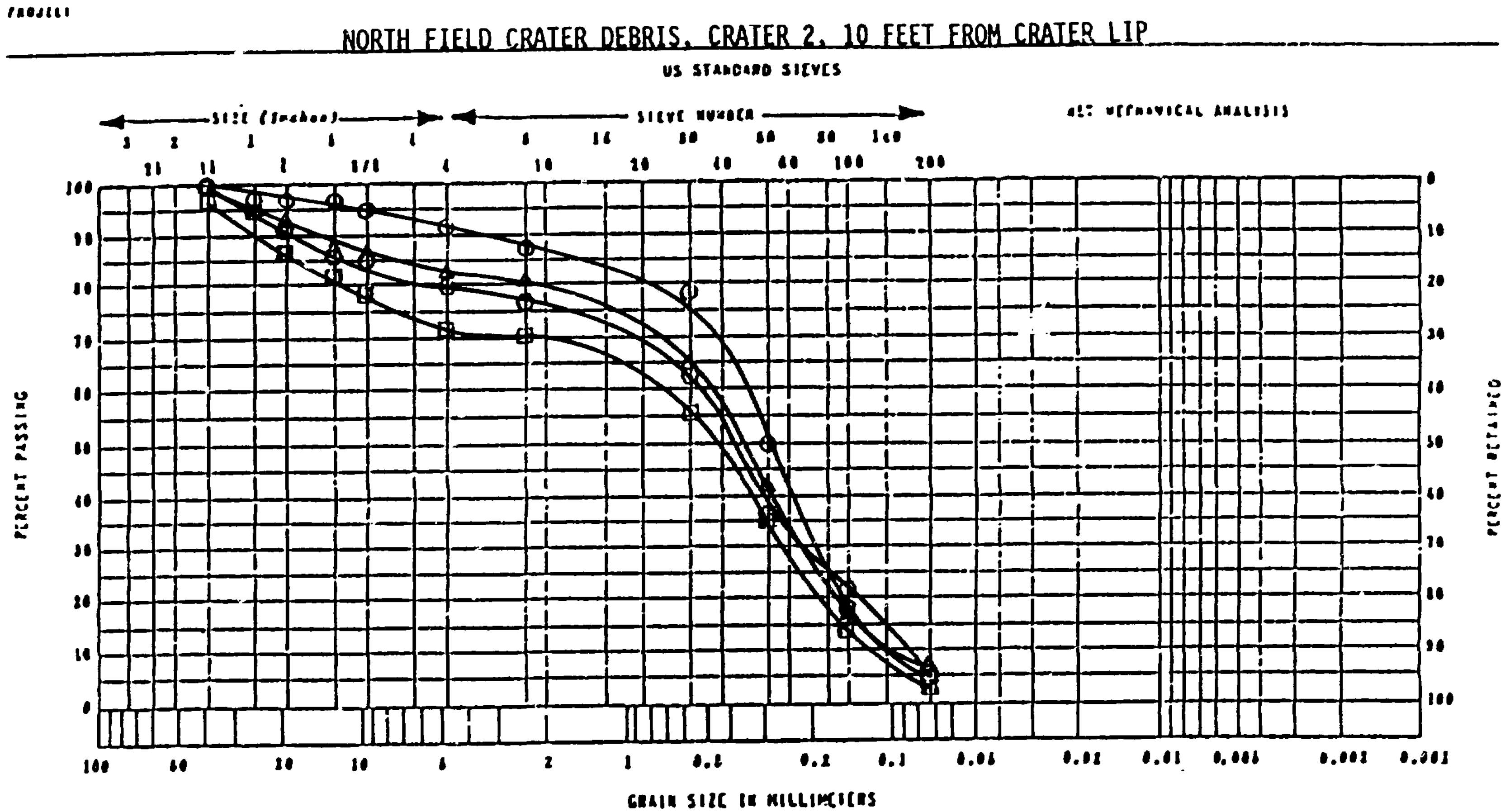
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ North	19,422	26,577
□ East	15,410	16,300
△ West	16,292	24,507
⬡ South	4,793	4,793

Figure C-21. Debris Density, Crater 2, 5 Feet, North, East, West, and South Radials



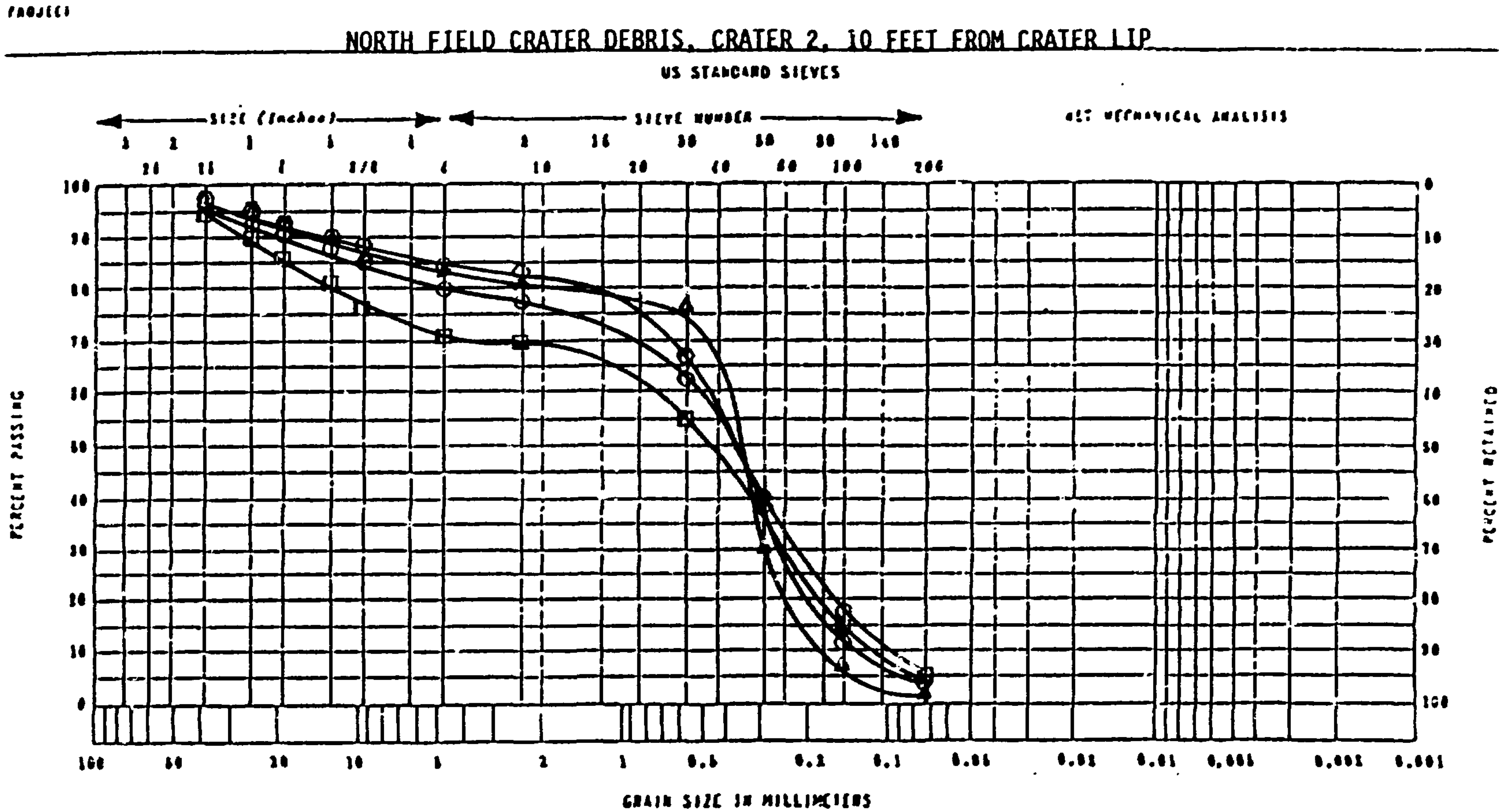
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northwest	17,689	35,560
□ Southeast	15,335	17,235
△ Southwest	11,151	12,513
⬡ Northeast	18,725	19,340

Figure C-22. Debris Density, Crater 2, 5 Feet, Northwest, Northeast, Southwest, and Southeast Radials



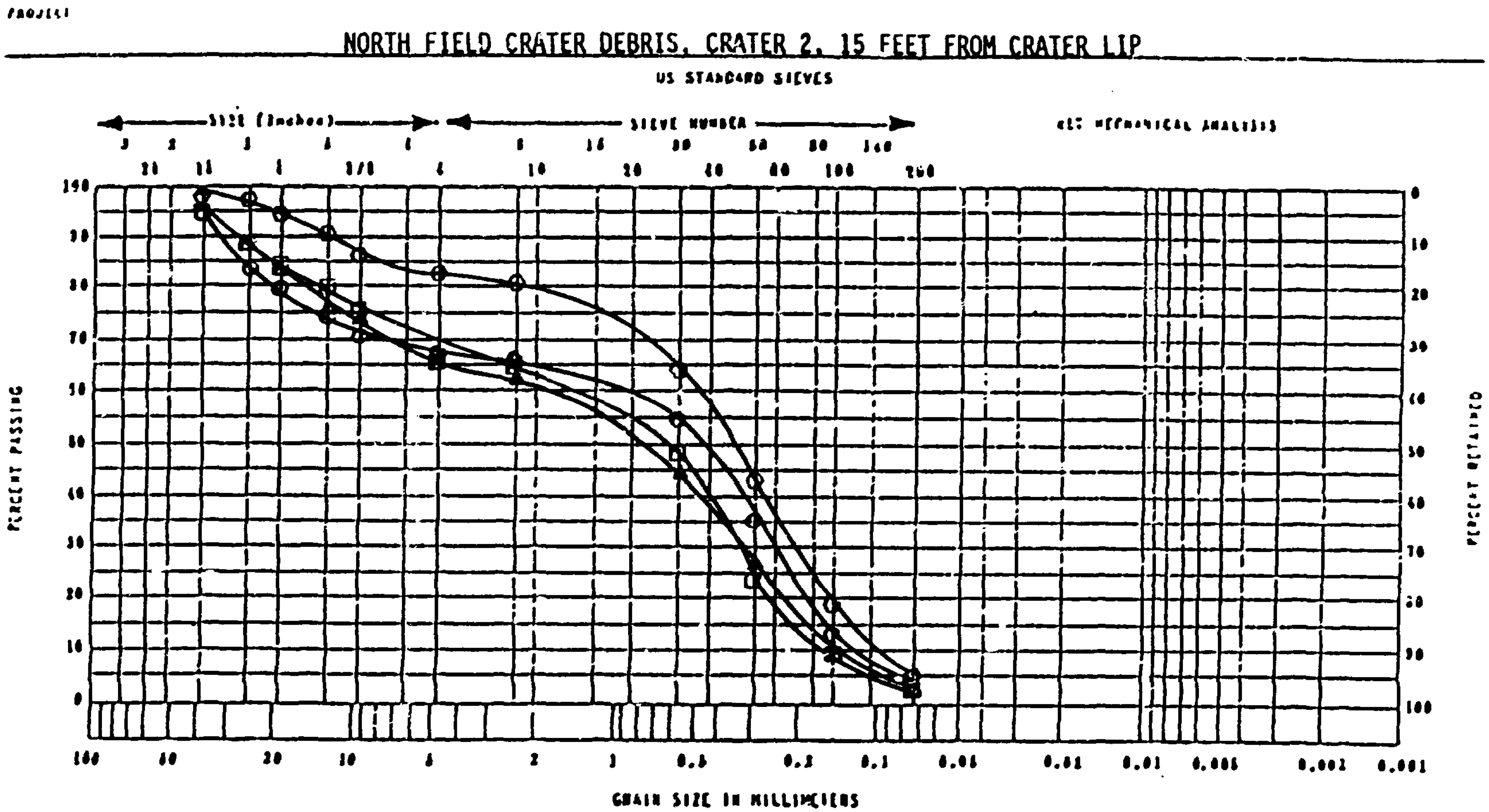
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northwest	21,752	21,752
△ Southeast	5,352	5,627
□ Northeast	8,921	19,828
⬡ Southwest	5,010	6,080

Figure C-23. Debris Density, Crater 2, 10 Feet, Northwest, Southeast, Northeast, and Southwest Radials



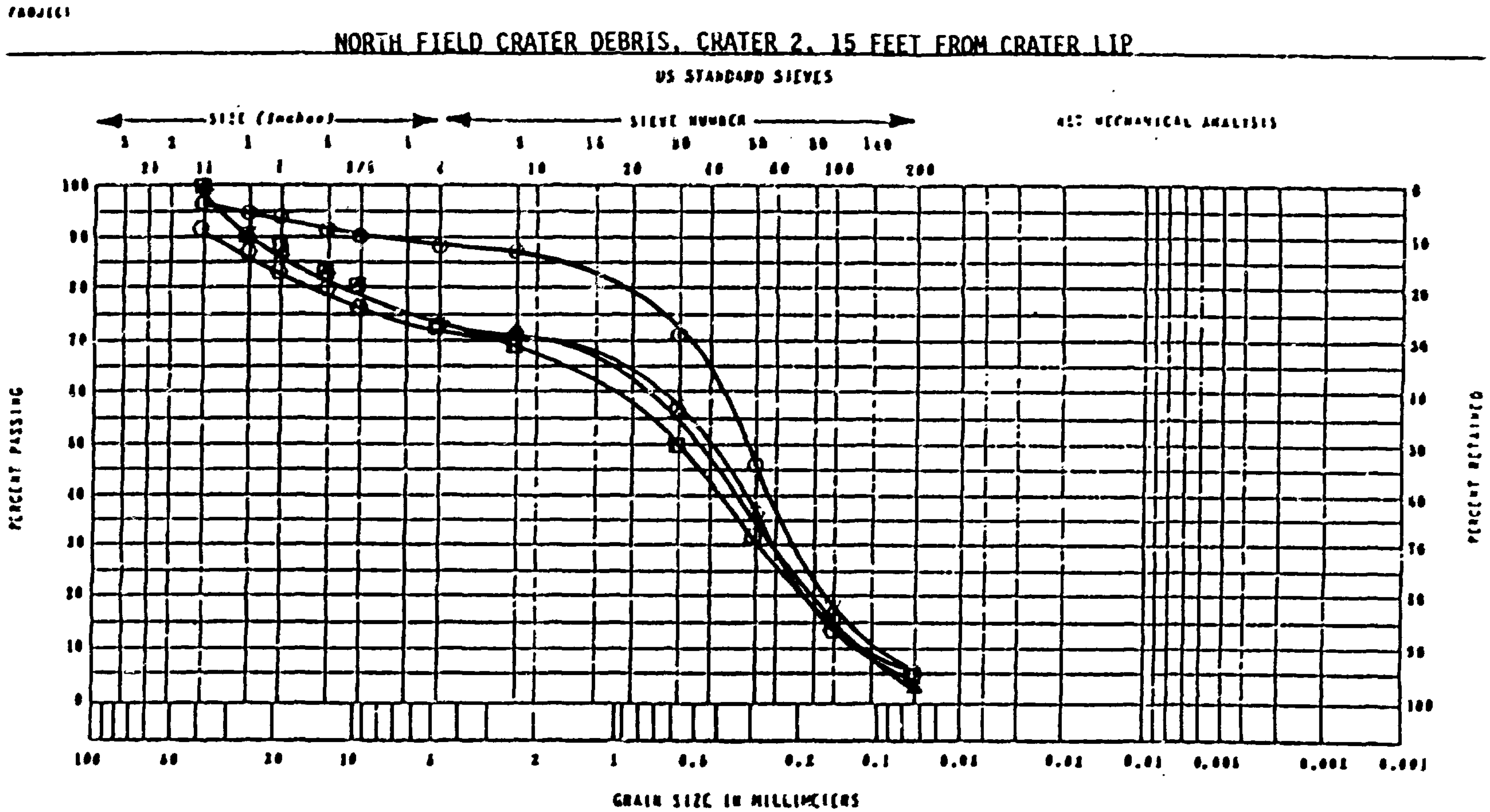
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ North	4,243	4,453
□ South	4,373	5,348
△ East	6,160	6,160
⬡ West	7,140	7,140

Figure C-24. Debris Density, Crater 2, 10 Feet, North, South, East, and West Radials



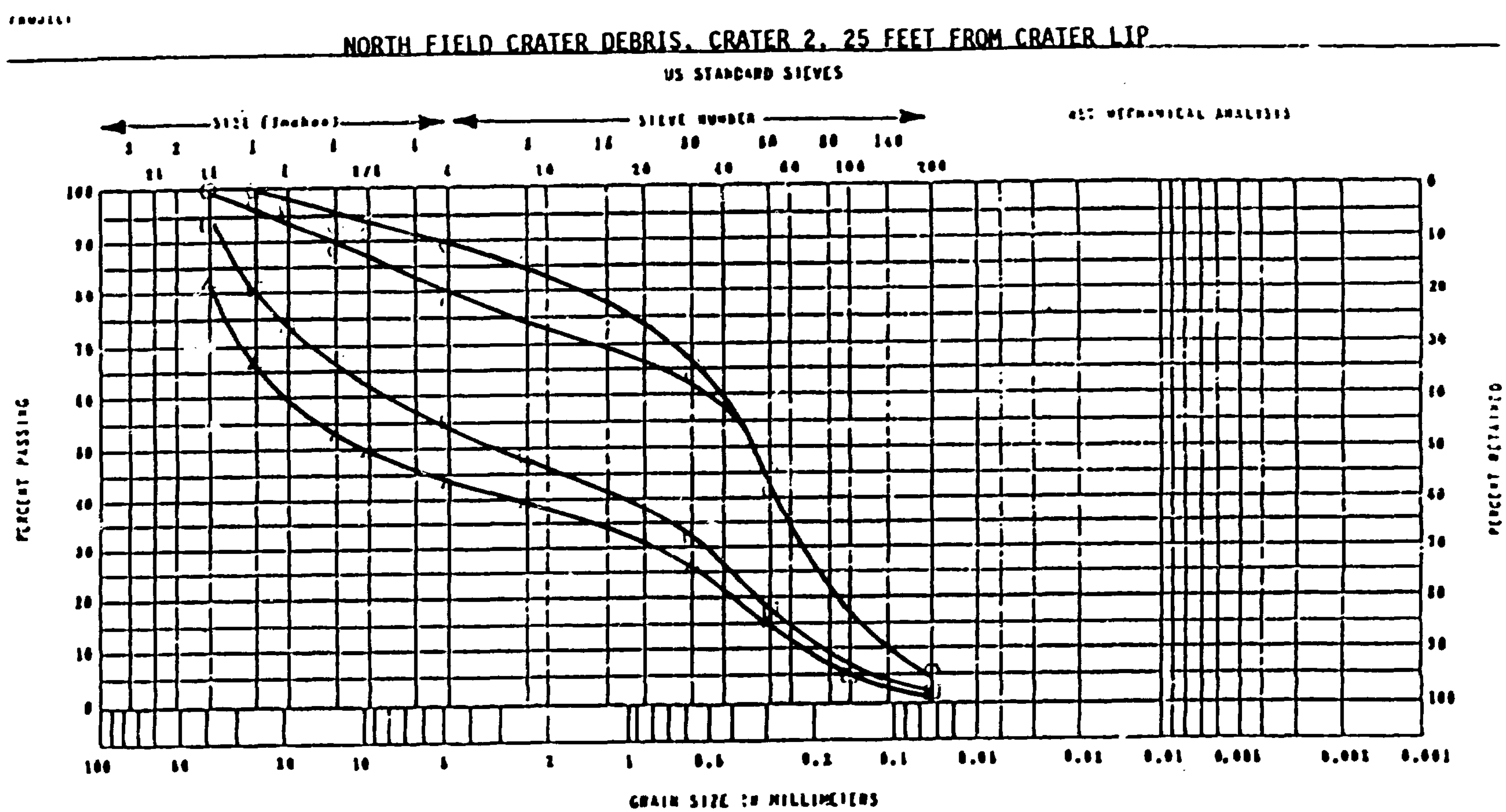
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ North	2,767	2,767
□ East	6,738	8,990
△ West	2,561	2,842
○ South	1,693	1,693

Figure C-25. Debris Density, Crater 2, 15 Feet, North, East, West, and South Radials



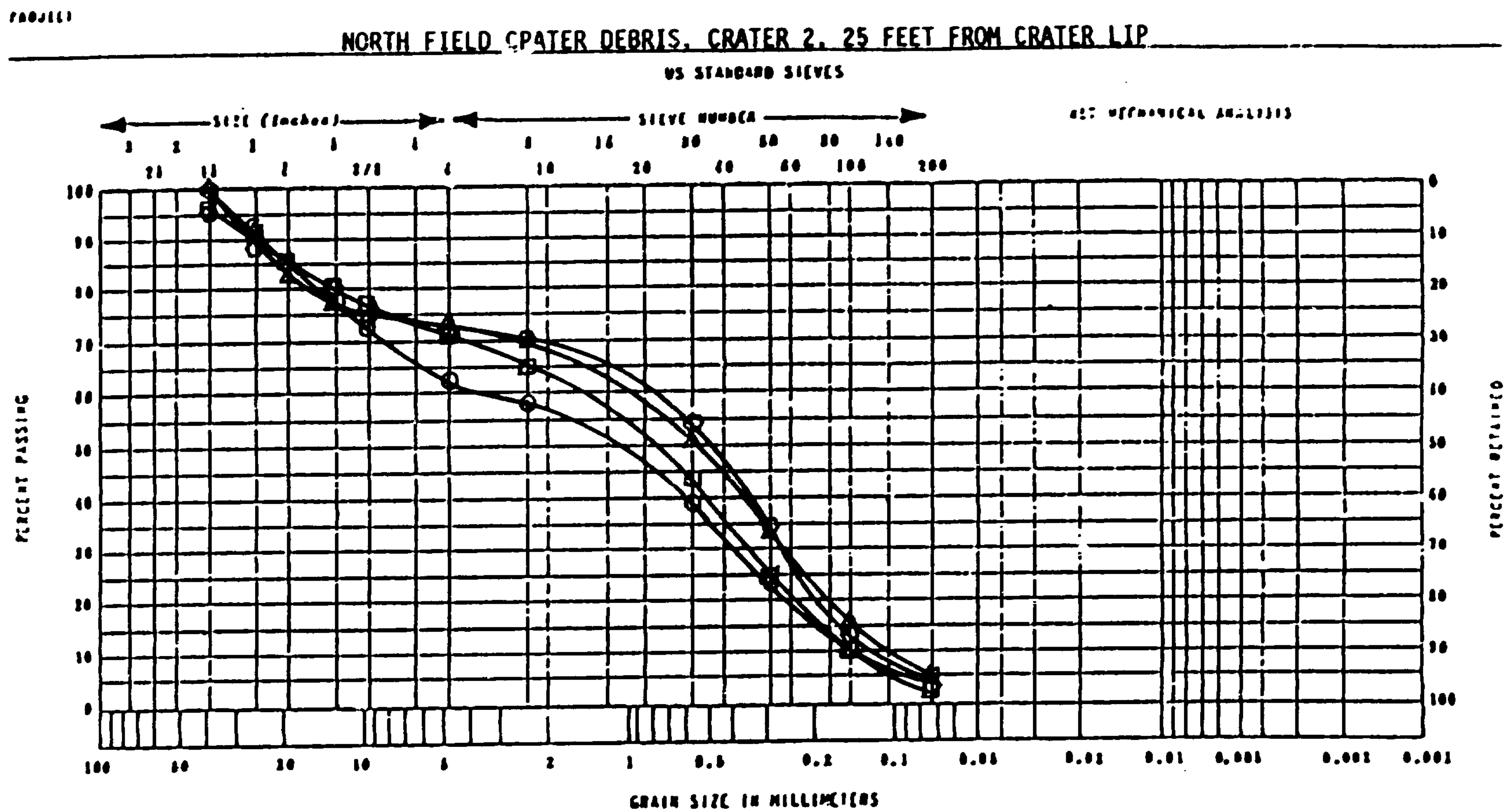
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northwest	2,800	2,800
□ Southeast	3,888	4,200
△ Southwest	2,495	3,300
⬡ Northeast	6,588	6,588

Figure C-26. Debris Density, Crater 2, 15 Feet, Northwest, Southeast, Southwest, and Northeast Radials



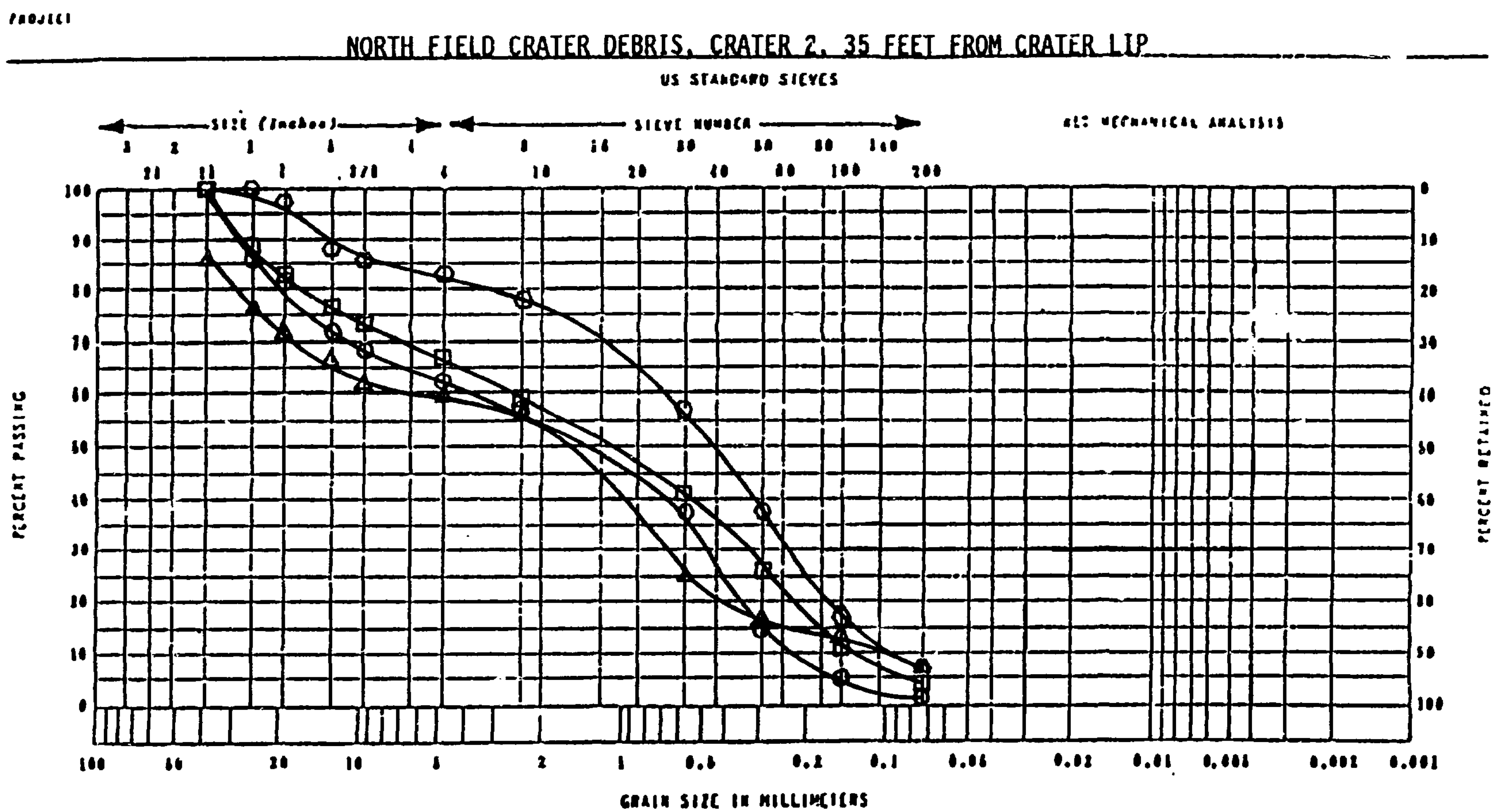
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ North	5,398	5,398
□ East	3,178	5,413
△ West	2,613	3,060
⬡ South	936	936

Figure C-27. Debris Density, Crater 2, 25 Feet, North, East, West, and South Radials



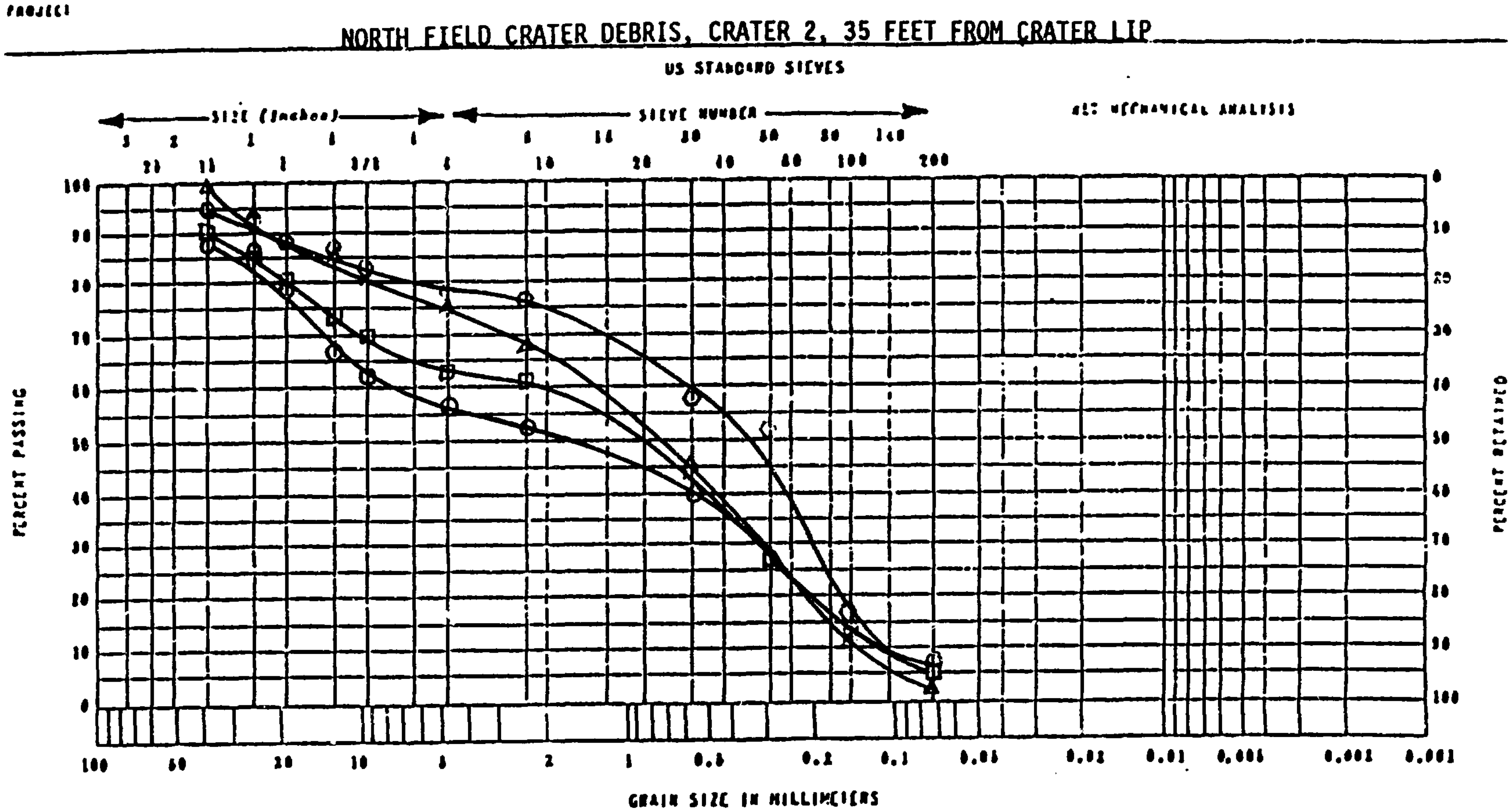
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northwest	657	657
□ Southeast	2,395	2,395
△ Southwest	472	472
⬡ Northeast	8,065	9,590

Figure C-28. Debris Density, Crater 2, 25 Feet, Northwest, Southeast, Southwest, and Northeast Radials



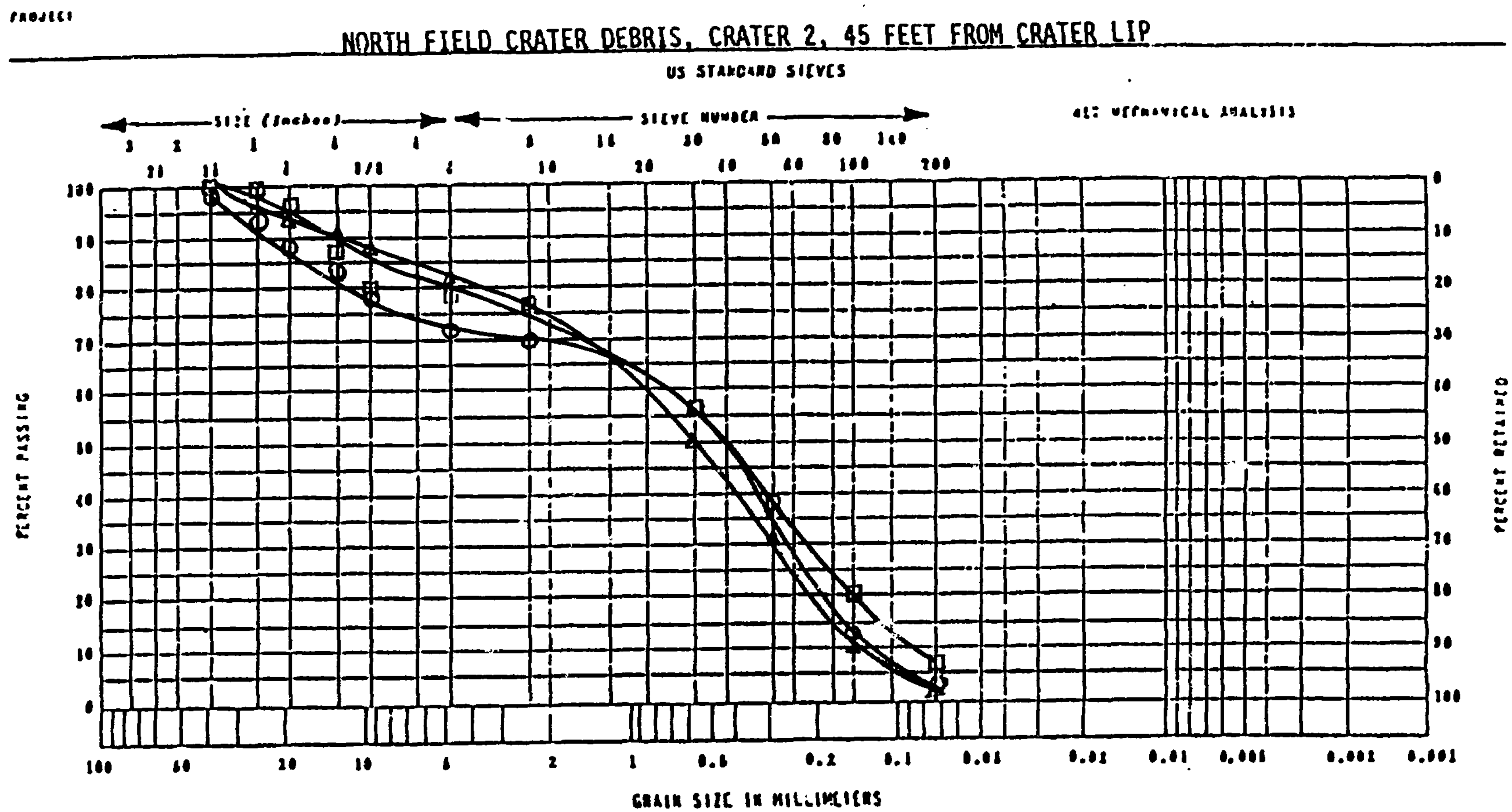
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ East	1,464	1,908
□ West	417	417
△ Southwest	1,015	1,181
⬡ South	875	875

Figure C-29. Debris Density, Crater 2, 35 Feet, East, West, Southwest, and South Radials



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northwest	468	468
□ Northeast	2,200	2,200
△ Southeast	2,418	2,545
⬡ North	2,328	2,328

Figure C-30. Debris Density, Crater 2, 35 Feet, Northwest, Northeast, Southeast, and North Radials

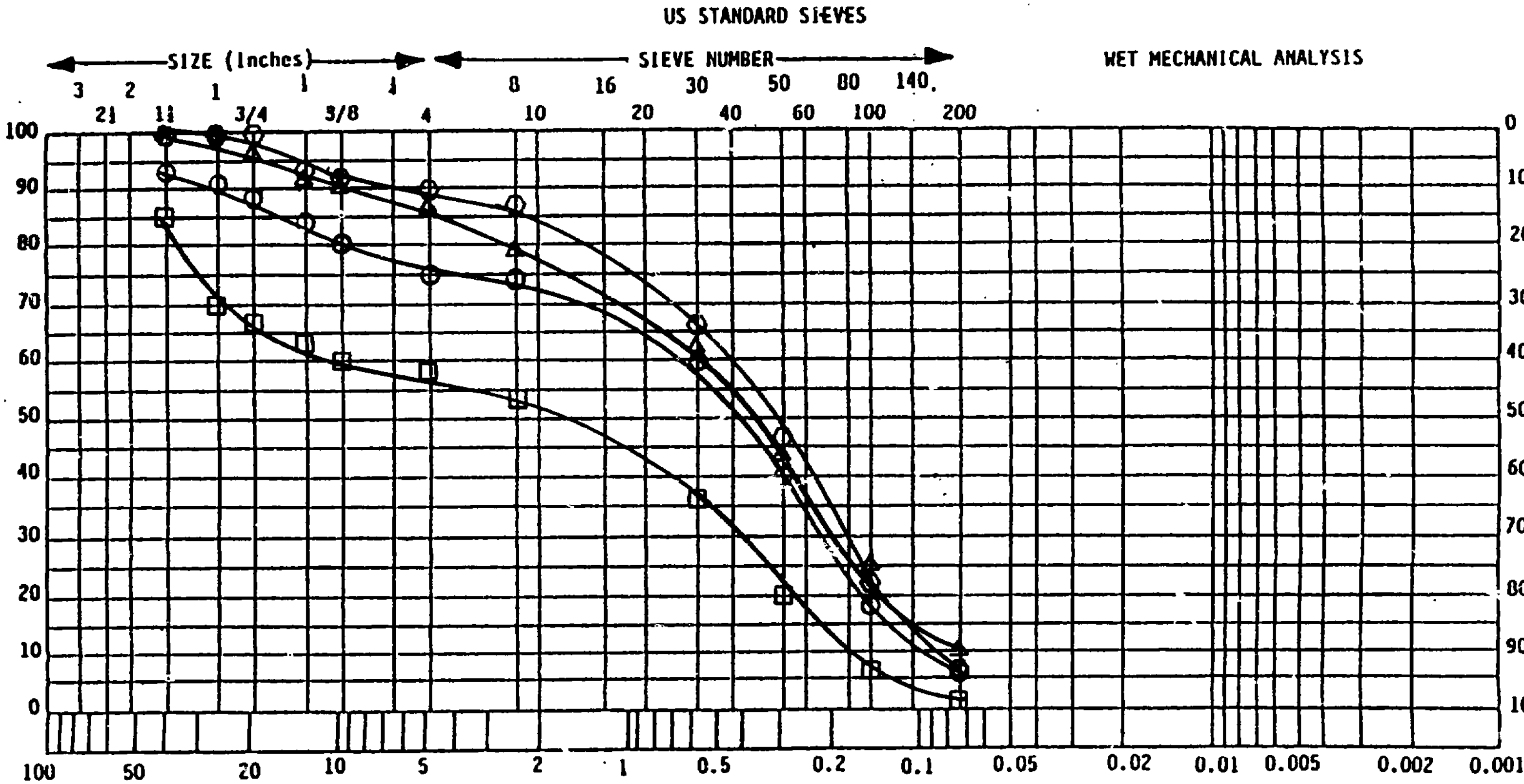


Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
□ Southwest	392	392
○ Northeast	2,037	2,822
△ Southeast	2,420	2,420

Figure C-31. Debris Density, Crater 2, 45 Feet, Southwest, Northeast, and Southeast Radials

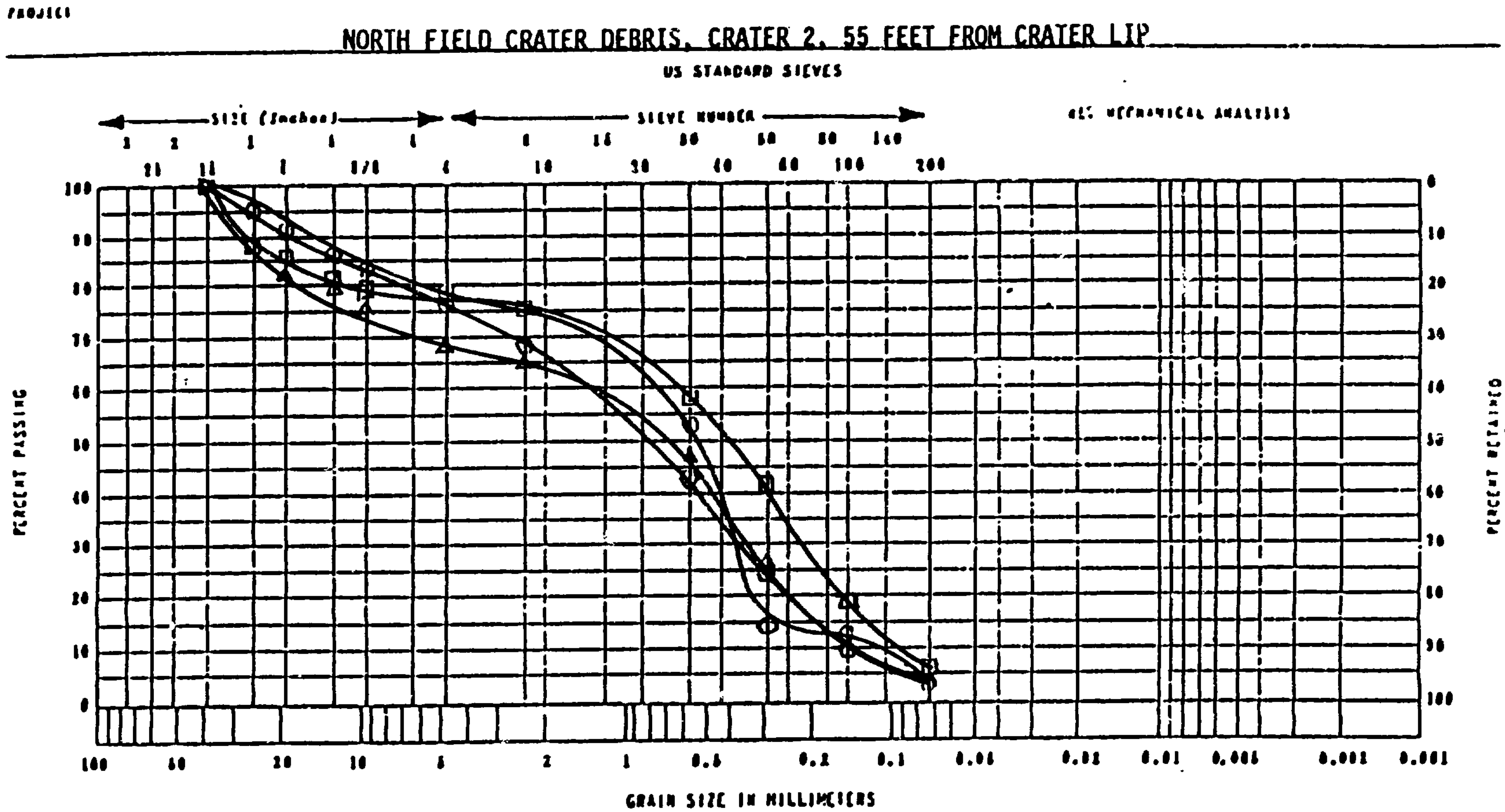
PROJECT

NORTH FIELD CRATER DEBRIS, CRATER 2, 45 FEET FROM CRATER LIP



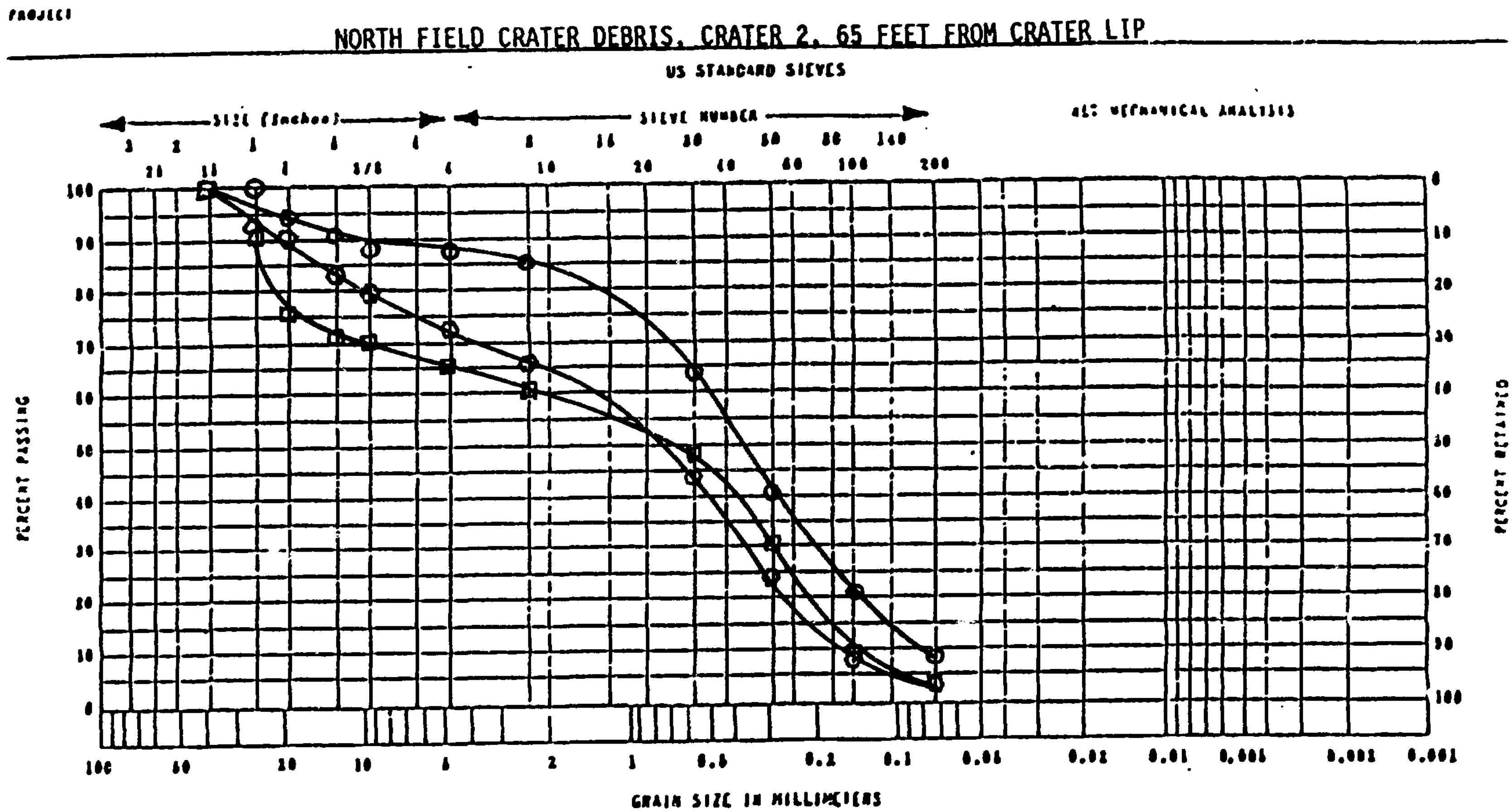
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
△ West	420.0	420.0
□ East	953.0	953.0
○ North	2,279.0	2,279.0
⬡ South	837.0	837.0

Figure C-32. Debris Density, Crater 2, 45 Feet, West, East, North, and South Radials



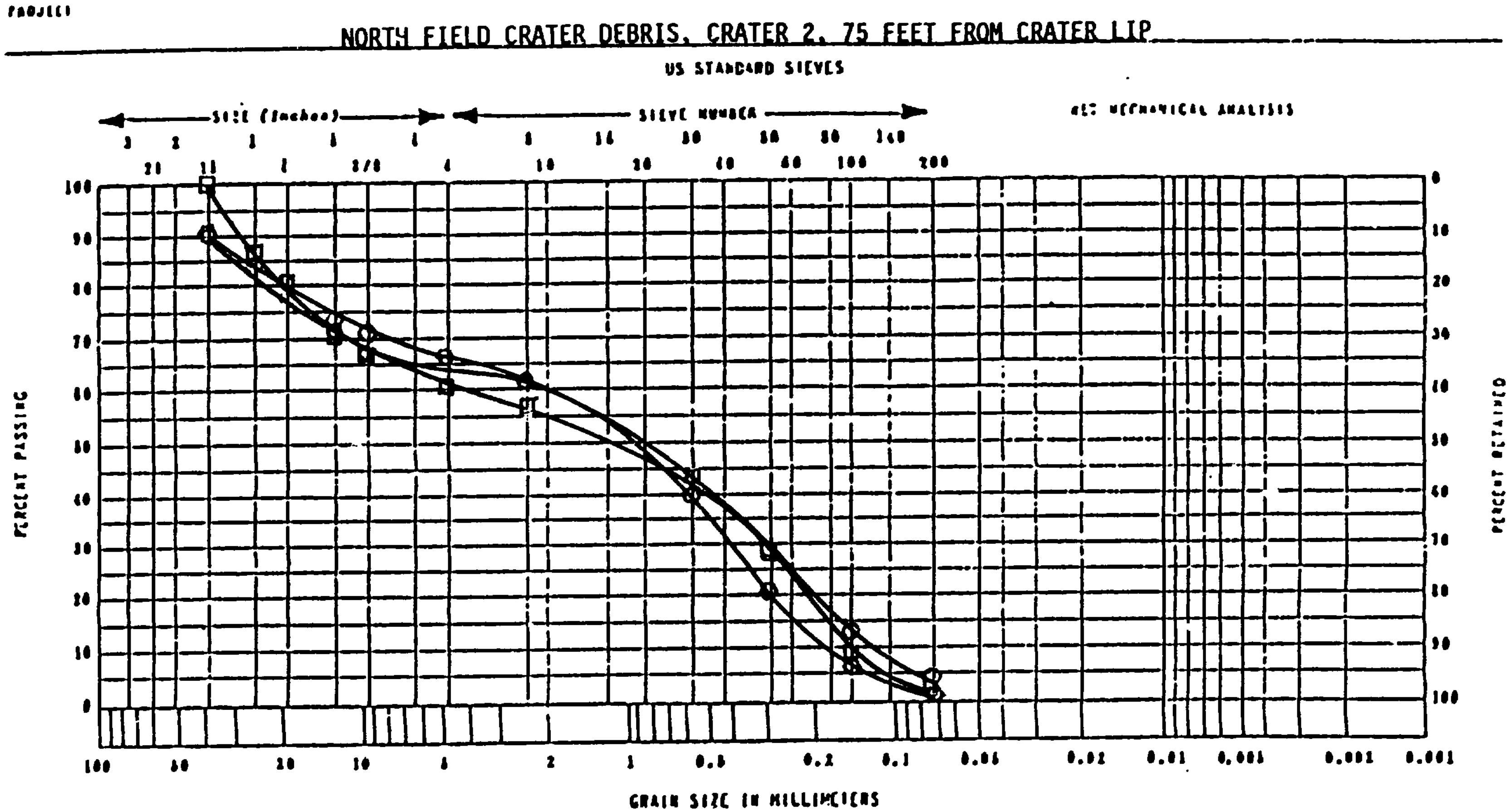
Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northeast	1,027	1,027
□ South	936	936
△ East	497	497
⬡ Southeast	2,225	2,225

Figure C-33. Debris Density, Crater 2, 55 Feet, Northeast, South, East, and Southeast Radials



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
○ Northeast	451.8	451.8
□ East	473	650
⬡ Southeast	1,080	1,080

Figure C-34. Debris Density, Crater 2, 65 Feet, Northeast, East, and Southeast Radials



Direction from Crater Lip	Sample Weight (gm)	Total Sample Weight (gm)
□ East	307	307
○ Northeast	591	916
⬡ Southeast	795	795

Figure C-35. Debris Density, Crater 2, 75 Feet, East, Northeast, and Southeast Radials

APPENDIX D

AIRCRAFT OPERATIONS

The following tables chronicle the aircraft operations conducted during the North Field 87 RRR Test. Each aircraft event (DT&E-oriented and OT&E-oriented) was assigned an event number. Low approaches are distinguished from operations where the aircraft came in contact with the repair. Each aircraft contact with the repair is assigned a pass number, in addition to an event number.

For taxi passes, speeds are indicated in the comment column. For many passes, the pilot reported the actual taxi speed. Where speeds were not reported, an approximate range was recorded.

Four MOS configurations are noted. Edge configuration signifies a MOS defined by edge markers and distance-to-go (DTG) markers only. The centerline configuration denotes a MOS defined by centerline and threshold triangles (painted in accordance with the MOS marking procedures) and DTG markers. The edge and center configuration signifies a MOS defined by a painted centerline and threshold triangles, edge markers, and DTG markers. A fourth MOS configuration was a field modification to the centerline configuration. The wide centerline consisted of a 3-foot wide solid centerline with solid 3-foot wide threshold lines.

TABLE D-1. AIRCRAFT EVENTS, 31 AUGUST 1987

EVENT NUMBER	EVENT DESCRIPTION	TIME	AIRCRAFT TYPE	MOS CONFIGURATION	AIRCRAFT PASS NUMBER		COMMENTS
					MAT 1	MAT 2	
1	Low Approach	1053	F-15	Edge			
2	Low Approach	1053	F-16	Edge			
3	Low Approach	1056	F-15	Edge			
4	Low Approach	1058	F-16	Edge			
5	Low Approach	1100	F-15	Edge			
6	Low Approach	1101	F-16	Edge			
7	Low Approach	1104	F-15	Edge			
8	Low Approach	1106	F-16	Edge			
9	Low Approach	1108	F-15	Edge			
10	Low Approach	1109	F-16	Edge			
11	Low Approach	1112	F-15	Edge			
12	Low Approach	1113	F-16	Edge			
13	Low Approach	1114	F-15	Edge			
14	Low Approach	1115	F-16	Edge			
15	Low Approach	1116	F-15	Edge			
16	Low Approach	1116	F-16	Edge			
17	Low Approach	1118	F-15	Edge			
18	Low Approach	1118	F-16	Edge			
19	Low Approach	1119	F-15	Edge			
20	Low Approach	1120	F-16	Edge			
21	Low Approach	1121	F-15	Edge			
22	Low Approach	1122	F-16	Edge			
23	Low Approach	1123	F-15	Edge			
24	Low Approach	1124	F-16	Edge			
25	Low Approach	1125	F-15	Edge			
26	Low Approach	1126	F-16	Edge			
27	Taxi Pass	1132	F-15	Edge	1	1	Low Speed, <20 knots
28	Taxi Pass	1133	F-16	Edge	2	2	Low Speed, <20 knots
29	Taxi Pass	1311	F-15	Edge	3	3	Low Speed, <20 knots
30	Taxi Pass	1324	F-15	Edge	4	4	Low Speed, <20 knots
31	Taxi Pass	1338	F-15	Edge	5	5	~40 knots
32	Taxi Pass	1343	F-15	Edge	6	6	~40 knots

TABLE D-1. AIRCRAFT EVENTS, 31 AUGUST 1987 (CONCLUDED)

EVENT NUMBER	EVENT DESCRIPTION	TIME	AIRCRAFT TYPE	MOS CONFIGURATION	AIRCRAFT PASS NUMBER MAT 1	MAT 2	COMMENTS
33	Taxi Pass	1345	F-15	Edge	7	7	~60 knots
34	Taxi Pass	1349	F-15	Edge	8	8	~40 knots
35	Taxi Pass	1355	F-16	Edge	9	9	~40 Knots
36	Low Approach	1403	F-16	Centerline			
37	Low Approach	1407	F-16	Centerline			
38	Low Approach	1310	F-16	Centerline			
39	Touch and Go	1414	F-16	Centerline	10	10	
40	Touch and Go	1418	F-16	Centerline	11	11	
41	Touch and Go	1420	F-16	Centerline	12	12	
42	Low Approach	1423	F-16	Centerline			
43	Touch and Go	1426	F-16	Centerline	13	13	
44	Low Approach	1429	F-16	Centerline			
45	Low Approach	1442	F-16	Centerline			
46	Low Approach	1444	F-16	Centerline			
47	Taxi Pass	1500	F-16	Centerline	14	14	~25 knots

TABLE D-2. AIRCRAFT EVENTS, 1 SEPTEMBER 1987

EVENT NUMBER	EVENT DESCRIPTION	TIME	AIRCRAFT TYPE	MOS CONFIGURATION	AIRCRAFT PASS NUMBER MAT 1	AIRCRAFT PASS NUMBER MAT 2	COMMENTS
48	Taxi Pass	1042	F-15	Centerline	15	15	48 knots
49	Taxi Pass	1044	F-16	Centerline	16	16	55 knots
50	Taxi Pass	1046	F-15	Centerline	17	17	18 knots
51	Taxi Pass	1047	F-16	Centerline	18	18	19 knots
52	Taxi Pass	1048	F-15	Centerline	19	19	41 knots, lt braking on Mat 1
53	Taxi Pass	1050	F-16	Centerline	20	20	44 knots, lt braking on Mat 1
54	Taxi Pass	1054	F-15	Centerline	21	21	19 knots
55	Taxi Pass	1056	F-16	Centerline	22	22	18 knots
56	Taxi Pass	1058	F-15	Centerline	23	23	44 knots, lt braking on Mat 1
57	Taxi Pass	1100	F-16	Centerline	24	24	43 knots, lt braking on Mat 1
58	Taxi Pass	1105	F-15	Centerline	25	25	20 knots
59	Taxi Pass	1106	F-16	Centerline	26	26	20 knots
60	Taxi Pass	1107	F-15	Centerline	27	27	41 knots, lt braking on Mat 2
61	Taxi Pass	1108	F-16	Centerline	28	28	46 knots, lt braking on Mat 2
62	Taxi Pass	1111	F-15	Centerline	29	29	20 knots
63	Taxi Pass	1113	F-16	Centerline	30	30	20 knots
64	Taxi Pass	1114	F-15	Centerline	31	31	62 knots
65	Taxi Pass	1115	F-16	Centerline	32	32	63 knots
66	Taxi Pass	1119	F-15	Centerline	33	33	20 knots
67	Taxi Pass	1120	F-16	Centerline	34	34	19 knots
68	Taxi Pass	1122	F-15	Centerline	35	35	41 knots
69	Taxi Pass	1123	F-16	Centerline	36	36	45 knots
70	Taxi Pass	1124	F-15	Centerline	37	37	20 knots
71	Taxi Pass	1124	F-16	Centerline	38	38	21 knots
72	Takeoff	1419	F-15	Centerline	39	39	Afterburner on both mats; rotation just past Mat 2
73	Takeoff	1421	F-16	Centerline	40	40	Afterburner on both mats; no rotation over either mat.

TABLE D-3 AIRCRAFT EVENTS, 2 SEPTEMBER 1987

EVENT NUMBER	EVENT DESCRIPTION	TIME	AIRCRAFT TYPE	MOS CONFIGURATION	AIRCRAFT PASS NUMBER MAT 1	MAT 2	COMMENTS
74	Low Approach	0945	F-15	Centerline			No visual acquisition distance reported; not included in total number of approaches.
75	Low Approach	0946	F-16	Centerline			No visual acquisition distance reported; not included in total number of approaches.
76	Low Approach	0947	F-15	Centerline			No visual acquisition distance reported; not included in total number of approaches.
77	Low Approach	0948	F-16	Centerline			No visual acquisition distance reported; not included in total number of approaches.
78	Low Approach	0951	F-15	Centerline			
79	Low Approach	0953	F-16	Centerline			
80	Low Approach	0954	F-15	Centerline			
81	Low Approach	0956	F-16	Centerline			
82	Touch and Go	0957	F-15	Centerline	41		Main gear only
83	Touch and Go	0958	F-16	Centerline		41	
84	Touch and Go	1000	F-15	Centerline	42	42	
85	Low Approach	1001	F-16	Centerline			
86	Touch and Go	1003	F-15	Centerline	43		
87	Touch and Go	1004	F-16	Centerline	44	43	
88	Touch and Go	1006	F-15	Centerline	45	44	
89	Touch and Go	1007	F-16	Centerline	46	45	
90	Touch and Go	1009	F-15	Centerline	47	46	
91	Touch and Go	1010	F-16	Centerline	48		
92	Touch and Go	1011	F-15	Centerline	49	47	
93	Touch and Go	1012	F-16	Centerline	50	48	
94	Touch and Go	1016	F-16	Centerline	51	49	
95	Touch and Go	1017	F-15	Centerline	52	50	

TABLE D-3. AIRCRAFT EVENTS, 2 SEPTEMBER 1987 (CONTINUED)

EVENT NUMBER	EVENT DESCRIPTION	TIME	AIRCRAFT TYPE	MOS CONFIGURATION	AIRCRAFT PASS NUMBER MAT 1	AIRCRAFT PASS NUMBER MAT 2	COMMENTS
96	Touch and Go	1019	F-16	Centerline	53	51	
97	Touch and Go	1020	F-15	Centerline	54	52	
98	Touch and Go	1021	F-16	Centerline		53	Afterburner on Mat 2
99	Touch and Go	1022	F-15	Centerline	55	54	Afterburner on Mat 2
100	Low Approach	1023	F-16	Centerline			
101	Touch and Go	1023	F-15	Centerline	56	55	Afterburner on Mat 2
102	Touch and Go	1025	F-16	Centerline		56	
103	Touch and Go	1026	F-15	Centerline	57		Afterburner on Mat 1
104	Touch and Go	1027	F-15	Centerline	58		Afterburner on Mat 1
105	Touch and Go	1029	F-15	Centerline	59		Afterburner on both mats
106	Taxi Pass	1032	F-16	Centerline	60	57	10 to 20 knots
107	Taxi Pass	1035	F-15	Centerline	61	58	10 to 20 knots
108	Takeoff	1118	F-16	Centerline	62	59	
109	Low Approach	1122	F-16	Centerline			
110	Takeoff	1123	F-15	Centerline	63	60	
111	Low Approach	1126	F-16	Centerline			
112	Low Approach	1127	F-15	Centerline			
113	Low Approach	1129	F-16	Centerline			
114	Low Approach	1129	F-15	Centerline			
115	Low Approach	1131	F-16	Centerline			
116	Low Approach	1132	F-15	Centerline			
117	Touch and Go	1134	F-16	Centerline	64	61	
118	Touch and Go	1135	F-15	Centerline		62	
119	Touch and Go	1137	F-16	Centerline	65	63	
120	Touch and Go	1138	F-15	Centerline	66	64	Touchdown on Mat 1
121	Touch and Go	1139	F-16	Centerline	67	65	
122	Touch and Go	1140	F-15	Centerline	68	66	
123	Touch and Go	1141	F-16	Centerline	69	67	
124	Touch and Go	1142	F-15	Centerline	70	68	
125	Touch and Go	1143	F-16	Centerline	71	69	Tear observed on Mat 2
126	Low Approach	1144	F-15	Centerline			
127	Low Approach	1218	F-16	Edge and Center			
128	Low Approach	1222	F-16	Edge and Center			
129	Low Approach	1222	F-15	Edge and Center			

TABLE D-3. AIRCRAFT EVENTS, 2 SEPTEMBER 1987 (CONCLUDED)

EVENT NUMBER	EVENT DESCRIPTION	TIME	AIRCRAFT TYPE	MOS CONFIGURATION	AIRCRAFT PASS NUMBER		COMMENTS
					MAT 1	MAT 2	
130	Low Approach	1224	F-16	Edge and Center			
131	Low Approach	1225	F-15	Edge and Center			
132	Low Approach	1227	F-16	Edge and Center			
133	Low Approach	1228	F-15	Edge and Center			
134	Low Approach	1229	F-16	Edge and Center			
135	Taxi Pass	1352	F-15	Edge and Center	72	70	10 to 20 knots
136	Taxi Pass	1353	F-16	Edge and Center	73	71	10 to 20 knots
137	Low Approach	1406	F-15	Edge and Center			
138	Low Approach	1406	F-16	Edge and Center			
139	Low approach	1408	F-15	Edge and Center			
140	Low Approach	1409	F-16	Edge and Center			
141	Low Approach	1411	F-15	Edge and Center			
142	Low Approach	1412	F-16	Edge and Center			
143	Low Approach	1414	F-15	Edge and Center			
144	Low Approach	1415	F-16	Edge and Center			
145	Low Approach	1415	F-15	Edge and Center			
146	Low Approach	1416	F-16	Edge and Center			
147	Low Approach	1417	F-15	Edge and Center			
148	Low Approach	1418	F-16	Edge and Center			
149	Low Approach	1419	F-15	Edge and Center			
150	Low Approach	1420	F-16	Edge and Center			

TABLE D-4. AIRCRAFT EVENTS, 3 SEPTEMBER 1987

EVENT NUMBER	EVENT DESCRIPTION	TIME	AIRCRAFT TYPE	MOS CONFIGURATION	AIRCRAFT PASS NUMBER MAT 1	AIRCRAFT PASS NUMBER MAT 2	COMMENTS
151	Low Approach	1144	F-15	Wide Centerline			
152	Low Approach	1147	F-15	Wide Centerline			
153	Touch and Go	1151	F-15	Wide Centerline	74	72	Touchdown on Mat 1
154	Touch and Go	1153	F-15	Wide Centerline	75	73	
155	Touch and Go	1200	F-15	Wide Centerline	76	74	
156	Touch and Go	1201	F-15	Wide Centerline	77	75	
157	Touch and Go	1203	F-15	Wide Centerline		76	
158	Low Approach	1204	F-16	Wide Centerline			
159	Touch and Go	1205	F-15	Wide Centerline	78	77	Afterburner on Mat 2
150	Low Approach	1209	F-16	Wide Centerline			
161	Touch and Go	1210	F-15	Wide Centerline	79	78	
162	Low Approach	1211	F-16	Wide Centerline			
163	Touch and Go	1212	F-15	Wide Centrerline	80	79	
164	Touch and Go	1214	F-15	Wide Centerline	81	80	
165	Touch and Go	1216	[illegible]	Wide Centerline	82	81	
166	Low Approach	1216	F-16	Wide Centerline			
167	Touch and Go	1217	F-15	Wide Centerline	83	82	
168	Touch and Go	1218	F-16	Wide Centerline	84	83	
169	Touch and Go	1219	F-15	Wide Centerline	85	84	
170	Touch and Go	1221	F-16	Wide Centerline	86	85	
171	Touch and Go	1221	F-15	Wide Centerline	87	86	
172	Touch and Go	1223	F-16	Wide Centerline	88	87	
173	Touch and Go	1224	F-15	Wide Centerline	89	88	
174	Touch and Go	1225	F-16	Wide Centerline	90	89	
175	Touch and Go	1226	F-15	Wide Centreline	91	90	
176	Touch and Go	1228	F-16	Wide Centerline	92	91	
177	Touch and Go	1229	F-15	Wide Centerline	93	92	
178	Low Approach	1230	F-16	Wide Centerline			
179	Touch and Go	1231	F-15	Wide Centerline	94	93	
180	Touch and Go	1232	F-16	Wide Centerline		94	
181	Touch and Go	1232	F-15	Wide Centerline	95	95	
182	Touch and Go	1234	F-15	Wide Centreline	96	96	
183	Touch and Go	1236	F-16	Wide Centerline		97	
184	Touch and Go	1237	F-15	Wide Centerline	97	98	
185	Touch and Go	1240	F-16	Wide Centerline		99	
186	Touch and Go	1243	F-16	Wide Centerline	98	100	

TABLE D-4. AIRCRAFT EVENTS, 3 SEPTEMBER 1987 (CONCLUDED)

EVENT NUMBER	EVENT DESCRIPTION	TIME	AIRCRAFT TYPE	MOS CONFIGURATION	AIRCRAFT PASS NUMBER MAT 1	MAT 2	COMMENTS
187	Taxi Pass	1249	F-15	Wide Centerline	99	101	10-20 knots, braking on Repair 1
188	Taxi Pass	1250	F-15	Wide Centerline	100	102	45 knots, Braking on Repair 2
189	Taxi Pass	1251	F-15	Wide Centerline	101	103	10-20 knots
190	Taxi Pass	1254	F-16	Wide Centerline	102	104	10-20 knots
191	Taxi Pass	1332	F-15	Wide Centerline	103	105	10-20 knots
192	Taxi Pass	1335	F-16	Wide Centerline	104	106	10-20 knots
193	Low Approach	1339	F-15	Wide Centerline			
194	Low Approach	1342	F-16	Wide Centerline			
195	Low Approach	1343	F-15	Wide Centerline			
196	Low Approach	1345	F-16	Wide Centerline			
197	Low Approach	1346	F-15	Wide Centerline			
198	Low Approach	1348	F-16	Wide Centerline			
199	Low Approach	1350	F-15	Wide Centerline			
200	Low Approach	1352	F-16	Wide Centerline			
201	Low Approach	1352	F-15	Wide Centerline			
202	Low Approach	1353	F-16	Wide Centerline			
203	Low Approach	1354	F-15	Wide Centerline			
204	Low Approach	1355	F-16	Wide Centerline			
205	Low Approach	1356	F-15	Wide Centerline			
206	Low Approach	1356	F-16	Wide Centerline			
207	Low Approach	1357	F-15	Wide Centerline			
208	Low Approach	1358	F-16	Wide Centerline			
209	Low Approach	1359	F-15	Wide Centerline			
210	Low Approach	1400	F-16	Wide Centerline			
211	Low Approach	1401	F-15	Wide Centerline			
212	Low Approach	1401	F-16	Wide Centerline			
213	Taxi Pass	1418	F-15	Wide Centerline	105	107	10-20 knots
214	Taxi Pass	1424	F-15	Wide Centerline	106	108	10-20 knots
215	Taxi Pass	1542	F-16	Wide Centerline	107	109	10-20 knots
216	Jet Blast	1542	F-15	-	108		Taxi over Repair 1, 80 percent engine runup for approx. 10 seconds
217	Jet Blast	1544	F-15	-		110	Taxi over Repair 2, 80 percent engine runup for approx. 30 seconds

APPENDIX E

FRICTION CHARACTERISTICS EVALUATION OF THE NORTH FIELD RRR TEST SITE

This appendix contains the results of a frictional characteristics evaluation of the North Field RRR test site conducted by AFESC/DEM on October 29, 1987. The purpose of the evaluation was to determine the skid resistance of the runway.

The material contained in this appendix is reproduced exactly as submitted. Therefore, some variations in format, i.e. marking of illustrative material, can be expected.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AIR FORCE BASE, FL 32403-6001

30 NOV 1987

REPLY TO ATTN OF: DEM

SUBJECT: Friction Characteristics Evaluation of North Field RRR Test Site

TO: DEY

1. On 29 Oct 87 our Pavement Surface Effects Team (PSET) conducted a partial friction characteristics evaluation of the Rapid Runway Repair (RRR) test site at North Auxiliary Airfield, South Carolina. The evaluation was performed, at the request of Mr. Perry Dukes, to determine the effect of the fiberglass matting on the runway's skid resistance.

2. The evaluation was conducted with a Mark IV Mu-Meter, a three-wheeled trailer unit which measures the side-force coefficient of friction between the measuring wheels and the pavement surface. The tow vehicle distributes 1mm of water ahead of each measuring wheel to simulate a wet runway condition. Measurements were conducted at standard testing speeds of 40 and 60 mph, starting approximately 1000 feet east of the first mat and continuing to 1000 feet west of the second (see attachment 1).

3. The charts in attachment 2 show the continuous printout of the coefficient of friction along the pavement surface for the entire test section. From these charts, it is evident that the asphalt surface within the testing area exhibits GOOD frictional properties, while the fiberglass matting exhibits POOR qualities at both test speeds. These low readings at both speeds are indicative of a surface with poor microtexture (see attachment 3). While texture measurements on both the pavement and the matting show them both to have good macrotexture, the marked difference in microtexture can be easily detected simply by touching each surface. The lack of sandpaper-like grit on the fiberglass mats inhibits intimate contact with the tire, causing poor wet skid resistance at any speed.

4. The coefficient of friction was also measured on a portion of the mats which had been painted (results not included) to evaluate any differences. The coefficient of friction on the painted area showed no change from the unpainted surface. Painting with a textured paint or some type of antiskid application could provide the necessary microtexture to improve the wet skid resistance of the mats.

5. The fiberglass mats, as they are configured now on the test area, pose no hazard to the runway's overall skid resistance. Even though the mats themselves exhibit poor frictional properties when wet, their size and present spacing would create an insignificant effect on a landing aircraft. Problems could arise, however, when a number of these are

arranged consecutively in the wheel paths, creating a large area with reduced wet friction properties. In the touchdown area, this could delay wheel spin-up and lengthen the landing roll. In the primary braking area, this could create an area where brakes are ineffective and, again, lengthen the landing roll.

6. The PSET is available for any further testing efforts whenvever they are not on the road. Please feel free to contact Major Rod Reay, ext 36336, for further assistance or for any questions on this report.

Ed E Wilson

ED E. WILSON,
Deputy Director, Operations
and Maintenance

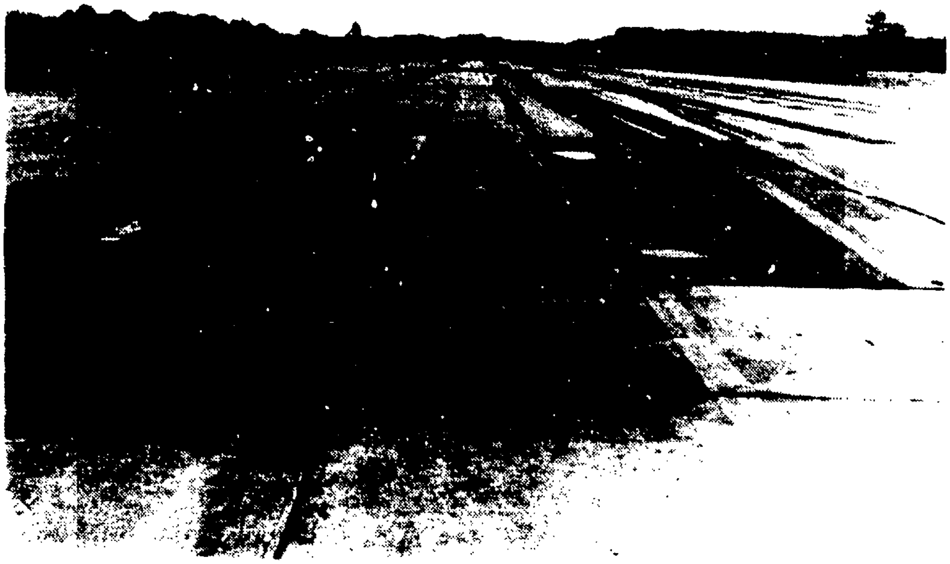
3 Atch
1. Test Surfaces
2. Coefficient of Friction Traces
3. Pavement Texture Segments

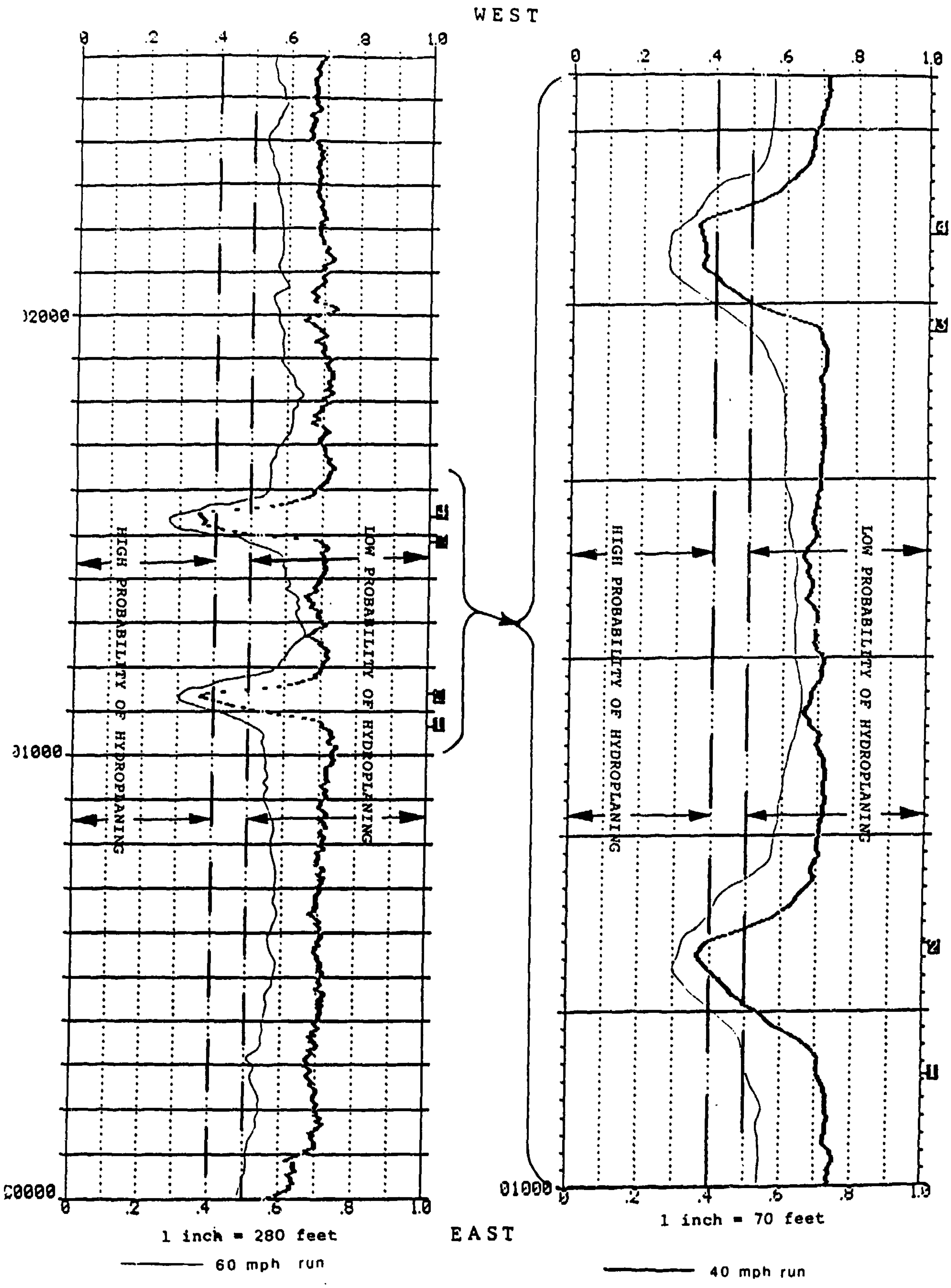
cc: HQ MAC/DEMM

TEST SURFACES

EAST

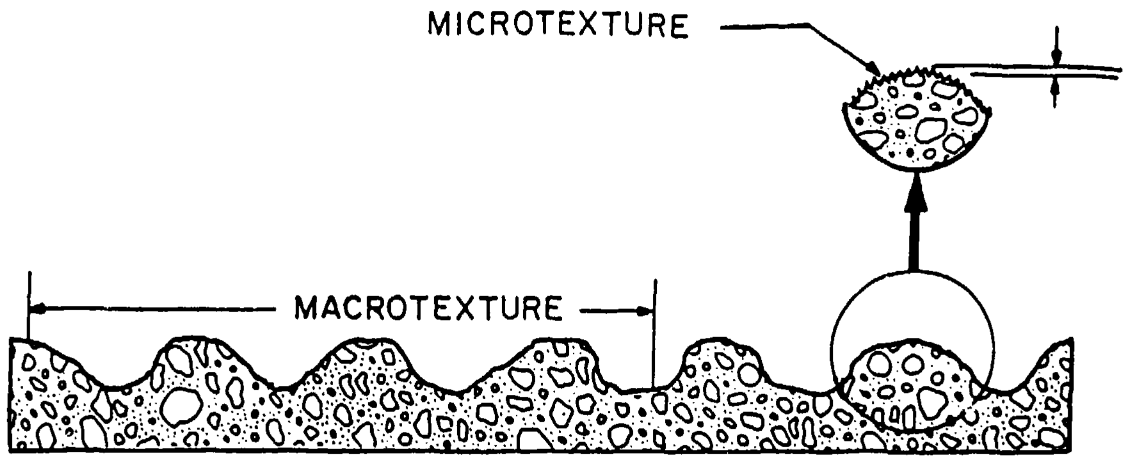
WEST





WEST
0
.2
.4
.6
.8
1.0
02000
01000
00000
HIGH PROBABILITY OF HYDROPLANING
LOW PROBABILITY OF HYDROPLANING
1 inch = 280 feet
60 mph run
01000
1 inch = 70 feet
40 mph run
EAST

PAVEMENT TEXTURE SEGMENTS



MACROTEXTURE – THE INDIVIDUAL ASPERITIES, OR AGGREGATE, IN A PAVEMENT SURFACE. PROVIDES ESCAPE CHANNELS TO DISPLACE THE BULK WATER BETWEEN THE TIRE AND PAVEMENT, AND THUS REDUCES THE POTENTIAL FOR DYNAMIC HYDROPLANING.

MICROTEXTURE – THE SHARP, FINE PARTICLES (OR GRIT) ON THE LARGER ASPERITIES. PENETRATES THE THIN RESIDUAL FILM OF WATER, PERMITTING INTIMATE CONTACT BETWEEN THE TIRE AND PAVEMENT, AND REDUCES THE POTENTIAL FOR VISCOUS HYDROPLANING.

SOURCE: REPORT* DOT/FAA/PM-85/33

APPENDIX F

WEATHER DATA

The following tables contain the hourly record of weather conditions recorded at North Field between August 26 and September 3, 1987. Weather observations were made and recorded by Capt. M. Davenport, AFESC/WE, Tyndall AFB, FL.

TABLE F-1. WEATHER DATA FOR 26 AUGUST 1987, 0745-1700

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
0745	30.22	obscured sky 1 1/4F	CLR	74	72	71	90	Calm	
0800	30.19	1 1/2F	CLR	75	73	72	90	Calm	
0900	30.18	2 1/2F	010 OVC	79	75	73	82	L/V	
1000	30.16	3 FH	010 SCT	85	77	74	70	250/03	
1100	30.21	5 H	CLR	93	79	74	54	300/04	
1200	30.17	5 H	CLR	96	81	76	53	280/05	
1300	30.14	6 H	040 SCT	97	81	76	51	370/08	
1400	30.11	6 H	040 SCT	100	81	74	49	300/07	
1500	30.10	5 H	040 BKN 250 BKN	97	79	72	45	230/05	
1600	30.08	4 H BLSA	030 BKN 250 OVC	89	76	71	55	150/10 G15	RB 1605 E 1621 E.08"
1700	30.14	5 H	0300 SCT 100SCT 250 OVC	85	77	74	69	L/V	
Summary			CLR 3 HRS BKN 1 HR SCT 3 HRS OVC 3 HRS						
Maximum				100	81		90	150/10 G15	.08" rain (est)
Minimum				74	72		45		

Key:

CLR - Clear	H - Haze	G - Gusts
OVC - Overcast	F - Fog	L/V - Light and Variable
SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
BKN - Broken	RW - Rain Shower	

TABLE F-2. WEATHER DATA FOR 27 AUGUST 1987, 0730-2200

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
0730	30.24	1 1/2F	CLR	72	70	69	90	Calm	
0800	30.23	1 1/2F	CLR	77	74	73	86	Calm	
0900	30.15	3 FH	CLR	83	76	73	71	240/02	
1000	30.14	5 FH	CLR	86	78	75	70	250/05 G10	
1100	30.11	6 H	CLR	88	79	76	68	270/07	
1200	30.13	6 H	CLR	94	80	75	54	270/05	
1300	30.09	5 H	035 SCT	96	82	77	54	280/06	
1400	30.06	5 H	035 SCT	97	81	75	49	300/05	
1500	30.05	4 H	035 SCT	100	80	72	41	L/V	
1600	30.02	4 H	035 SCT 250 SCT	99	72	70	39	L/V	Rain Shower in West

Key:

CLR - Clear	H - Haze	G - Gusts
OVC - Overcast	F - Fog	L/V - Light and Variable
SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
BKN - Broken	RW - Rain Shower	

TABLE F-2. WEATHER DATA FOR 27 AUGUST 1987, 0730-2200 (CONCLUDED)

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
1700	30.01	4 H	035 SCT	97	77	69	40	320/05	
1800	30.00	4 H	035 SCT	97	77	69	40	300/05	
1900	30.01	4 H	035 SCT 100 SCT	93	74	65	39	180/03	
2000	30.04	4 H	035 SCT 250 BKN	89	73	66	46	180/02	
2100	30.00	---	SCT	86	72	66	51	180/01	
2200	30.10	---	SCT	83	72	68	60	CALM	
Summary			CLR-6 BKN-1 SCT-7 OVC-0						
Maximum				100			90	250/05 G10	
Minimum				72			39		

Key:

CLR - Clear	H - Haze	G - Gusts
OVC - Overcast	F - Fog	L/V - Light and Variable
SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
BKN - Broken	RW - Rain Shower	

TABLE F-3. WEATHER DATA FOR 28 AUGUST 1987, 0730-2200

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
0730	30.21	2 1/2F	CLR	76	73	72	88	200/02	
0800	30.14	2 1/2F	CLR	77	73	71	82	220/02	
0900	30.14	4 F	CLR	82	76	74	76	230/04	
1000	30.12	5 HF	250 SCT	88	77	73	61	290/05	
1100	30.11	5 H	SCT 250 BKN	90	78	73	57	290/05 G10	
1200	30.09	5 H	030 SCT 120 SCT 250 BKN	95	79	73	49	310/08	
1300	30.03	5 H	030 SCT 250 SCT	99	79	71	41	280/07 G12	

Key:

CLR - Clear	H - Haze	G - Gusts
OVC - Overcast	F - Fog	L/V - Light and Variable
SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
BKN - Broken	RW - Rain Shower	

TABLE F-3. WEATHER DATA FOR 28 AUGUST 1987, 0730-2200 (CONCLUDED)

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
1400	30.03	5 H	030 SCT	100	79	71	39	280/06 G10	
1500	30.00	5 H	030 BKN	96	79	73	46	310/07 G12	Rain Shower Moving East
1600	29.94	4 H	030 SCT	101	78	69	35	290/10	
1700	29.97	4 H	030 SCT	98	79	72	43	280/07	
1800	-------------MISSING--------------								
1900	29.99	4 H	030 SCT 250 BKN	87	76	72	61	L/V	
2000	30.06	---	030 SCT 250 BKN	85	75	71	63	L/V	
Summary			CLR-3 BKN-5 SCT-5 OVC-0						
Maximum				101	79		88	270/07 G12	
Minimum				76	73		35		

Key:

CLR - Clear	H - Haze	G - Gusts
OVC - Overcast	F - Fog	L/V - Light and Variable
SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
BKN - Broken	RW - Rain Shower	

TABLE F-4. WEATHER DATA FOR 29 AUGUST 1987, 1300-1800

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
1300	30.04	6 H	030 SCT	100	80	72	41	280/05	
1400	29.95	6 H	030 SCT	102	77	66	31	260/10	
1500	29.97	6 H	030 SCT	101	78	69	36	260/10	
1600	29.99	6 H	030 BKN	101	78	69	36	250/10	
1700	29.97	5 H	030 SCT/BKN	100	78	70	38	230/08	
1800	29.96	2 RW-	010 BKN 030 OVC	79	78	77	96•	VRB 10/15	
Summary			SCT/BKN-1 BKN-1 SCT-3 OVC-1						
Maximum				102	80		96		
Minimum				79	78		31		

Key:

CLR - Clear	H - Haze	G - Gusts
OVC - Overcast	F - Fog	L/V - Light and Variable
SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
BKN - Broken	RW - Rain Shower	

TABLE F-5. WEATHER DATA FOR 31 AUGUST 1987, 0700-1700

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
0700	30.12	2 1/2F	120 SCT 250 SCT	71	70	69	93	CALM	
0800	30.08	3 F	120 SCT 250 SCT	74	72	71	90	070/02	
0900	29.98	4 HF	005 SCT/BKN 120 BKN 250 BKN	78	75	74	86	L/V	
1000	29.98	6 H	005 SCT 030 BKN 120 BKN 250 BKN	83	78	76	79	L/V	
1100	29.99	6 H	005 SCT 020 SCT 250 SCT	86	79	77	75	200/05	
1200	29.95	7	030 BKN 250 BKN	90	79	75	61	270/08	
1300	29.95	7	030 SCT 250 SCT	91	78	73	55	290/08	
1400	29.89	7	020 SCT 025 BKN 100 BKN 250 OVC	89	77	72	57	180/02	
1500	29.90	6 RW-	015 BKN 025 OVC	78	74	72	81	120/05 G15	
1510	-----	1 1/2 RW+	010 OVC	--	--	--	--	030/10 G15	
1600	29.97	6 RW-	010 BKN 020 OVC	74	72	71	90	070/07 G15	
1700	29.99	4 RW-	010 SCT 025 BKN 100 OVC	72	71	71	96	090/05 G10	
Maximum				91	79		96		
Minimum				71	70		55		

Rain showers fell 1502L 1700 (when I left)

Total Rainfall 1502-1700L = .28 inch

Key:			
	CLR - Clear	H - Haze	G - Gusts
	OVC - Overcast	F - Fog	L/V - Light and Variable
	SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
	BKN - Broken	RW - Rain Shower	

TABLE F-6. WEATHER DATA FOR 1 SEPTEMBER 1987, 0800-1400

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
0800	30.07	1 F	009 OVC	72	70	69	90	CALM	
0900	30.03	2 F	009 OVC	72	70	69	90	CALM	
1000	29.98	3 1/2 F	012 BKN 030 OVC	76	72	70	81	360/02	
1100	29.99	5 FH	012 BKN 030 OVC	76	71	69	79	040/02	
1200	29.99	5 H	015 BKN 030 OVC	77	73	71	81	030/02	
1300	29.98	5 H	015 SCT 030 BKN	79	74	72	81	040/04	
1400	29.98	4 H	015 SCT/BKN 035 OVC	80	75	73	80	070/03	
Maximum				80	75		90		
Minimum				72	70		79		

Key:			
	CLR - Clear	H - Haze	G - Gusts
	OVC - Overcast	F - Fog	L/V - Light and Variable
	SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
	BKN - Broken	RW - Rain Shower	

TABLE F-7. WEATHER DATA FOR 2 SEPTEMBER 1987, 0800-1500

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity (%)	Wind Direction & Speed (Degree/MPH)	Comments
0800	30.05	2 F	120 SCT 250 BKN	73	70	69	86	CALM	
0900	30.01	3 F	120 SCT 250 SCT	77	73	72	84	L/V	
1000	29.99	4 F	120 SCT 250 SCT	80	75	73	79	070/02	
1100	29.94	4 FH	009 SCT 040 SCT 120 BKN 250 BKN	82	75	72	71	060/03	
1200	29.94	4 H	020 SCT 120 BKN 250 BKN	86	76	72	63	130/04	
1300	29.93	4 H	020 SCT 120 BKN 250 BKN	85	75	71	62	110/03	
1400	29.91	4 H	020 SCT 120 BKN 250 BKN	83	74	70	65	100/03	
1500	29.89	3 H	020 SCT 120 BKN 250 OVC	83	75	72	70	170/05	
Maximum				86	76		86		
Minimum				73	70		62		

Key:

CLR - Clear	H - Haze	G - Gusts
OVC - Overcast	F - Fog	L/V - Light and Variable
SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
BKN - Broken	RW - Rain Shower	

FIGURE F-8. WEATHER DATA FOR 3 SEPTEMBER 1987, 0800-1500

Time	Barometric Pressure (in)	Visibility and Restriction	Sky Cover	Temp (°F)	Wet Bulb Temp °F	Dew Point °F	Relative Humidity -(%)	Wind Direction & Speed (Degree/MPH)	Comments
0800	30.01	1/4 F	002 OVC	71	70	70	96	020/05 G07	
0900	30.03	1 1/2 F	010 OVC	72	71	71	96	020/04	
1000	29.98	3 F	010 SCT 120 BKN 250 BKN	77	73	71	81	030/07 G10	
1100	29.97	5 F	012 SCT 250 BKN	82	76	74	76	010/06 G10	
1200	29.96	7	018 SCT/BKN 250 BKN	82	75	72	72	060/08	
1300	29.95	7	022 BKN 250 BKN	82	75	72	73	050/05	
1400	29.95	7	025 BKN 120 BKN 250 BKN	83	75	72	72	050/05 G10	
1500	29.89	6 H	025 SCT 120 BKN 250 OVC	84	75	71	69	060/06 G10	
Maximum				84	76		96		
Minimum				71	70		69		

Key:

CLR - Clear	H - Haze	G - Gusts
OVC - Overcast	F - Fog	L/V - Light and Variable
SCT - Scattered	BLSA - Blowing Sand	VRB - Variable
BKN - Broken	RW - Rain Shower	

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APPENDIX G

NORTH FIELD '87 TEST PLAN

This test plan is included for reference. Annexes F and L have been deleted entirely. Also, the data forms from Annex K have been removed.

Material contained in this appendix is reproduced exactly as submitted. Therfore, some variations in format, i.e., marking of illustrative material, can be expected.

North Field '87 Rapid Runway Repair (RRR) Test
North Auxillary Airfield SC

Test Plan
July 1987

PERRY E. DUKES
Test Director

Approved:

GUY A. MORGAN, Colonel, USAF
Director, RRR Program Office

Rapid Runway Repair Program Office
Air Force Engineering and Services Center
Tyndall Air Force Base Florida 32403-6001

LIST OF ACRONYMS

CBW	Chemical Biological Warfare
CCS	Combat Control Squadron
CESHR	Civil Engineering Squadron, Heavy Repair
DT&E	Development Test and Evaluation
FFGM	Folded Fiberglass Mat
FGM	Fiberglass Mat
FOD	Foreign Object Damage
FSO	Flight Safety Officer
HUD	Head Up Display
IOT&E	Initial Operational Test and Evaluation
MAAS	Mobile Aircraft Arresting System
MOS	Minimum Operating Strip
OI	Operational Instruction
PCC	Portland Cement Concrete
PCS	Precast Concrete Slab
R&M	Reliability and Maintainability
RRR	Rapid Runway Repair
SALTY DEMO	1985 Airbase Survivability Demonstration
SOF	Supervisor of Flying
TACAN	Tactical Air Navigation
TAFSON	Tactical Air Forces Statement of Operational Need
VASI	Visual Approach Slope Indicator

SECTION I

INTRODUCTION

The North Field 87 Rapid Runway Repair (RRR) Test to be conducted at North Auxiliary Field, SC, refers collectively to four separate tests: (1) a Minimum Operating Strip (MOS) marking test, (2) a spall repair test, (3) a crater repair test, and (4) an upheaval measurement test. The North Field Test will provide data to evaluate the following: MOS marking procedures and marking effectiveness; a hand-mixed spall repair method; improved methods of determining the extent of upheaved pavement surrounding a crater; improved mat anchoring methods; training and equipment; and reliability and maintainability. In addition, the performance of the folded fiberglass mat repair will be evaluated by subjecting the mats to fighter aircraft operations.

A. BACKGROUND

Existing methods of repairing bomb-damaged runways include the AM-2 mat, the Fiberglass Mat (FGM), and the Precast Concrete Slab (PCS). FGM and PCS repairs were tested during the May 1985 Air Base Survivability Capability Demonstration (SALTY DEMO) at Spangdahlem Air Base, Germany. Explosively formed craters were repaired using each method, then trafficked by fighter aircraft. In October 1985 at RAF Wethersfield, England, craters were repaired using the same two methods (except a folded fiberglass mat was used in place of the rigid mats previously used at SALTY DEMO). These repairs were trafficked by C-141 and C-5 cargo aircraft, and results indicated that improvements were desirable and that further testing was required.

Folded fiberglass mats have not been trafficked by fighter aircraft. Also, a better understanding of the mat's behavior under the dynamic conditions of trafficking is needed. Bow wave phenomena (observed during previous aircraft trafficking) jet blast, and their effects on mat and anchor stresses require further study. Alternative anchoring techniques, such as angling the mat folds to the direction of traffic, and improved material design, such as the modified bushing and slotted mat, may reduce the effects previously observed during aircraft trafficking.

Two methods of spall repair also were compared during SALTY DEMO. The fielded Silikal® repair method was compared with a hand-mixed polymer spall repair method. In the hand-mixed method, A-side and catalyzed B-side polymer components were measured and poured into separate buckets, mixed, then poured into aggregate-filled spalls. Initial Operational Test and Evaluation (IOT&E) of the hand-mixed method is required. This method will be fielded in 1988, while development continues on an improved dispensing method.

A MOS marking system, which included a paint striper and edge markers, also was tested during SALTY DEMO. This test, although favorable, uncovered deficiencies in both the marking procedures and the paint striper. Testing efforts following SALTY DEMO have focused on edge marker deployment, painting, reference grid development and layout, and procedures for marking both a parallel and an angled MOS. The system, resulting from these tests, is ready for IOT&E.

B. AUTHORITY

The need for this program is established by the Tactical Air Forces Statement of Operational Need (TAFSON) 319-79 (SECRET), Postattack Launch and Recovery, 26 January 1979. The tasking directive is Program Management Directive 4021(11), dated 17 March 1987. TAFSON 319-79 (SECRET) has a 2-7 precedence rating.

C. PURPOSE

The purpose of the North Field 87 test is (1) to conduct IOT&E of the MOS marking system, (2) to conduct IOT&E of the hand-mixed spall repair method, (3) to test mat and overall crater repair reaction to fighter aircraft operations, (4) to conduct Development Test and Evaluation (DT&E) of upheaval measuring devices.

D. SCOPE

This test plan includes the overall organization, management, safety requirements, schedule, and logistical support for the entire North Field 87 Test. In addition, it provides details for the planned DT&E efforts and an informational overview of IOT&E. Details of the IOT&E tests are found under separate cover in the North Field 87 IOT&E test plan produced by USAFTAWC. If * a conflict arises between the IOT&E events in this document and the IOT&E test plan, the IOT&E test plan will take precedence.

SECTION II

ORGANIZATIONAL RESPONSIBILITIES

Organizational relationships for the North Field 87 RRR test are depicted in Figure 1. Test team organization is shown in Figure 2. Organizational responsibilities are listed below.

A. HQ AFESC

1. AFESC/DEY is responsible for

a. Providing overall test coordination;

b. Directing the DT&E portions of the test;

c. Providing the DT&E test director;

d. Publishing the DT&E test plan;

e. Publishing the test schedule;

f. Managing data collection;

g. Reducing and analyzing DT&E test data;

h. Publishing the DT&E test report;

i. Providing unique test resources, including;

(1) Folded fiberglass mats,

(2) MOS marking system and support,

(3) Spall repair system and polymer material,

(4) Upheaval measurement devices;

j. Providing overall funding for test ground operations and material;

k. Training the test team and data collection team;

l. Providing data collectors;

m. Providing soils and material testing and survey support;

n. Performing permanent runway restoration;

o. Providing crater repair equipment;

NORTH FIELD 87 RRR TEST

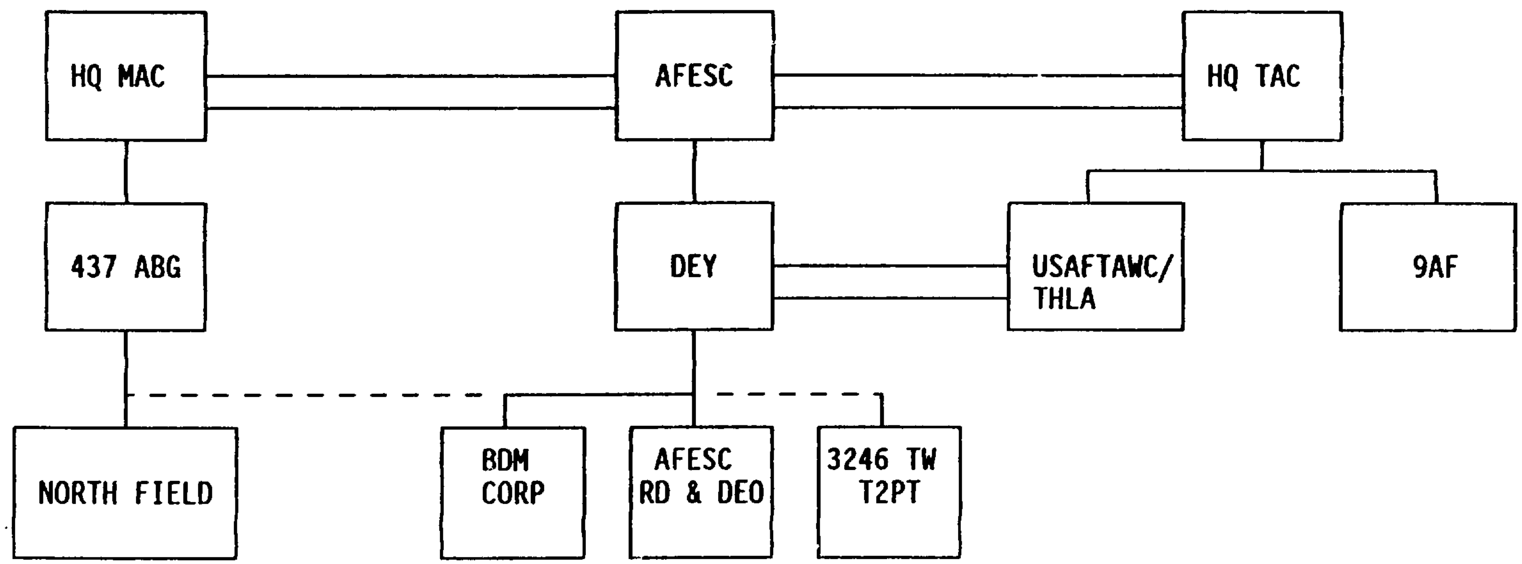

Figure 1. North Field 87 Organizational Relationships

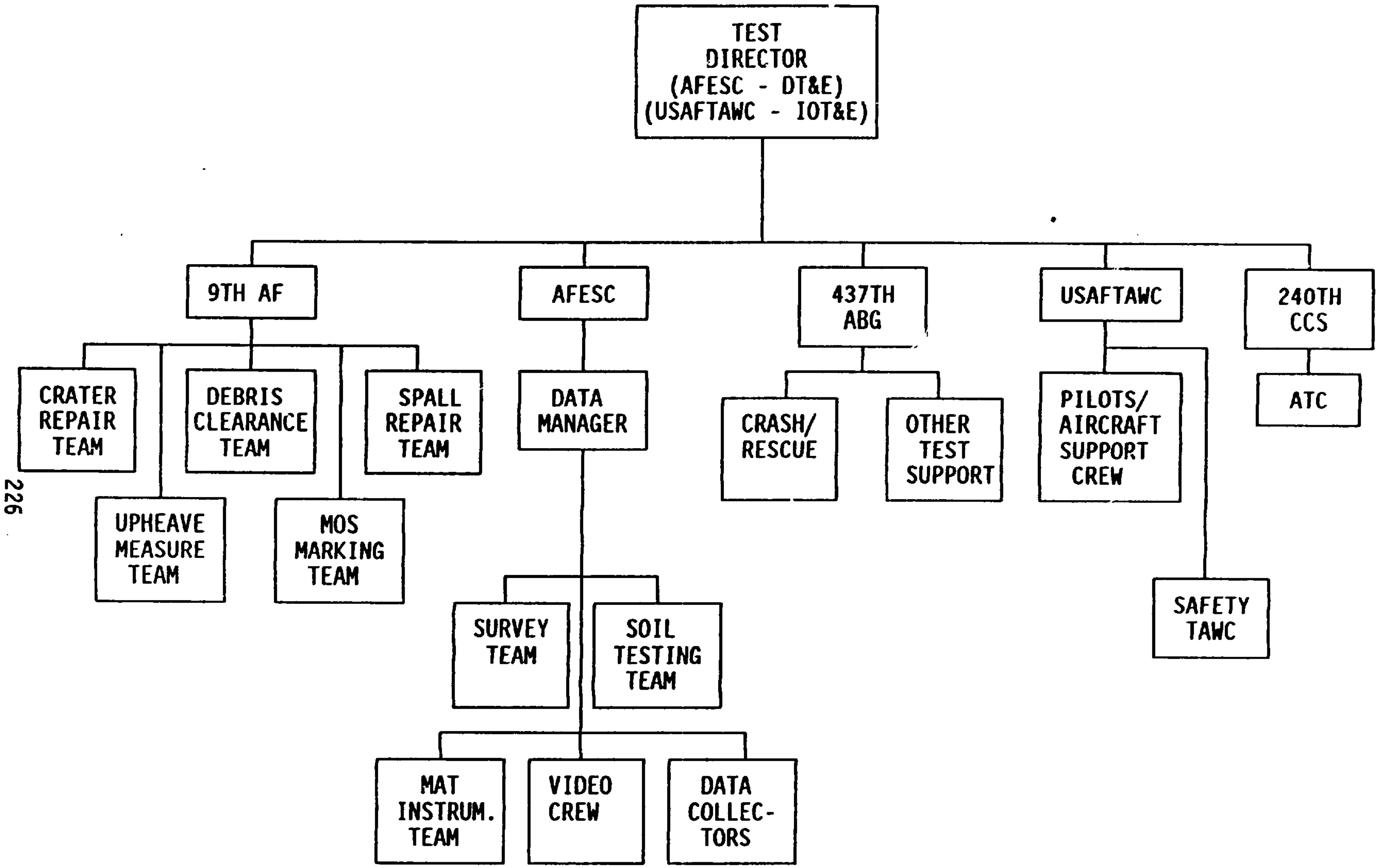

Figure 2. Test Team Organization

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p. Providing RRR communications support;

q. Forming spalls and craters;

r. Providing crater fill materials,

s. Providing hazardous waste disposal,

t. Managing the service report system.

2. AFESC/RDCP

AFESC/RDCP is responsible for

a. Providing individual project officer support, including input to the technical portions of the test plan;

b. Conducting technical review of the test plan;

c. Providing project officers for on-site technical support and supervision; (The same project officers are responsible for item development.)

d. Conducting technical review of the test report.

3. AFESC/RDCO

AFESC/RDCO is responsible for

a. Providing a supervisor for equipment operators;

b. Providing three experienced equipment operators and one mechanic;

c. Providing a loadcart and other equipment listed in Annex H;

d. Providing instrumentation support, as specified in Annex J.

4. AFESC/DEO

AFESC/DEO is responsible for

a. Coordinating the selection of MOS marking, spall repair, and crater repair teams, and other required manpower with 9th AF, as listed in Annex H;

b. Coordinating with the 823rd CESHR and the 240th CCS;

c. Reviewing the training plan.

B. HQ TAC

HQ TAC is responsible for conducting IOT&E of developed RRR systems. Accordingly, TAC, USAFTAWC, and 9th AF, will support the North Field 87 Test. HQ TAC will provide tasking and overall direction to subordinate units.

1. USAFTAWC/THL

USAFTAWC/THL will be responsible for

a. Providing an IOT&E test director;

b. Directing the IOT&E portion of the test;

c. Conducting IOT&E test planning;

d. Managing IOT&E test data;

e. Reducing and analyzing IOT&E test data;

f. Publishing the IOT&E test report;

g. Providing additional data collectors;

h. Providing test aircraft, aircrews, maintenance, and support;

i. Providing a Flight Safety Officer (FSO) and a Supervisor of Flying (SOF);

j. Supervising test flight operations;

k. Requesting waivers from HQ TAC for airfield operations.

2. 9th AF

The 9th AF will be responsible for the following:

a. Providing crater repair, MOS marking, and spall repair teams;

b. Providing fuel for aircraft operations;

c. Providing ground maintenance support for aircraft;

d. Providing air traffic control through 240 Combat Control Squadron (CCS).

C. 437th ABG (MAC)

437th ABG is responsible for

1. Providing a test location;

2. Arranging adequate crash and/or fire protection;

3. Providing work space for engineers, technicians, data collectors, and test management;

4. Providing secure storage areas for equipment used in the test;

5. Providing runway sweeping equipment and other equipment specified in Annex H;

6. Providing contract support for runway restoration;

7. Coordinating explosive crater formation with the Wing Safety Officer;

8. Harvesting trees on the Runway 27 approach.

D. OTHER ORGANIZATIONS

Other organizations which will provide test support include:

1. 3246 TW/TZPT, Eglin AFB, FL

The 3246 TW/TZPT is responsible for providing high-speed camera and videocamera recordings and for providing a pyrometer.

2. 823 Civil Engineering Squadron, Heavy Repair (CESHR), Hurlburt Field, FL

The 823 CESHR is responsible for

a. Providing a demolition plan for crater formation,

b. Forming craters,

c. Installing an aircraft arresting system,

d. Installing a Visual Approach Slope Indicator (VASI) on Runway 09/27.

3. 240 CCS, McEntire ANGB, SC

The 240 CCS is responsible for

a. Controlling air traffic during the test,

b. Installing portable Tactical Air Navigation (TACAN) equipment along Runway 09/27.

SECTION III

TEST DESCRIPTION

North Field 87 is an accumulation of four separate tests: (1) MOS Marking, (2) Spall Repair, (3) Crater Repair, and (4) Upheaval Measurement. Figure 3 illustrates the organization for the concurrent IOT&E/ DT&E testing.

DT&E objectives for the folded fiberglass mat are addressed in Section V.A., Crater Repair Test. The Upheaval Measurement Test will be conducted in conjunction with the repair portion of the Crater Repair Test. Trafficking the repairs with fighter aircraft will complete the objectives of the Crater Repair Test.

The MOS Marking Test and part of the Spall Repair Test are designed to satisfy IOT&E objectives. MOS marking test events will be integrated with the crater repair trafficking events. IOT&E of the hand-mixed spall repair system will occur as an independent test. A detailed test schedule is found in Annex I.

The tests will be conducted at North Auxiliary Field, SC, on Runway 09/27 (Figure 4). The 8000-foot runway consists of two sections. The major section of this runway is 5000 feet long and 150 feet wide from the 27 end to the point of intersection with the northeast-southwest (NE-SW) runway. A 3000- by 75-foot overrun extends west from this intersection to the intersection with the main runway. Runway 09/27 is composed of Portland Cement Concrete (PCC) approximately 6 inches thick. The overrun is covered with a thin asphalt overlay.

All tests will occur on the 5000-foot runway section in the area indicated in Figure 4. Figure 5 shows the test area details.

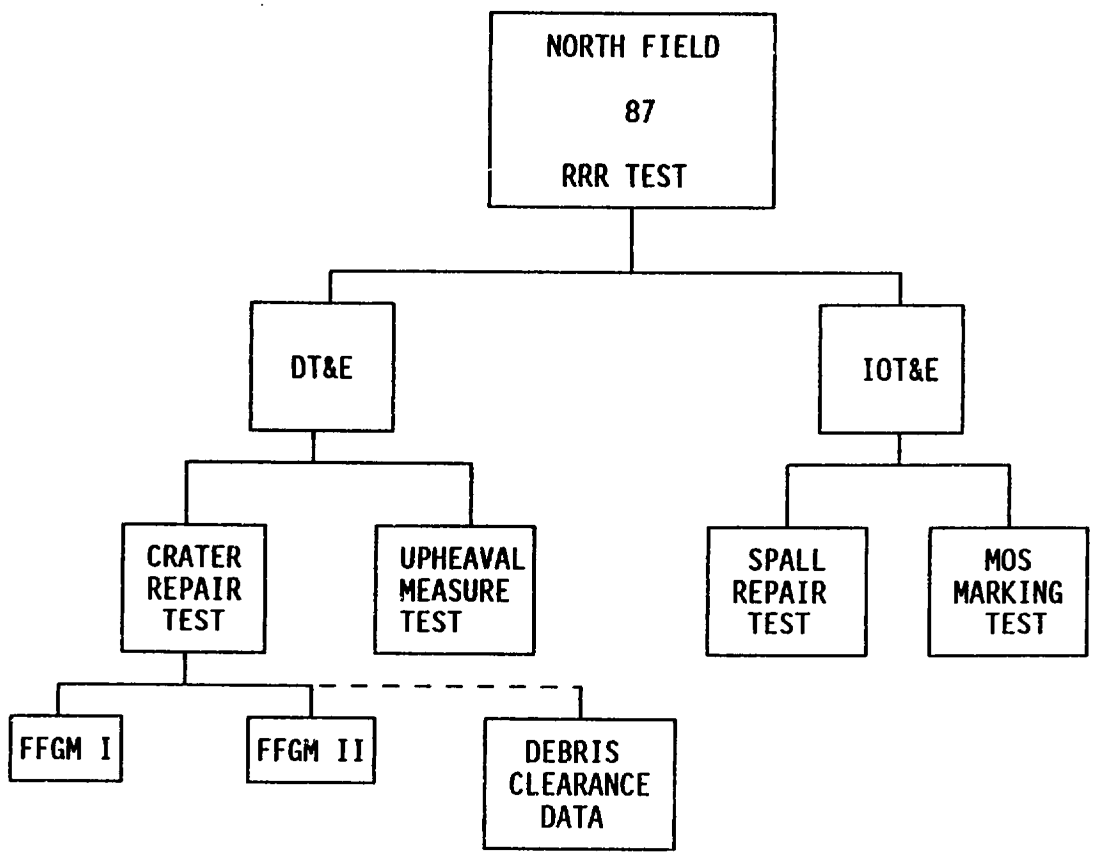

Figure 3. Test Organization

KEY

A. BUILDING 8
B. CARETAKER'S TRAILER
C. TEST AREA
D. AGGREGATE STORAGE
E. EQUIPMENT PARKING
F. DUMP
G. HAZARDOUS WASTE TEMPORARY STORAGE
H. PAINT MACHINE FLUSHING AREA
I. HOT BRAKES PAD
J. HYDRAZINE HOLD AREA
K. AIRCRAFT REFUELING AREA
L. BAK-12 BARRIER
M. MATERIEL STORAGE

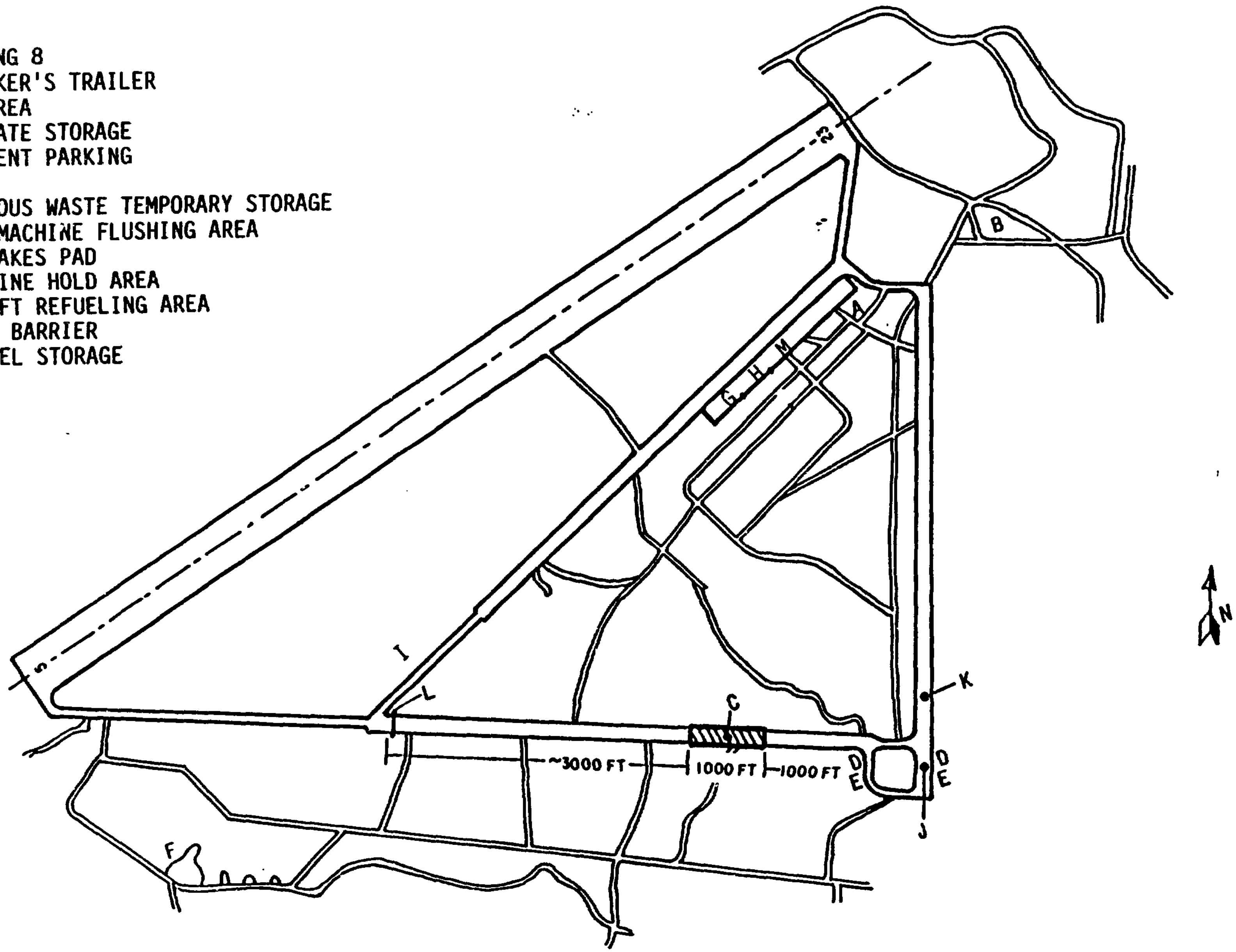

Figure 4. North Auxiliary Field

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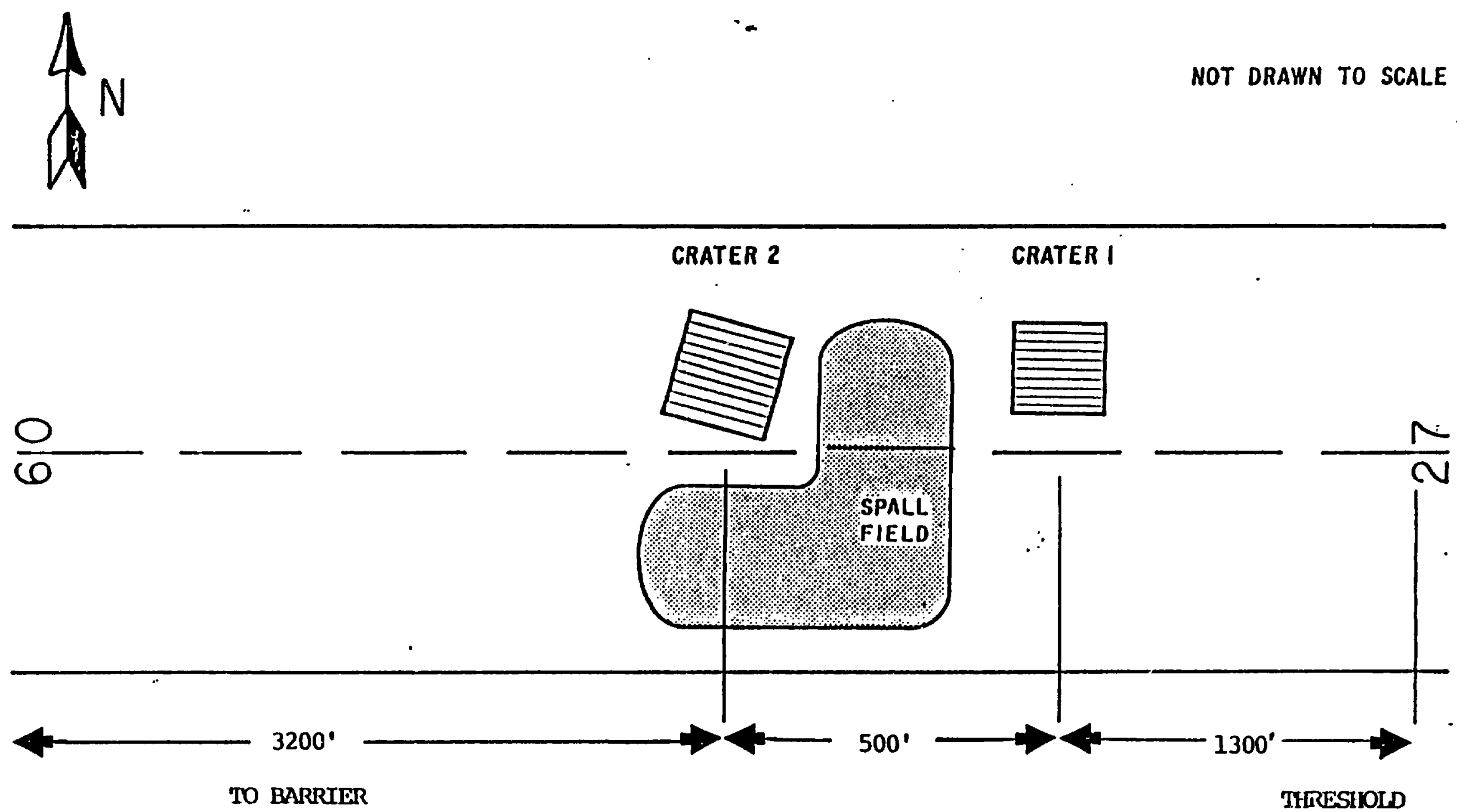

Figure 5. Test Area (Detailed View)

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SECTION IV

IOT&E TESTS

This section provides an informational description of the two IOT&E tests to be conducted at North Field. Details of these tests are found in the North Field IOT&E plan produced by USAFTAWC. If a conflict arises between the IOT&E events in this document and the IOT&E test plan, the IOT&E test plan will take precedence. *

A. MOS MARKING TEST

1. Test Objectives

a. Verify, under ideal conditions, that the subsystem can be employed in the time required by TAFSON 319-79 (SECRET).

<u>Evaluation Criteria</u>

(1) The MOS must be marked in 15 minutes, and markings must be retrieved or concealed in 5 minutes.

(2) The marked MOS must be positioned within 3 feet of the coordinates specified by the Survival Recovery Center.

(3) Edge markers must be placed to within 18 inches laterally and 10 feet longitudinally of the selected MOS.

(4) Distance-to-go marker placement must be correct to within 25 feet, longitudinally.

b. Evaluate MOS marking at night and during a simulated chemical environment.

<u>Evaluation Criteria</u>

Same as the first objective.

c. Evaluate the ease with which the subsystem can be employed.

<u>Evaluation Criteria</u>

Subjective response from equipment operators and the marking team.

d. Evaluate the subsystem's effectiveness in identifying the MOS boundaries to pilots during takeoff, landing, taxiing, and parking operations.

<u>Evaluation Criteria</u>

The MOS must be identifiable to pilots at 4 nautical miles.

e. Evaluate the adequacy of the employment concept and the training program.

Evaluation Criteria

(1) MOS marking must meet the time and accuracy criteria established in the first objective.

(2) Subjective evaluation by trainees.

(3) Subjective evaluation by the test director.

f. Evaluate the organizational-level maintainability of the paint machine.

Evaluation Criteria

Operator must identify and correct the problem within 30 minutes.

g. Evaluate the paint machine's reliability.

Evaluation Criteria

The paint machine must be operational for 14 days with a maximum downtime of 8 hours.

2. Test Description

The test will evaluate the MOS marking method, the marking effectiveness, the training program, and equipment reliability and maintainability. The MOS Marking System, comprised of the equipment listed in Table 1, will be employed to mark a 50- by 5000-foot MOS on a bomb-damaged runway. The MOS Marking System will be evaluated based on placement and recovery time. Marking effectiveness will be evaluated from pilots' comments. Figure 6 illustrates the marking pattern to be tested at North Field.

TABLE 1. MOS MARKING EQUIPMENT

Distance Markers	Paint Machine
Distance-To-Go-Markers	Pickup Truck
Edge Markers	Traffic Cones
	Utility Trailer

a. Pretest Activities

Before the first MOS marking event, a station marker reference system, using collapsible highway mileage markers, will be installed on each side of Runway 09/27. The station markers complement an airfield's existing reference system and facilitate postattack damage assessment, crater and spall

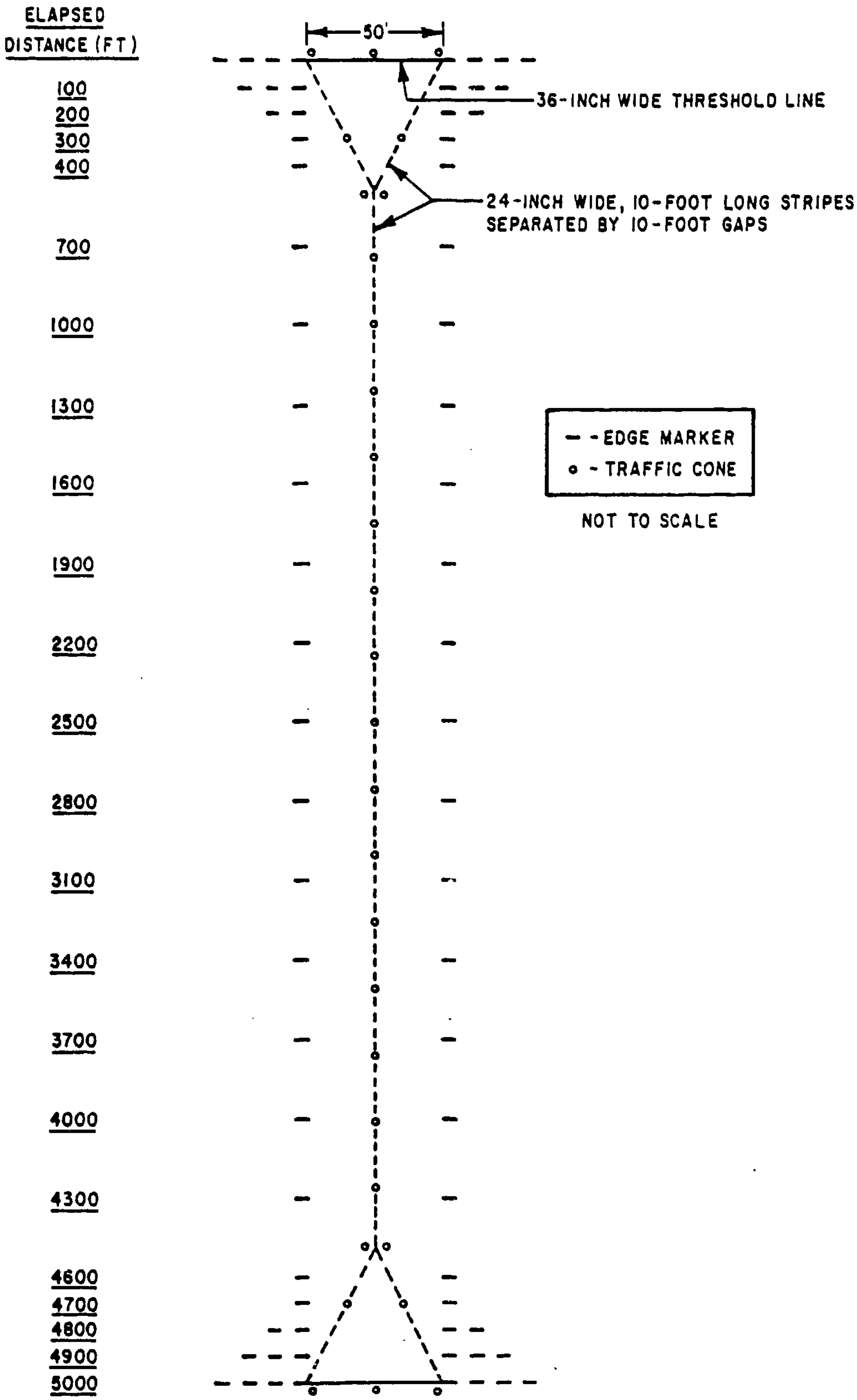

Figure 6. MOS Marking Pattern

repair, MOS marking, and other activities where a relationship to a fixed-runway position is required. The initial installation time for the station markers will be recorded to supplement the database.

Two three-worker MOS marking teams, comprised of members from a 9th AF Prime BEEF Team, will be trained in MOS marker deployment and equipment operation and maintenance before the test.

b. MOS Marking Test Events

MOS marking events planned for the North Field 87 RRR Test will be conducted under both "ideal conditions" (i.e., daytime with workers in chemical biological warfare (CBW) gear without hoods, masks, gloves, and boots) and "adverse conditions" (full CBW gear, and night operations). MOSs will be marked, in accordance with procedures to be incorporated in AFR 93-12. Three variations of the MOS pattern will be tested. The variations include marking with edge markers only, with a painted centerline (and threshold triangle) only, and with a combination of edge and centerline. To limit the paint quantity used during the test, most MOSs requiring a painted centerline will be applied with water-soluble oil, which eventually evaporates. Two MOSs will be expanded from 50 by 5000 feet to 75 by 7400 feet.

Four pilots, operating F-15 and F-16 aircraft, will fly against each MOS pattern variation. Pilots will comment on marking visibility and effectiveness. Each pilot will film at least one approach using the aircraft's Head-Up Display (HUD) video recorder.

c. Evaluation

Deployment and retrieval times will be compared to target times developed before the test. The marked MOSs' accuracy will be determined visually (crooked lines, misplaced markers, etc.) and by measurement. Utility of the edge and distance-to-go markers will be determined subjectively from pilots' comments. Reliability and maintainability data will be recorded for the paint machine and edge markers (see Annex K). Training duration and personnel experience with marking a MOS will be documented and related to team performance.

3. Test Support

a. Training

The marking team will be trained in MOS marking and paint machine operation and maintenance by AFESC at Tyndall AFB, Florida. Training requirements for the test will be established by AFESC. All training will be documented. One day of practice marking, to ensure proper paint machine operation, will occur at North Field before the test. Practice marking will occur on a taxiway, to be designated.

Detailed aircrew training is not anticipated. Before each MOS marking test event, pilots will be briefed on test aspects.

b. Technical Support

An AFESC contractor will provide technical and maintenance support for the paint machine throughout the test.

c. Communications

The test director must be able to communicate with the marking team and with air traffic control to coordinate low approaches. Communication procedures during the MOS marking test are outlined in Section VII.

d. Aircraft Support

USAFTAWC will provide aircraft for the MOS marking test. Four pilots are required to fly low approaches against the marked MOS. The same four pilots must be used in each MOS marking test event to obtain valid comparisons between MOS patterns.

B. SPALL REPAIR TEST

This method's impending fielding requires verifying the field procedures.

1. Test Objectives

a. Evaluate the Hand-Mixed Spall Repair System's adequacy during day, night, wet, and simulated CBW environments.

Evaluation Criteria

(1) Repair 33 spalls within 1 hour.

(2) Spalls should be filled to 1/2 inch below the pavement.

b. Evaluate the ease of employing the Hand-Mixed Spall Repair System.

Evaluation Criteria

Favorable responses by spall team members.

c. Evaluate the repair's effectiveness.

Evaluation Criteria

Repairs must meet the following criteria:

(1) Sustain 100 aircraft passes without rocking, chipping, or spalling.

(2) Produce no foreign object damage (FOD).

d. Evaluate the effectiveness of the Hand-Mixed Spall Repair System training and employment concept.

Evaluation Criteria

Trainees will be able to repair the spalls, as specified, after receiving the specified training.

2. Test Description

A total of 350 spalls, ranging in diameter from 1 to 5 feet, but with an average diameter of 2 1/2 feet, will be formed in a designated area on Runway 09/27 at North Field. Spalls will be formed using excavators or jackhammers. Procedures for spall formation are found in Annex G.

Spalls will be repaired by two four-man teams from a designated 9th AF Prime BEEF unit. Using repair procedures developed for AFR 93-12, each team will repair 133 spalls under ambient day conditions in CBW gear (including mask, gloves, and boots). Each team also will repair 20 spalls at night, in full CBW gear. Some night spall repairs will be conducted as wet weather repairs. (Aggregate will be wet, drained, then 3 ounces of water per square foot of aggregate surface area will be added to the spall to simulate a 2-inch-per-hour rainstorm). Approximately 85 of the repaired spalls will receive aircraft trafficking to test the spall repairs' durability. Spall repairs in the aircraft trafficking zone will be proofrolled with an F-15 loadcart before trafficking.

3. Evaluation

The test will measure the adequacy of the field procedures. The primary measures of effectiveness for the spall repair procedures are spall repair time, ease of operations, and repair integrity. Comments about the procedures will be obtained from the repair team at a debriefing following the test.

The reliability and maintainability (R&M) of the Hand-Mixed Polymer Spall Repair System will be evaluated according to the R&M plan (Annex K). Spall repairs also will be examined for repair quality, including spalling, chipping, and foaming.

Each team will be trained in current spall repair procedures to a level of proficiency established by AFESC. All spall training will occur at North Field. Each team will repair approximately 20 practice spalls (enough to consume one kit of polyurethane) before the test.

SECTION V

DT&E TESTS

This section contains the details of the Crater Repair and Upheaval Measurement Tests, which comprise the DT&E testing schedule for North Field 87.

A. CRATER REPAIR TEST

1. Test Objectives

a. Evaluate the performance of a crushed stone repair covered with a commercially produced, hinged, fiberglass mat.

<u>Pass/Fail Criteria</u>

The repair must meet the following criteria:

(1) Support a minimum of 100 fighter aircraft passes, remain within established surface roughness criteria, and not require maintenance necessitating mat removal.

(2) Sustain trafficking and jet blast without:

(a) loss of anchors;

(b) permanent mat deformation;

(c) mat fragmentation or delamination;

(d) producing FOD.

b. Compare bolt loads and mat strains to those predicted by mat analysis. (Report number BDM/MCL 86-0035-TR).

<u>Pass/Fail Criteria</u>

(1) Relevant anchor bolt loads and mat strains for 10 trafficking events.

(2) Qualitative and quantitative correlation of test data with the appropriate analytical model.

c. Compare the rutting performance of a crater repair with hinges parallel to the MOS centerline to that of a mat skewed 3 to 4 degrees off the MOS centerline.

Pass/Fail Criteria

The repair should not develop ruts which exceed the surface roughness limits after 100 aircraft passes.

d. Evaluate all bushings' ability to remain tight, and compare the performance of standard and modified bushings.

Pass/Fail Criteria

All bushings should remain tight for a minimum of 30 aircraft passes, and the modified bushings should remain tight longer than the standard bushings.

e. Measure bow wave amplitudes, and compare the amplitude of bow waves on standard mats versus slotted and skewed mats.

Pass/Fail Criteria

Bow waves on slotted mats should be smaller than those on standard mats, and bow waves should not damage either mat system.

f. Appraise the anchoring system's adequacy during loadcart and aircraft trafficking.

Pass/Fail Criteria

Each anchor must keep the mat secured to the ground.

g. Appraise each mat's structural integrity and the anchoring system's adequacy during exposure to jet blast from engine run-ups by F-15 and F-16 aircraft. *

Pass/Fail Criteria

The mats should not sustain damage which would prevent their continued use, and each anchor must keep the mat secured to the ground.

2. Test Description

This test will evaluate the performance of two crater repairs under fighter aircraft trafficking. The craters will be repaired using the Folded Fiberglass Mat (FFGM) repair method, employing a crushed stone base course and polyester mats. Polyester mats were selected based on their performance during an April 1987 FFGM test at Tyndall AFB.

One mat, used for Crater Repair 1 (Figure 5), will have the conventional round anchor holes and will be anchored with its hinges parallel to the MOS centerline. Before the test, an additional anchor hole will be formed in each mat panel, midway between the existing holes. Anchor spacing on each panel will be 18 inches. Both the mat and the anchor bolts will be instrumented with strain gauges for recording mat strain and anchor bolt load. Instrumentation details are found in Annex J.

The second mat, used in Crater Repair 2 (Figure 5), will have slotted anchor holes at the edges (Figure 7). Anchor bolt spacing will be the same as the first mat. Mat sections will be spliced with modified splice panel bushings (Figures 8 and 9). The mat will be secured to the pavement with modified anchor bushings (Figure 8). In addition, this mat will be oriented 4 degrees off the MOS centerline (Figure 10).

After proofrolling with an F-15 loadcart, the repairs will be subjected to F-15 and F-16 trafficking, consisting of low- and high-speed taxis, takeoffs, and touch-and-goes. Each repair also will be subjected to jet blast. Jet blast exposure will simulate a maximum thrust allowable for pretakeoff engine run-up. The run-ups will be directed at the mat's trailing edges only.

Each repair's performance will be measured in inches of sag per a fixed number of trafficking passes, and in the number of repair maintenance actions per fixed number of trafficking passes.

a. Crater Preparation

Runway 09/27 was surveyed according to the procedures outlined in Annex D to establish a repair baseline for input to a preliminary surface roughness analysis.

Two craters will be formed explosively in the runway, according to the Operating Instruction (OI) developed by 823 CESHR. Each crater will be formed to an apparent diameter of 15 to 25 feet, yielding a repair diameter of approximately 25 to 40 feet. Craters will be situated as shown in Figure 5. This orientation permits each crater to receive all scheduled trafficking operations (taxiing, touch-and-goes, etc.).

After crater formation, the runway and the craters will be surveyed and soils tests performed, according to the procedures outlined in Annex D.

b. Crater Repair

The craters will be repaired using one method per day, according to the procedures in Annex A. Deviations to the repair procedures must be approved by the test director. Repairs will be controlled, with time-outs for surveys, moisture/density readings, or other data collection requirements.

With the FFGM method, the crater first is backfilled with crater debris, then a layer of crushed stone is added, leveled, and compacted. A fiberglass mat is pulled over the repair, then anchored. Figure 11 shows a cross section of a completed FFGM repair.

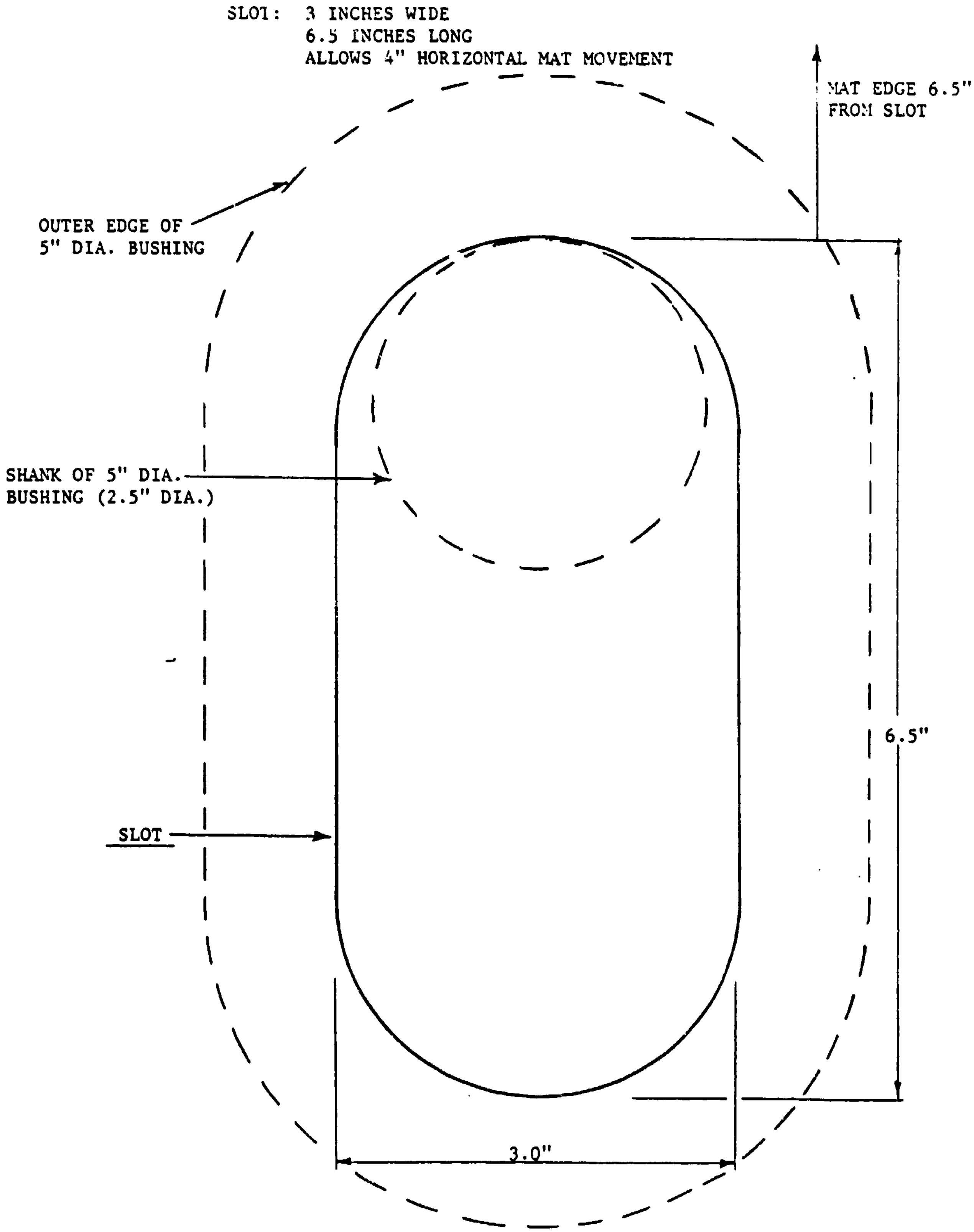

Figure 7. Slot Design for Mat Anchor Hole

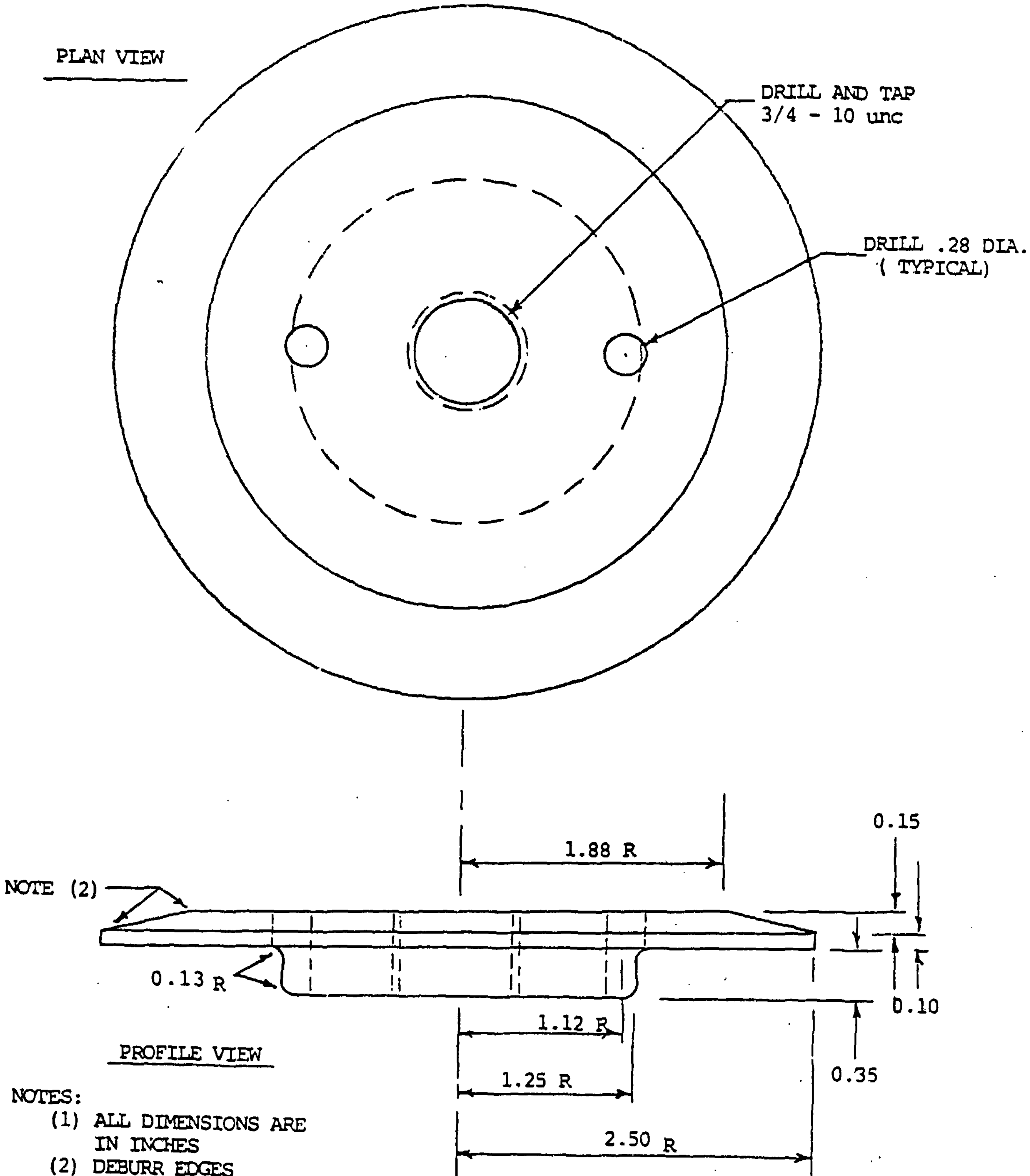

Figure 8. Modified Upper Splice and Anchor Bushing

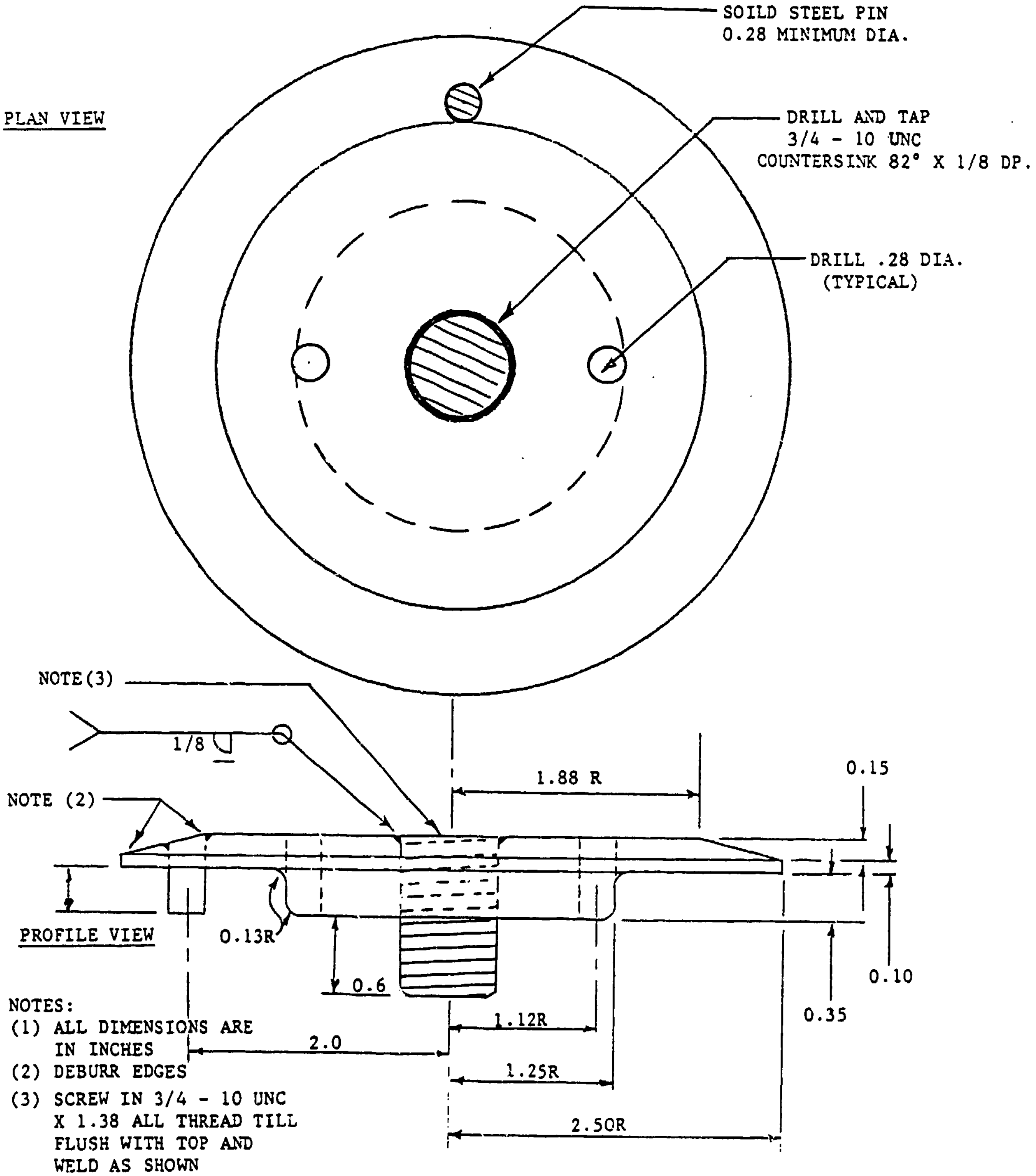

Figure 9. Modified Lower Splice Bushing

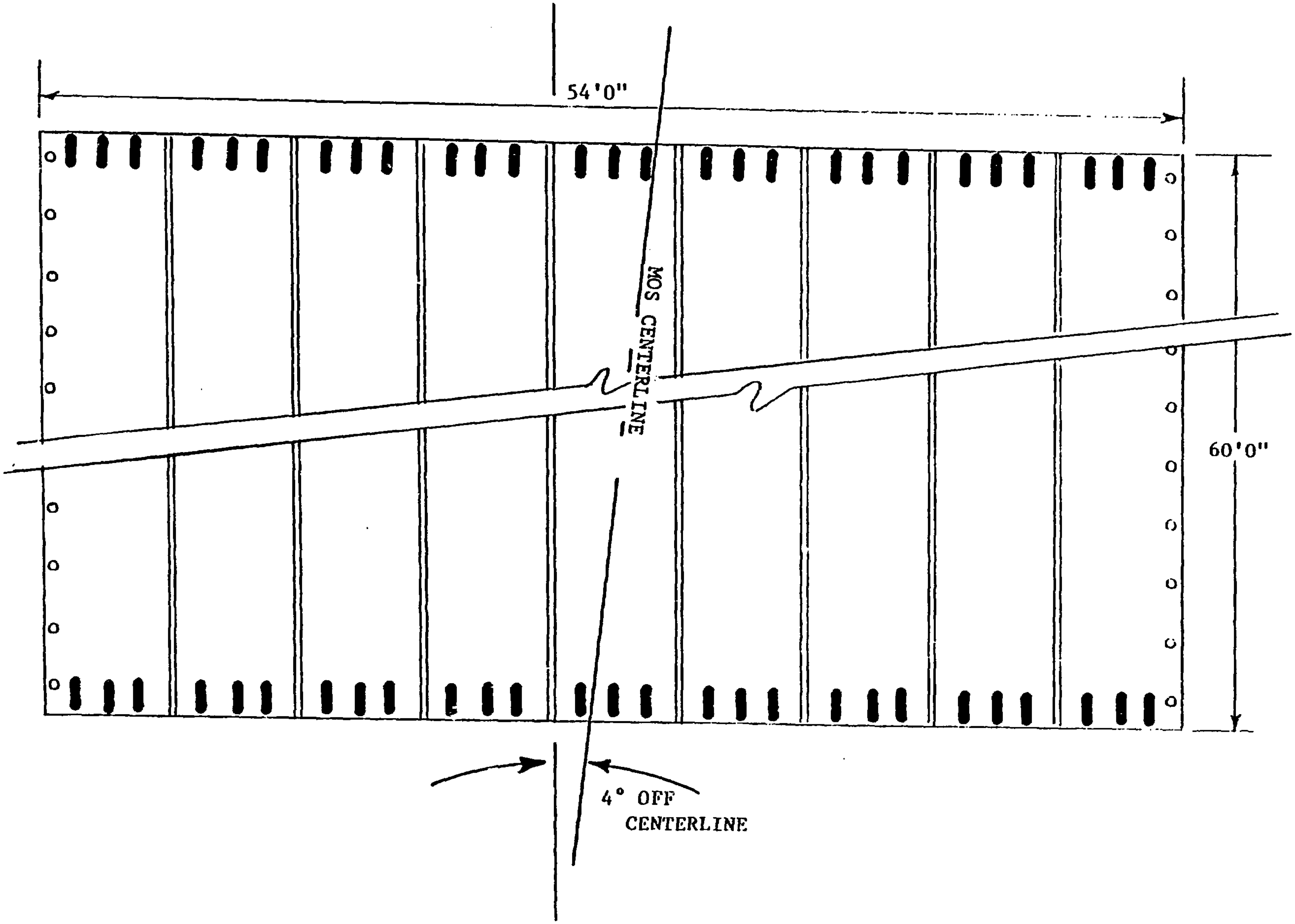

Figure 10. Orientation of Mat

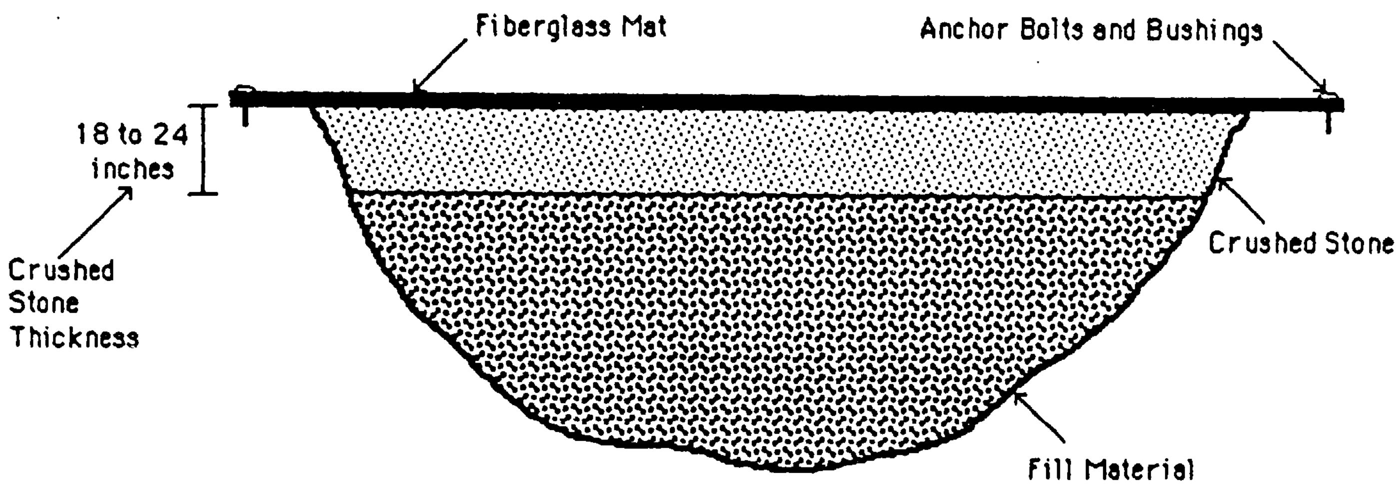

Figure 11. Cross Section of Crushed Stone Folded Fiberglass Mat Repair

The craters will be repaired by a team from a designated 9th AF Prime BEEF unit, augmented by AFESC repair specialists.

Data requirements for this test are listed in Annex F, "Data Collection and Management Plan." Laboratory soils tests will include, as a minimum, Atterberg limits, fill gradations, moisture content, and compaction curve determin^tion. Structural data collected during the repair will include, as a minimum, moisture/density and airfield cone penetrometer tests for the subgrade, and moisture/density measurements after compaction of each layer. Timed repair data are not required to satisfy DT&E objectives.

c. Repair Quality

Craters will be repaired flush (±3/4 inch). The maintenance criteria will be developed by AFESC from TAXIG computer runs which simulate anticipated repair roughness and repair spacing effects on aircraft operations. Surface roughness criteria will be based on limiting maximum dynamic loading to 80 percent of aircraft design limit load. Repair quality will be verified through stringline elevation checks and surveys immediately after the repair and periodically throughout aircraft trafficking. The procedure for stringline checks is found in Annex B.

Each repair will be proofrolled using an F-15 loadcart, according to the procedures found in the repair procedure annex. Any resulting repair deficiencies will be corrected before aircraft trafficking. Elevation measurements will be taken for surface roughness calculations and for a data baseline. Elevation measurements also will be taken daily and before and after each maintenance action. *

d. Aircraft Trafficking

Crater repairs will be trafficked by F-15 and F-16 aircraft. Operations will include low- and high-speed taxiing, braking, touch-and-goes, and jet blast. Section VII addresses the specific test procedures and limitations governing aircraft operations.

Trafficking will be monitored by the test director, selected data collectors, and the flight safety officer (FSO). Trafficking events also will be photographed by videocamera and high-speed film to record the repairs' reaction to aircraft operations. Repair quality during trafficking will be evaluated at specific intervals (i.e., every 10 passes). Adherence to surface roughness criteria will be determined by stringline elevation checks and by periodic elevation profiles. Maintenance will be required when the peak sag reaches the predetermined limits. In addition, mats will be examined for excessive wear, rutting, and tears, and anchors will be examined for integrity. Initially, inspections will occur after each pass, and then as often as required by the test director. *

When maintenance is required, trafficking will halt and repairs will be upgraded. Detailed maintenance instructions are found in each repair procedure annex. Elevation measurements will be taken before and after each required maintenance action. A complete record of repair maintenance will be kept.

3. Test Support

a. Training

Only experienced Prime BEEF and AFESC crater repair team members will be used. Additional training is not required.

b. Posttest Airfield Restoration

After the test, areas used for crater repair will be restored to pretest conditions or better. Restoration will include repaving runway portions, as well as sandblasting old runway markings and repainting the original markings. AFESC will design and fund runway restoration which will be contracted through 437 ABG.

B. UPHEAVAL MEASUREMENT TEST

Three methods for measuring upheaval have been developed by the U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, and by AFESC engineers at Tyndall AFB, Florida. These methods will undergo final DT&E during North Field 87.

1. Test Objectives

a. Determine the absolute accuracy of the stringline, the superstring, and the dipstick method.

<u>Pass/Fail Criteria</u>

(1) Initial measurement of start of upheaval: within 2 feet of point determined by rod and level. *

(2) Intermediate measurement: ±3/4 inch (vertical) of rod and level measurement.

b. Identify each method's repeatability.

<u>Pass/Fail Criteria</u>

Each team must have identified all upheaval to be removed (±3/4 inch as established for a flush repair).

c. Determine the absolute measurement time, and compare each of the three tested method's measurement time.

<u>Pass/Fail Criteria</u>

(1) Initial measurement completed within 10 minutes of team arrival at the repair site.

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(2) Intermediate measurement completed in 15 minutes.

2. Test Description

The three upheaval measurement devices to be used are a dipstick, the currently used stringline, and the super stringline. The dipstick, shown in Figure 12, is an electronic slope detector which measures the difference in elevation of two points separated by 12 inches. A repeated series of these elevations, input to the dipstick's companion TRS-80 PC-2 computer, creates a graphic profile from which the upheaval limit can be determined.

Figure 13 illustrates the basic stringline procedure. In the currently used stringline method, a string is pulled taut between two upheaval marker posts, establishing a level line. Upheaval is determined by measuring from the level line to the pavement.

The modified or super stringline was developed to reduce the inherent inadequacies in the current stringline method and to increase its capabilities. The super stringline's main components are a winch, base plates to stand on, and a 1/8-inch steel cable. With 100 feet of cable between the baseplates and the individuals standing on them, the winch can tighten the cable so the sag in the middle of the cable is 3/4 inch or less. Slope detection is inherent in the modified stringline by comparing different measurements along the line.

This test will be run in conjunction with the crater repair test. Three upheaval measurement teams, one two-worker team for the dipstick and two three-worker teams for the stringlines, will be provided from a 9th AF Prime BEEF unit. All three measurement teams will measure upheaved pavement limits for each crater repair.

After crater formation, to determine pavement elevations, each crater will be surveyed by rod and level according to procedures outlined in Annex D. This will produce the control survey to determine the accuracy of each device.

The upheaval measurement devices will be operated in accordance with procedures detailed in Annex B. The measured upheaval limits will be recorded, then compared with the control survey limits. If the measured limits differ significantly from the control limits, the control limits will be used for the crater repair. The time taken to measure the upheaval limits will be collected.

3. Test Support (Training)

Three teams will be selected, each specializing in one measurement method. Training will be conducted by AFESC at North Field before the test.

UPHEAVAL CROSS-SECTION

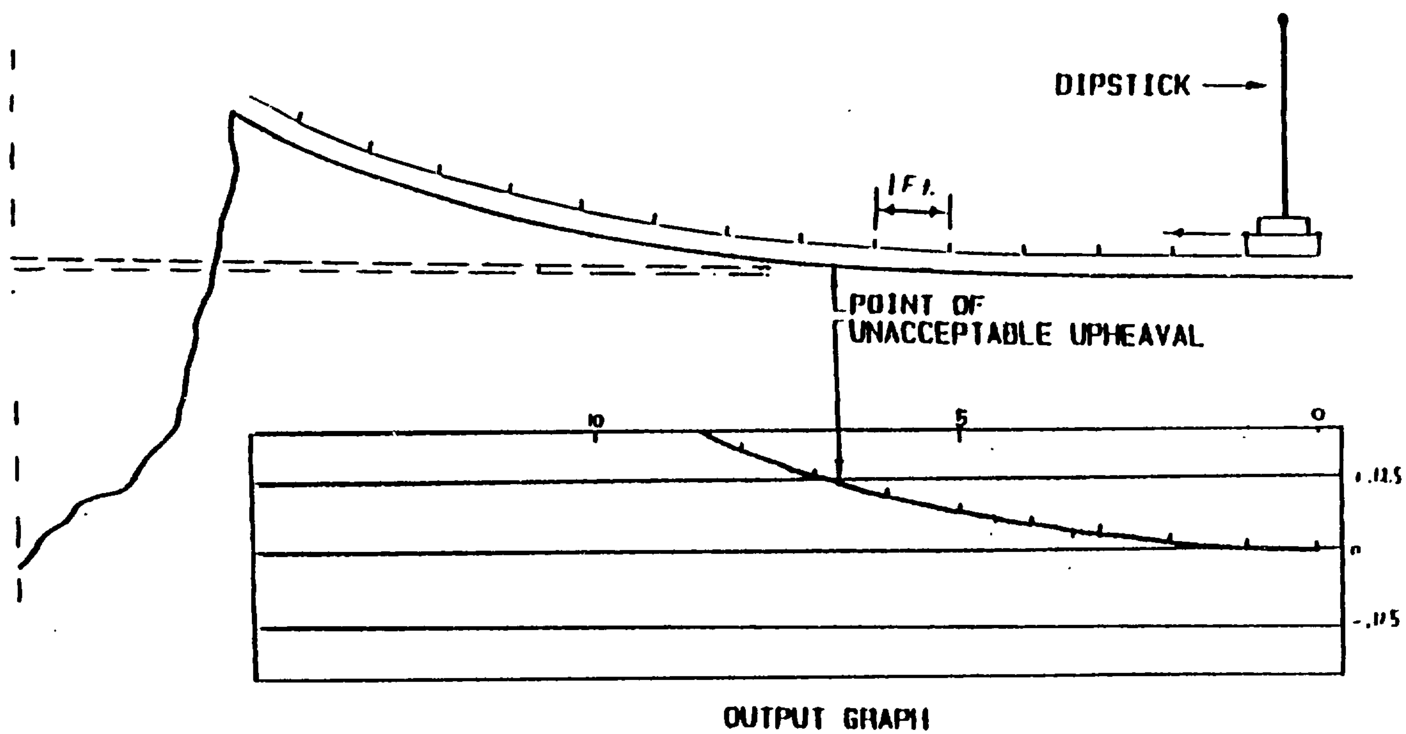
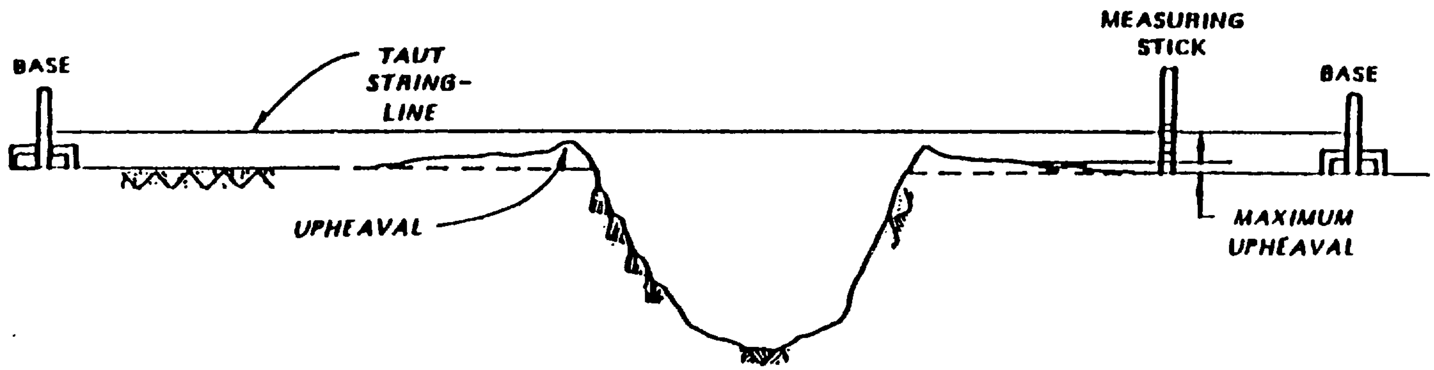


Figure 12. Dipstick Upheaval Measurement Method



NOTE. HEIGHT OF STRING AT THE TWO BASES MUST BE THE SAME.

Figure 13. Stringline Upheaval Measurement Method

SECTION VI

DEBRIS CLEARANCE DATA COLLECTION

Past tests show that the time required to clean the MOS to operational readiness following crater repairs may add significantly to the total RRR recovery time. Since the craters at North Field will be formed explosively, an opportunity exists to determine the degree of runway cleanliness which can be achieved at different stages of the total debris clearance effort. Though not a test, data on runway cleanliness will be collected to support a forthcoming debris clearance study.

Using existing North Field debris clearance equipment and the procedures listed in Annex C, a 50- by 5000-foot MOS, established on Runway 09/27, will be cleared for aircraft operations. The MOS for debris clearance will start west of the instrumented mat (Crater Repair 1), and continue west into the overrun area. The clearance area will include Crater 2 and the spall field. The instrumented mat will not be swept with either a sweeper or a towed broom at any time during the test because of potential damage to sensors and wires. For aircraft operations, the instrumented mat will be hand swept or cleaned with leaf blowers.

Runway debris will be measured three times during the test: (1) after crater formation to determine initial debris distribution, (2) after crater repairs, and (3) after one pass of the debris clearance equipment.

Debris samples taken before and during the Crater Repair Test and during sweeping will be analyzed to determine maximum debris size and gradation. When all the craters have been repaired, the entire MOS will be cleared and swept. Debris clearance of the entire MOS will be timed.

SECTION VII

FIGHTER AIRCRAFT OPERATIONS

As part of the North Field 87 Test, fighter aircraft operations will be conducted from Runway 09/27 to verify aircraft operability with a marked MOS, and the integrity of the spalls repaired during IOT&E. In addition, aircraft trafficking on the MOS will provide the dynamic conditions necessary to evaluate the crater repairs' performance.

Authority to conduct aircraft operations, in accordance with this test plan, will be provided by HQ TAC when approving the final test plan.

A. TEST EVENTS

Aircraft support is required

1. To determine the effectiveness of a MOS marked only with edge markers, only with paint, and with both edge markers and paint.

2. To evaluate the integrity of spall repairs made during IOT&E.

3. To evaluate the FFGM repair's performance under fighter aircraft operations.

The MOS Marking Test requires pilots to make low approaches and touch-and-goes against the MOS to determine the ease with which the pilot is able to acquire and align on a designated MOS. The effectiveness of edge marking on taxi operations also will be examined. The spall repair and crater repair tests require pilots to taxi and to conduct touch-and-go operations over the repairs to provide an effective number of passes and to induce the appropriate dynamic conditions.

To use the aircraft efficiently, MOS marking and crater repair test events will be integrated. The test matrix, Table 2, shows the aircraft operation events required to complete testing and the cumulative totals of MOS approaches and crater and spall repair passes. Each matrix event will be repeated for F-15 and F-16 aircraft.

The test matrix has been designed conservatively, increasing in complexity as confidence in the marking and the repairs is achieved. Each test day will begin with low-speed taxis, increase to a higher speed taxi, then continue to a takeoff, a series of low approaches, and touch-and-goes. On the first test day, one taxi pass, 90 knots or greater, will be used to test the installed arresting barrier. *

All high-speed taxis (40 knots or greater) will occur toward the barrier. Low-speed taxi passes may occur in either direction. Figure 14 illustrates the bidirectional taxi pattern.

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TABLE 2. AIRCRAFT OPERATIONS MATRIX

DAY 1

TEST EVENT	OPERATIONS	MOS	PILOT	REPAIR EVENT CRATER 1	REPAIR EVENT CRATER 2	REMARKS
1	10 - 20 kt Taxi	Edge	1	x	x	
2	40 - 60 kt Taxi	Edge	1	x	x	
3	10 - 20 kt Taxi	Edge	1	x	x	
4	40 - 60 kt Taxi	Edge	1	x	x	
5	10 - 20 kt Taxi	Edge	1	x	x	
6	80+ kt Taxi	Edge	1	x	x	Barrier Test
	Refuel					
7	Takeoff	Edge	1	x	x	
8	Low Approach	Edge	1	-	-	
9	Low Approach	Edge	1	-	-	
10	Touch and Go	Edge	1	x	x	
11	Touch and Go	Edge	1	AB	-	Afterburner on CTR 1
12	Touch and Go	Edge	1	x	AB	Afterburner on CTR 2
13	Touch and Go	Edge	1	x	x	
14	Touch and Go	Edge	1	x	x	
	Refuel					
15	Takeoff	Edge	2	x	x	
16	Low Approach	Edge	2	-	-	
17	Low Approach	Edge	2	-	-	
18	Touch and Go	Edge	2	x	x	
19	Touch and Go	Edge	2	x	x	
20	Touch and Go	Edge	2	x	x	
21	Touch and Go	Edge	2	x	x	
22	Touch and Go	Edge	2	x	x	
CUMULATIVE MOS APPROACHES 14	CUMULATIVE SPALL AND CRATER PASSES			18	17	

NOTES:
1. REPEAT MATRIX FOR F-15 AND F-16
2. REFUEL AFTER EVENTS 7 AND 14
3. EDGE MARKERS AT 50 FEET FOR LOW APPROACHES; WIDER FOR OTHER EVENTS

TABLE 2. AIRCRAFT OPERATIONS MATRIX (CONTINUED)

DAY 2

TEST EVENT	OPERATIONS	MOS	PILOT	REPAIR EVENT CRATER 1	REPAIR EVENT CRATER 2	REMARKS
23	10 - 20 kt Taxi	CL	1	x	x	
24	40 - 60 kt Taxi	CL	1	x	x	
25	10 - 20 kt Taxi	CL	1	x	x	
26	40 - 60 kt Taxi	CL	1	x	x	Braking on CTR 2
27	10 - 20 kt Taxi	CL	1	x	x	
	Refuel					
28	Takeoff	CL	1	x	x	
29	Low Approach	CL	1	-	-	
30	Low Approach	CL	1	-	-	
31	Touch and Go	CL	1	x	x	
32	Touch and Go	CL	1	AB	-	Afterburner on CTR 1
33	Touch and Go	CL	1	x	AB	Afterburner on CTR 2
34	Touch and Go	CL	1	x	x	
35	Touch and Go	CL	1	x	x	
	Refuel					
36	Takeoff	CL	2	x	x	
37	Low Approach	CL	2	-	-	
38	Low Approach	CL	2	-	-	
39	Touch and Go	CL	2	x	x	
40	Touch and Go	CL	2	x	x	
41	Touch and Go	CL	2	x	x	
42	Touch and Go	CL	2	x	x	
43	Touch and Go	CL	2	x	x	
CUMULATIVE MOS APPROACHES 28	CUMULATIVE SPALL AND CRATER PASSES			35	33	

NOTES:
1. REPEAT MATRIX FOR F-15 AND F-16
2. REFUEL AFTER EVENTS 27 AND 35
3. MOS PATTERN IS PAINTED CENTERLINE WITH NO EDGE MARKERS

TABLE 2. AIRCRAFT OPERATIONS MATRIX (CONTINUED)

DAY 3

TEST EVENT	OPERATIONS	MOS	PILOT	REPAIR EVENT CRATER 1	REPAIR EVENT CRATER 2	REMARKS
44	10 - 20 kt Taxi	Edge & CL	1	x	x	
45	40 - 60 kt Taxi	Edge & CL	1	x	x	
46	10 - 20 kt Taxi	Edge & CL	1	x	x	
47	40 - 60 kt Taxi	Edge & CL	1	x	-	Braking on CTR 1
48	10 - 20 kt Taxi	Edge & CL	1	x	x	
	Refuel					
49	Takeoff	Edge & CL	1	x	x	
50	Low Approach	Edge & CL	1	-	-	
51	Low Approach	Edge & CL	1	-	-	
52	Touch and Go	Edge & CL	1	x	x	
53	Touch and Go	Edge & CL	1	AB	-	Afterburner on CTR 1
54	Touch and Go	Edge & CL	1	x	AB	Afterburner on CTR 2
55	Touch and Go	Edge & CL	1	x	x	
56	Touch and Go	Edge & CL	1	x	x	
	Refuel					
57	Takeoff	Edge & CL	2	x	x	
58	Low Approach	Edge & CL	2	-	-	
59	Low Approach	Edge & CL	2	-	-	
60	Touch and Go	Edge & CL	2	x	x	
61	Touch and Go	Edge & CL	2	x	x	
62	Touch and Go	Edge & CL	2	x	x	
63	Touch and Go	Edge & CL	2	x	x	
64	Touch and Go	Edge & CL	2	x	x	

CUMULATIVE MOS APPROACHES 42 CUMULATIVE SPALL AND CRATER PASSES 52 48

NOTES:
1. REPEAT MATRIX FOR F-15 AND F-16
2. REFUEL AFTER EVENTS 48 AND 56
3. MOS PATTERN IS EDGE AND CENTERLINE, MOS MARKERS PLACED WIDER THAN 50 FEET.

TABLE 2. AIRCRAFT OPERATIONS MATRIX (CONCLUDED)

DAY 4

TEST EVENT	OPERATIONS	MOS	PILOT	REPAIR EVENT CRATER 1	REPAIR EVENT CRATER 2	REMARKS
65	10 - 20 kt Taxi	Edge & CL	1	x	x	
66	40 - 60 kt Taxi	Edge & CL	1	x	-	Braking on CTR 1
67	10 - 20 kt Taxi	Edge & CL	1	x	x	
68	40 - 60 kt Taxi	Edge & CL	1	x	x	Braking on CTR 2
69	10 - 20 kt Taxi	Edge & CL	1	x	x	
	Refuel					
70	Takeoff	Edge & CL	1	AB	-	Afterburner on CTR 1
71	JET BLAST	---	1	x	-	30 second, mil thrust
72	JET BLAST	---	1	-	x	30 second, mil thrust
73	Takeoff	Edge & CL	1	-	AB	Afterburner on CTR 2
74	Takeoff	Edge & CL	1	-	-	

CUMULATIVE MOS APPROACHES 42 CUMULATIVE SPALL AND CRATER PASSES 59 54

NOTES: 1. REPEAT MATRIX FOR F-15 AND F-16
2. REFUEL AFTER EVENT 69

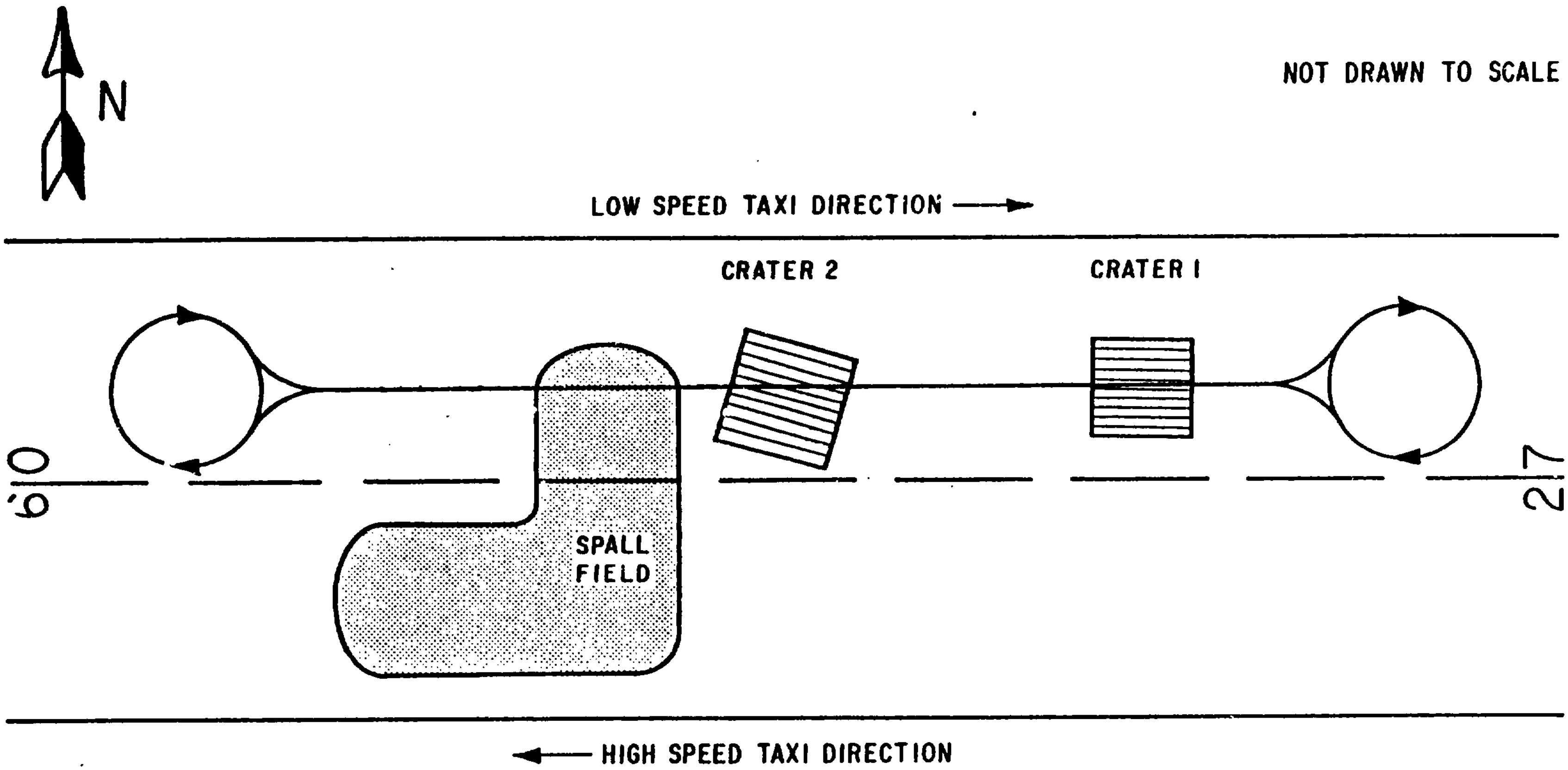

Figure 14. Taxi Pattern

Following taxiing events, sorties will be launched from Runway 09/27. Each pilot will make a minimum of one low approach to the marked MOS. After one or more low approaches, each pilot will complete multiple touch-and-goes, as scheduled. On all touch-and-goes, the aircraft will touch down before reaching the repairs. Following the scheduled touch-and-goes, or when the test director signals the end of testing, the aircraft will recover on the main runway.

B. AIRCRAFT OPERATIONS

1. Authority

Aircraft operations during North Field 87 will be under the auspices of HQ TAC (through USAFTAWC), the AFESC test director, the SOF, and the FSO. All aircraft operations will be conducted in accordance with Air Force Regulation (AFR) 60-16, local implementing directives, special procedures related to and approved for this test, and any waivers or special instructions issued by HQ TAC and HQ MAC. Figure 1 describes the management relationships for aircraft operations during North Field 87. Test events will be conducted in accordance with the approved test plan. On-site modifications to the test matrix will be agreed upon and approved in advance by the AFESC test director, the USAFTAWC test director, the FSO, and the SOF.

2. Special Planning Factors

The following special approval will be required for aircraft operations:

a. Waiver of AFR 88-16 for using nonstandard runway markings for the MOS. HQ TAC/DO is the office of primary responsibility.

b. Waiver for airfield and airspace obstructions within 328 feet (100m) clear zone of Runway 09/27. HQ TAC/DO is the office of primary responsibility.

c. Waiver to do touch-and-goes on Runway 27. HQ TAC/DO is the office of primary responsibility.

3. Operational Ground Rules

All landings will occur on the North Field main runway. All test events, except for low-speed taxis, will take place on Runway 27. Additional operational ground rules include

a. Weather Minimums--Ceiling 2,000 feet, visibility 5 nautical miles;

b. 0-knot tailwind;

c. 10-knot crosswind, maximum;

d. An operable arresting system (MAAS);

e. Normal hot brakes procedures.

In addition, all aircraft landing gear struts and tires will be serviced according to the appropriate technical orders, before conducting operations on the repaired MOS.

4. Air Traffic Control

Air traffic control during the test will be provided by the 240th CCS. The controllers and the FSO will remain in constant contact with the aircraft, the RRR test director(s), and the SOF.

5. Communication

Figure 15 illustrates the communication scheme envisioned for North Field flight operations.

As a minimum, the test director and FSO each shall have a dedicated portable UHF radio capable of operating on variable frequencies. These radios are intended for emergency use and not for routine test communications. In addition, a dedicated VHF FM frequency will be used by the data collection team and monitored by air traffic control and North Field personnel during flight operations.

Communications protocol will be in accordance with procedures developed by USAFTAWC and the air traffic control squadron. Aircraft will respond only to directions from the tower except when a safety emergency is declared by the test director, the FSO, or the SOF. Communications in the FM net will be in accordance with standard protocol. Test team members will be briefed on the communications protocol before the test.

C. AIRCRAFT LOGISTICS SUPPORT

1. Equipment and Personnel

F-15 and F-16 aircraft will be provided by USAFTAWC. The F-15 will operate at a weight of approximately 42,500 pounds, and the F-16 at approximately 24,700 pounds. A minimum of four pilots are required to evaluate MOS marking effectiveness. *

2. Aircraft Maintenance

Aircraft maintenance will be provided by USAFTAWC.

3. Fuel

Shaw AFB will deliver jet fuel by tanker to North Field for flight operations.

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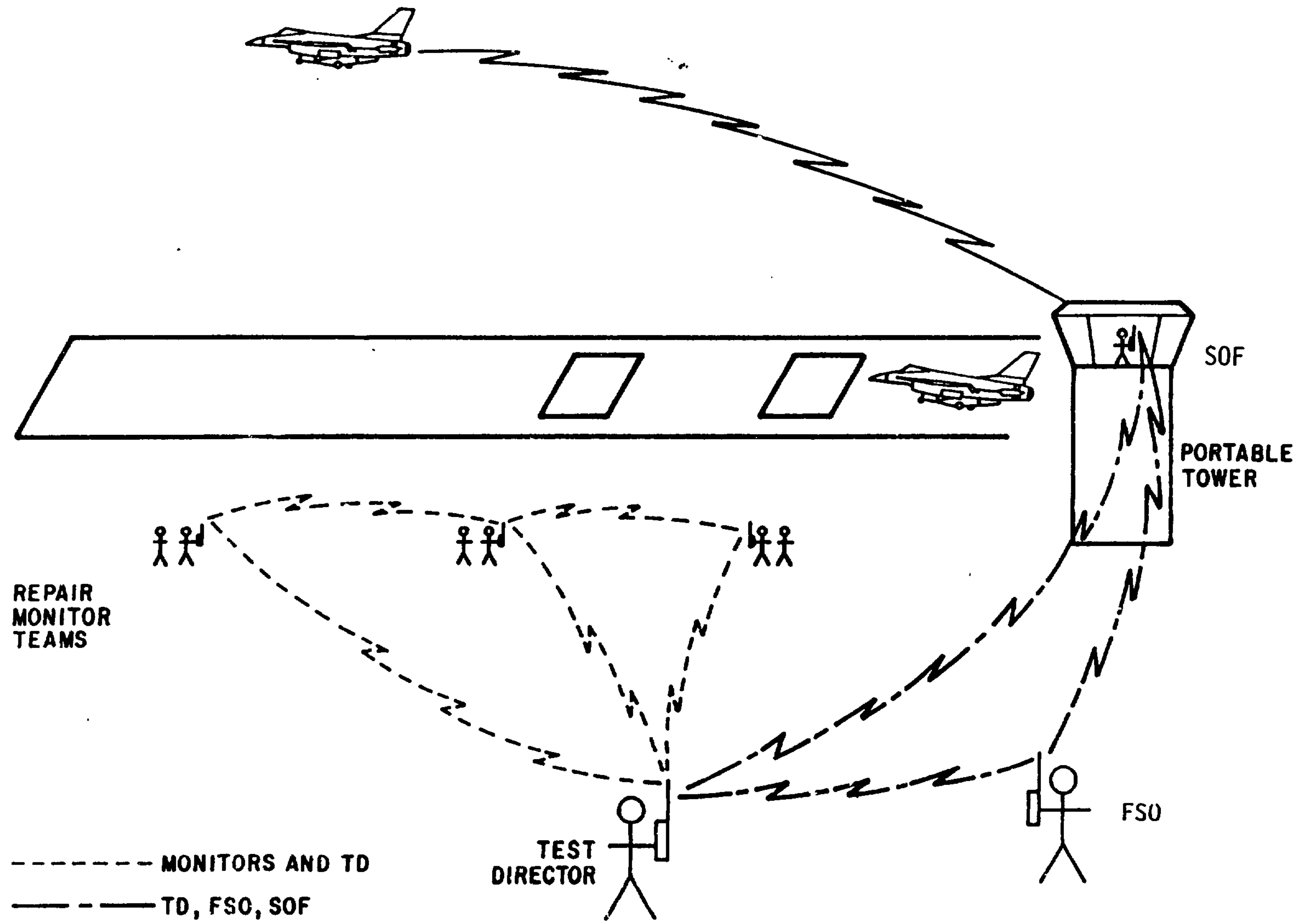

Figure 15. Communications During Aircraft Operations

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4. Security

North Field personnel will provide physical security during test operations.

5. Crash, Rescue, and Medical Support

North Field personnel will provide crash, rescue, and medical support. They will be trained in F-15 and F-16 egress before the test.

6. Airfield Preparation

Runway 27 will require the installation of an aircraft arresting barrier, a VASI, and a portable TACAN. An expeditionary BAK-12 barrier and * VASI will be provided and installed by the 823 CESHR. The barrier will be installed approximately 3,000 feet from the last crater (see Figure 5). The TACAN will be installed by the 240th CCS.

D. SAFETY DURING FLIGHT OPERATIONS

Safety during aircraft operations is ensured through effective communications and constant monitoring of the repairs and aircraft landing gear (tire and brake temperature). The test director, the FSO, or the SOF has the authority to stop a test if an unsafe condition arises. The FSO, appointed by USAFTAWC, will be present during all flight operations. The aircraft commander has the final authority to make "go/no go" decisions regarding aircraft safety.

Six data collectors will serve as repair monitors during trafficking, two per repair, plus two for the spall field. After each aircraft pass, each monitoring team will inspect the repair through binoculars to ensure that the repair is functional and safe for trafficking. Any repair irregularity, such as loose anchor bolts, torn mats, damaged mat hinges, or visible rutting will be reported immediately to the test director by radio. The test director will suspend the test until the irregularity is checked and corrected, if necessary.

At specified intervals (every pass for the first three events, every 10th pass for later events), trafficking will be suspended and the repair monitors will inspect the repairs and use a stringline check for surface roughness measurements (Interim Guidance Procedures). Monitors will record the results and relay the repair status to the test director and SOF. If excessive rutting or repair damage has not occurred, trafficking will resume. Otherwise, repairs will be maintained in accordance with procedures found in Annex A.

To prevent aircraft tires and brakes from overheating during taxiing test events, tire and brake temperatures will be monitored before each pass by ground personnel using an optical pyrometer. Both F-15 and F-16 aircraft

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operations will be halted if observed tire temperatures exceed 200°F*. Operations will resume with tire temperatures of 110°F and brake temperatures of 150°F. Portable blowers will be available to speed the cooling process. If a hot-brake problem arises, aircraft will be held at a designated hot brake location at the west end of Runway 27. Test personnel will not be allowed near the aircraft until maintenance personnel have determined that tire and brake temperatures are within safe limits.

E. DATA COLLECTION

Aircraft data will be collected before each trafficking event or at the end of the test day. These data will include aircraft weights and servicing information, such as tire and strut pressures.

A monitoring team will be stationed near each crater and will observe and record each crater and spall repair's reaction to trafficking.

Standard and high-speed videocameras and high-speed film cameras will record the repair's reaction to each trafficking pass. High-speed film equipment will be provided by the 3246th Test Wing (TZPT), Eglin AFB. Anticipated camera positions are shown in Figure 16.

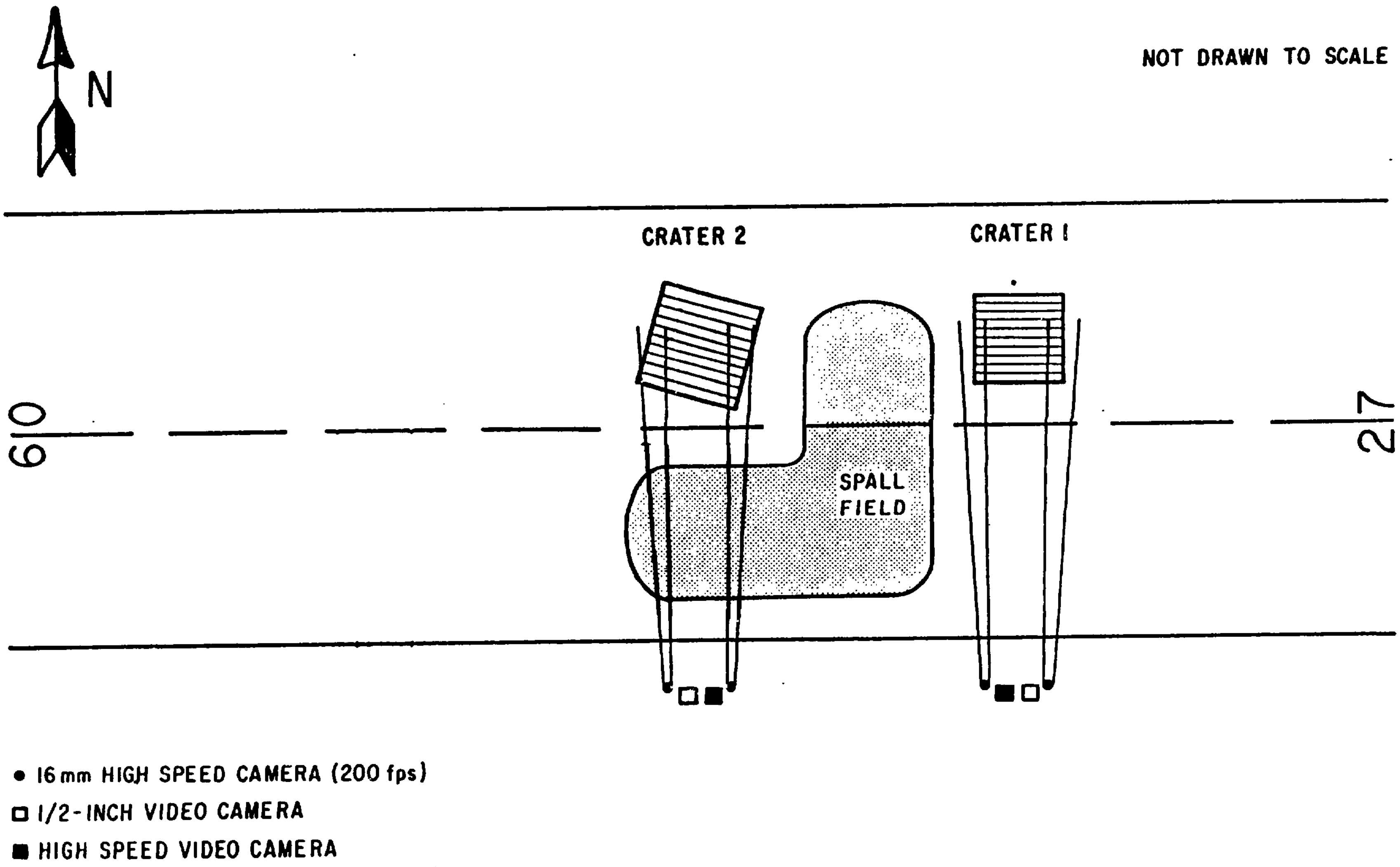
After every 10 passes, the monitoring team will examine the crater and spall repairs closely for evidence of wear, excessive sag, or other indications that the repair requires maintenance. The location of loose anchor bolts, mat tears, etc., will be recorded on a data form before maintenance or repair begins.

Pilots' comments will be collected at a debriefing at the end of the test day.

F. TRAINING REQUIREMENTS

USAFTAWC will define any aircrew training requirements for this test.

* Temperature limit used in HAVE BOUNCE Program.



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SECTION VIII

SAFETY

A. GENERAL

All tests and data collection procedures will be designed to ensure maximum safety precautions. Personnel and equipment safety will take precedence over completing any part of this test. Special emphasis will be placed on providing adequate supervision and guidance during all construction and testing phases.

Specific safety guidelines are provided in the spall and MOS marking fielding documents, as well as in test plan annexes, as required. All participants will be briefed daily on test events and on any potential hazards. Each test team participant is responsible for safety during the test. Communication will play an important role in maintaining test safety.

B. FLIGHT SAFETY

An FSO and SOF, appointed by USAFTAWC, will be present during all aircraft operations. During the test, the FSO and SOF will advise the test director on all flight safety issues. Safety during flight operations is discussed in detail in Section VII of this plan and in the USAFTAWC IOT&E test plan.

C. GROUND SAFETY

Adequate guidance and supervision will be provided during all test phases. Operational or maintenance hazards will be reported immediately to the test director. The weather at North Field in August and September will be hot and humid. Daily temperatures could exceed 90°F. All personnel will be briefed on the dangers of working under these conditions and precautions to be taken. All work requiring the ground crew ensemble (chemical warfare suit) shall be conducted in accordance with Draft AFR 355-8.

D. IDENTIFIED HAZARDS

1. Heavy Equipment

Heavy equipment, used throughout this test, is a potential hazard to repair crews and data collectors. Individuals will be briefed on this potential hazard.

2. Polymer

Polymer used for spall repairs is hazardous if it comes in contact with the eyes or skin, or if the vapor is inhaled. Spall repair personnel will wear full face respirators with organic vapor cartridges, chemical resistant gloves, and coveralls. Detailed safety instructions are found in the spall repair procedures.

3. Hydrazine

Hydrazine, used in F-16 aircraft, is extremely hazardous. North Field firefighting personnel are trained in emergency procedures in the event of an accidental hydrazine release. Aircraft maintenance personnel will be available on site. A hydrazine response team is available nearby at Shaw AFB.

The east end of Runway 09/27 is designated as an emergency hold location for an aircraft leaking hydrazine.

4. Solvents

Solvents used for flushing the paint machine's paint tanks are hazardous if they come in contact with the skin or eyes, or are inhaled. They also are flammable. Detailed safety instructions are found in the MOS marking field employment document.

E. SAFETY REPORTING

Accidents, incidents, and serious hazards will be reported, in accordance with AFR 127-4, through AFESC/SEG and 437 MAW/SE.

SECTION IX

RISKS

Specific risks which may prevent the accomplishment of all or part of this test include:

(1) Unavailability of USAFTAWC aircraft because of an unexpected conflict with a higher priority test;

(2) Conflicts between test schedule and the developmental schedule for specific equipment items;

(3) Limitations or unavailability of major test resources, such as crater repair materials, equipment, etc.;

(4) Logistic considerations, such as the acquisition of heavy equipment, including the loadcart;

(5) Conflict with other operational exercises;

(6) Inability to explode craters;

(7) Unfavorable weather conditions.

SECTION X

ENVIRONMENTAL PROTECTION

The North Field 87 RRR Test will require the use of hazardous materials. The test also will produce hazardous wastes. Known hazardous materials will include polymer resins, paints, and solvents. Hazardous materials and resulting hazardous wastes will be stored, transported, and disposed of in accordance with all Environmental Protection Agency (EPA), Air Force, and State of South Carolina environmental regulations. Chemical spills will be cleaned up in accordance with the appropriate Material Safety Data Sheet, and absorbent material for spill cleanup will be available on site during the test. Spill residues and off-ratio polymer components will be treated as hazardous waste. All hazardous materials and wastes will be removed from North Field at the end of the test.

This test qualifies for categorical exclusion in accordance with AFR 19-2, Attachments 7, 2f, 2k, and 2w. AF Form 813 has been submitted to 437 CES/DEEV, Charleston AFB, SC. The EPA hazardous waste generator ID number for this test is SC1570024470.

ANNEX A

CRATER REPAIR AND MAINTENANCE PROCEDURES

A. PRETEST ACTIVITIES

1. Material Testing: Fill Material

AFESC will test all fill material, including crushed stone and ballast rock during and after acquisition to ensure adherence to specifications. Tests will include, as a minimum, gradation, moisture-density relationship, Proctor, and in-place density.

2. Fiberglass Mat Inspection

The fiberglass mats used during the North Field Test are manufactured commercially. Mat quality will be inspected at Tyndall AFB before shipment to North Field.

3. Soils Testing and Surveys

After forming craters, AFESC will conduct laboratory soils tests on each crater's subgrade. This testing will include Atterberg Limits, grain size analysis, and airfield cone penetrometer measurements. Crater profiles will be recorded according to procedures outlined in Annex D.

4. Material and Equipment Preparation

Crater repair equipment (listed in Annex H) will be prepared, fueled, and staged at the intersection of the north-south taxiway and Runway 09/27. Diesel fuel for equipment will be delivered to the test site daily. Fill material will be stockpiled near the equipment staging area.

In the folded FGM repair, two crated mats will be used. These mats will be provided by AFESC and will be uncrated in the equipment staging area before the repair.

5. Data Collection Preparation

Prepare the following data collection equipment:

a. Videocameras (2),

b. Rod and Level,

c. Airfield Cone Penetrometer,

d. Troxler Moisture/Density Testing Device,

e. Sand Cone Apparatus and Sand, and

f. Data Forms.

B. FFGM REPAIR PROCEDURES

1. Crater Repair

After pretest activities are completed, the team will repair the crater using the following procedures:

_____a. Remove debris and ejecta from around the crater lip using the FEL and excavator blade and/or grader.

_____b. Perform initial surface roughness check to identify the extent of pavement to be removed. (NOTE: This step is the Upheaval Measurement Test.)

_____c. Remove upheaved pavement using an excavator bucket. Use the FEL to return debris to the crater or to push debris into a single pile which will be removed by dump trucks. (Construction debris will be taken to the dump shown in Figure 5).

_____d. Perform intermediate surface roughness check. (Note: This step is part of the Upheaval Measurement Test.)

_____e. If debris backfill is used, fill the bottom of the crater with debris 18 to 24 inches below the crater lip; level with an excavator or FEL bucket. If crater contains standing water, use ballast rock instead of debris.

_____f. Survey the crater after the debris or ballast rock is leveled.

_____g. Fill the crater with crushed stone to 4 inches above the crater lip.

_____h. Compact the crushed stone with four coverages of the 10-ton vibratory roller.

_____i. Using the grader, perform final grading by removing any excess crushed stone, leaving the repair level with the runway surface.

_____j. Complete crushed stone compaction with four additional coverages of the 10-ton vibratory roller.

_____k. Perform the quality control upheaval measurement check. (Note: This is part of the Upheaval Measurement Test.)

_____l. Survey the crater repair after final grading is completed. Measure moisture/density.

2. FFGM Mat Anchoring Procedures (Crater Repair 1)

The FFGM I repair will use the conventional mat, anchor bolts and bushings, and splice bolts and bushings. For test purposes, however, this mat will be instrumented. Instrumentation details are found in Annex J. The instrumented mat will be anchored by the instrumentation team. Once the mat is in place, only the instrumentation team is authorized access to the mat.

Anchor the mat as follows:

_____a. Using the FEL, tow the fiberglass mat over the repair. The fiberglass mat should overlap the crater by a minimum of 2 feet on each side.

_____b. Orient the mat with hinges parallel to the trafficking direction.

_____c. Anchor the fiberglass mat to the pavement as follows:

(1) Using 5/8-inch, carbide-tipped, hollow drill bits and a pneumatic drill, drill holes in the runway centered in the fiberglass mat's anchor holes.

(2) Countersink the holes to a 1-inch depth using a 1 1/2-inch diameter drill bit.

(3) Remove dust and debris using a compressed air jet.

(4) Screw the low profile threaded bushing, with washer, onto the bolt until the washer is snug against the wire ends. The wedges must be fully up before placing the bolt in the hole.

(5) Push the bolt in the hole until the bushing is seated against the fiberglass mat or the pavement, as required. The bolt may be tapped carefully with a hammer to ensure seating to the proper depth.

(6) Tighten the bushings until they are snug (35 foot-pounds of torque). DO NOT OVERTORQUE.

(7) With a rotary grinder, grind off any bolts protruding above the bushings.

_____d. For larger crater repairs (greater than 30 by 30 feet), mats may be joined together. Splice the mats BEFORE anchoring, using the following procedures:

(1) Plan the splice perpendicular to the traffic direction.

(2) Obtain a splice panel. The splice panel is a fiberglass mat panel 2 feet wide and the length of a mat edge. Embedded on

one side of the panel are two rows of threaded anchor bolts spaced 3 feet apart, corresponding to the mat anchor holes.

(3) Raise the mat's edge and slide the splice panel, with anchor bolts up, beneath the mat.

(4) Align splice bolts with splice holes.

(5) Thread joining bushings onto bolts to secure the splice panel to the mat. Do not tighten bolts.

(6) Align bolts in the splice panel with the holes in the second mat.

(7) Thread joining bushings onto the bolts to secure the splice panel to the second mat.

(8) Tighten anchor bushings on both sides of the splice.

(9) Anchor the spliced mat to the runway pavement.

_____e. Perform the final crater repair survey before loadcart proofrolling. This data will be used to determine the actual surface roughness.

_____f. Proofroll the repair, in accordance with Subsection E.

3. FFGM Mat Anchoring Procedures (Crater Repair 2)

The FFGM II repair will use the mat, with slotted anchor holes on the leading and trailing edges, anchored and spliced with modified anchor and splice bushings and bolts. Anchor the mat as follows:

_____a. Using the FEL, tow the fiberglass mat over the repair.

_____b. Orient the mat hinges 4 degrees off the MOS centerline. The fiberglass mat should overlap the crater by a minimum of 2 feet.

_____c. Anchor the fiberglass mat to the pavement as follows:

(1) Using 3/4-inch, carbide-tipped, hollow drill bits and a pneumatic drill, drill holes in the runway corresponding to the fiberglass mat's slotted anchor holes. Accurately center the pavement anchor holes 1.5 inches from the edge of the slot nearest to the mat's leading or trailing edge.

(2) Remove dust and debris using a compressed air jet.

(3) Screw the low profile threaded bushing, with washer, onto the bolt until the washer is snug against the wire ends. The wedges must be fully up before placing the bolt in the hole.

(4) Push the bolt in the hole until the bushing is seated against the fiberglass mat or the pavement, as required. The bolt may be tapped carefully with a hammer to ensure seating to the proper depth.

(5) Tighten the bushings until they are snug (35 foot-pounds of torque). DO NOT OVERTORQUE.

(6) With a rotary grinder, grind off any bolts protruding above the bushings.

_____d. For large crater repairs (greater than 30 by 30 feet), mats may by joined together using a splice panel. If a spliced mat is required, use the following procedures BEFORE anchoring the mat to the pavement:

(1) Plan the splice approximately perpendicular to the traffic direction.

(2) Obtain a splice panel. The splice panel is a fiberglass mat panel 2 feet wide and the length of the mat edge. Embedded on one side of the panel are two rows of threaded anchor bolts with the same spacing as the mat anchor holes.

(3) Raise the mat's edge and slide the splice panel, with anchor bolts up, beneath the mat.

(4) Align splice bolts with splice holes in the mat. Holes in the splice panel are not slotted.

(5) Thread joining bushings onto bolts to secure the splice panel to the mat. Do not tighten splice bolts at this time.

(6) Align anchor bolts in the splice panel with the anchor holes in the second mat.

(7) Thread joining bushings onto bolts to secure the splice panel to the second mat. For Mat I's repair, use the modified splice bushings.

(8) Tighten splice bushings on both sides of the splice.

(9) Anchor the spliced mat to the runway pavement.

_____e. Perform the final crater repair survey before loadcart proofrolling. This data will be used to determine surface roughness.

_____f. Proofroll the repair, in accordance with Subsection D.

C. DATA COLLECTION PROCEDURES

Two videocameras will be used during each crater repair to record repair procedures. Weather data will be collected from the Columbia Airport at various times during the test. Local weather variations will be observed at

North Field. Soils data will be taken, as indicated in Annex D. Other data will be collected on data forms, as required. After the repair, profiles will be taken, according to procedures outlined in Annex D.

D. POSTREPAIR ACTIVITIES

1. Loadcart Proofrolling

After completion, the repair will be proofrolled with one coverage of an F-15 loadcart, weighing 30,600 pounds with a tire pressure of 355 psi. A proofrolling coverage consists of one pass per lane over the entire repair surface. After proofrolling, surface roughness measurements and elevation profiles of the crater will be taken and compared with data taken before loadcart applications. If necessary, maintenance will be conducted to upgrade the craters to surface roughness standards before aircraft operations begin.

2. Data Collection

All data collection forms and videotapes will be returned to the data manager immediately after the test each day.

3. Repair Maintenance

If stringline checks or crater surveys indicate that a FFGM crater repair has reached the designated surface roughness sag limit, aircraft operations will be suspended and maintenance performed on the defective crater repair, according to the following maintenance procedures:

a. Crushed Stone Base Course--Excessive Rutting (Criteria)

_____(1) Survey the repair.

_____(2) Remove the mat.

_____(3) Add crushed stone to the rutted areas.

_____(4) Compact with a minimum of six coverages of a 10-ton vibratory or towed roller.

_____(5) Replace the fiberglass mat on the existing anchor bolts, if possible; if not, drive unused bolts into the pavement with a sledge hammer, redrill the anchor holes, and anchor, in accordance with mat anchoring procedures.

_____(6) Sweep area.

_____(7) Survey the repair.

b. FFGM Repair--Mat Damage Only

Fiberglass mats usually can be repaired in place.

_____(1) Remove damaged or delaminated pieces of the affected mat.

_____(2) Insert a piece of polyethylene sheet, larger than the repair area, between the mat and the underlying stone. (This sheet will act as a bond breaker.)

_____(3) Place a piece of fiberglass, larger than the repair area, beneath the mat and on top of the bond breaker.

_____(4) Place a second ply of fiberglass, the size of the repair area, on top of the first piece of fiberglass.

_____(5) Mix a small amount of polyurethane resin (with a 1- to 2-minute set time) in a 5-gallon bucket, and pour the resin over the fiberglass patch. Use just enough resin to soak the fiberglass. (Excess resin will bond the underlying stone to the mat's underside.)

_____(6) Smooth out the patch using a rubber squeegee. The resin should cure in 5 to 10 minutes.

To repair damage to the folded mat hinge, use the mat damage-repair procedures.

c. FFGM Repair--Mat Anchor Damage Only

_____(1) Drill new mat anchoring holes in the mat and pavement near the damaged anchors.

_____(2) Reanchor the mat with new anchor bolts, in accordance with the original mat anchoring procedures.

ANNEX C

UPHEAVAL MEASUREMENT TEST PROCEDURES

A. PRETEST ACTIVITIES

Before crater formation, the original runway profile will be determined from a rod and level survey (Annex D, Subsection A.1).

After crater formation, each crater will be surveyed by rod and level to determine the extent of upheaval. Survey procedures are found in Annex D, Subsection A.2. Results from this survey will be known only by the data collection team to prevent a test bias.

B. UPHEAVAL MEASUREMENT TEST

The Upheaval Measurement Test will be conducted on each crater, concurrently with the Crater Repair Test. Three teams will measure upheaval on each crater, each team using a different measurement method. Measuring Team 1 will use the super stringline, Measuring Team 2 will operate the dipstick, and Measuring Team 3 will employ the stringline method currently used in USAFE.

During the Crater Repair Test, each team will perform the following activities:

_____1. Measure the pavement upheaval according to the appropriate procedures.

_____2. Determine the points around the crater at which upheaval begins.

_____3. Record the upheaval start points on the furnished data sheet.

_____4. Compare the data sheet with the test monitor's record of upheaval start points. If the measured locations do not agree with the test monitor's record, mark the crater based on the test monitor's record.

C. DATA COLLECTION PROCEDURES

Procedures for this test will be integrated with the Crater Repair Test data collection procedures. Videocameras used in the Crater Repair Test will be used to record procedures. Times will be recorded by observers. Measured upheaval start points will be collected by the survey team and compared with the upheaval team's measured values. Equipment malfunctions will be recorded.

D. CONVENTIONAL STRINGLINE MEASUREMENTS

The stringline procedure currently used by USAFE employs a stringline and two upheaval marker posts. The team will measure upheaval according to procedures found in the <u>AFESC RRR Interim Guidance</u>, September 1984.

E. MODIFIED STRINGLINE MEASUREMENT PROCEDURES

1. Initial Measurement

a. On clear pavement, check the maximum tension that may be applied to the stringline by completing the following actions:

(1) Set the eye-bolt height on the hook base to 12 1/2 inches.

(2) Set the cable height on the winch base to 12 inches.

(3) Unwind 60 feet of cable and attach it to the eye bolt on the hook base.

(4) Have one member stand on each baseplate and winch the cable taut until one baseplate moves.

b. At the test director's signal, begin timing the event. With 60 feet of cable unwound, move to the designated crater, and begin the initial measurement.

(1) Position the bases so the cable forms a line next to, but about 8 feet away from the crater lip (see Figure B-1).

(2) Have one member stand on each baseplate, and winch the cable taut.

(3) If one baseplate moves, retighten the cable as much as possible before the baseplate moves again.

(4) When the test team signals that the bases are in position and the required cable tension has been reached, stop the clock.

c. On Data Sheet 16, record the line's height from the ground at each end, the exact cable length between stanchions, the weight of each person standing on the baseplates, and the elapsed time for the setup.

d. At the test director's signal, begin timing the event.

(1) With the aluminum measuring bar in hand, move one half the distance between the bases, and measure the distance from the ground to the cable.

(2) If this distance is less than 11 1/2 inches, the upheaval is between the current location and one baseplate.

(3) Move one half the distance between the current position and one baseplate. Continue with Paragraph e.

(4) If the measured distance is more than 11 1/2 inches, the cable is not passing over the upheaval.

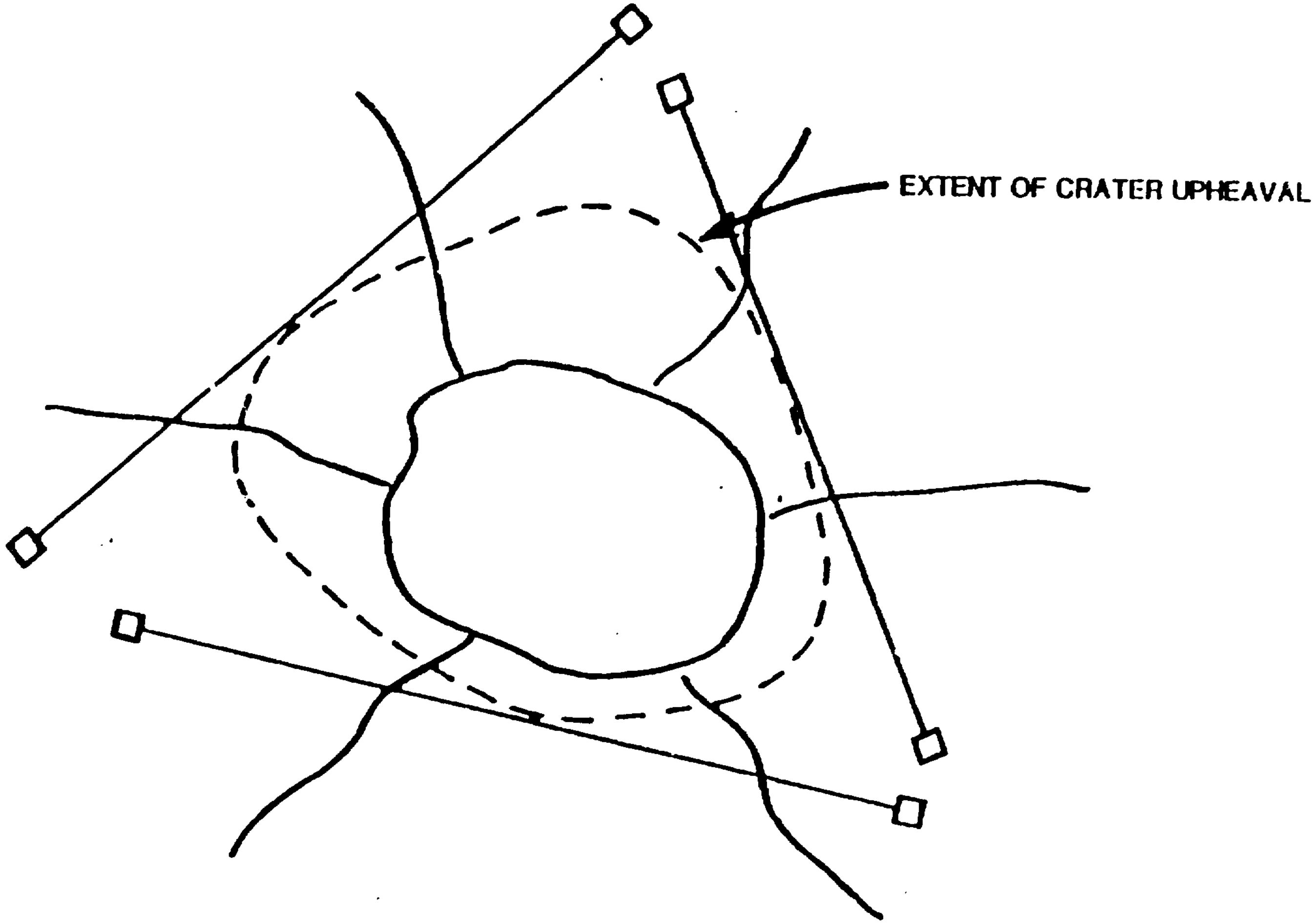


Figure B-1. Initial Measurement Using the Stringline

(5) Stop timing this event and move both bases closer to the crater (parallel to the previous line).

(6) Repeat the measuring procedure.

e. Again, measure the distance between the cable and the pavement. If the distance is greater than 11 1/2 inches, the upheaval is between the team member and the previous measurement. If the measurement is less than 11 1/2 inches, the upheaval is between the team member and the baseplate.

(1) In either case, move one half the distance between the current location and the last measurement location in the direction of the upheaval.

(2) Repeat this procedure at the new location.

(3) If the measurement is 11 1/2 inches (±1/8 inch), this is the start of upheaval. Mark this spot.

(4) Stop the stopwatch and record, on Data Sheet 16, the elapsed time for measuring.

f. Repeat procedures in Paragraphs d. and e. for the other baseplate.

g. Repeat Paragraphs b. through f. for the second measurement by turning one baseplate approximately 120 degrees and repositioning the other.

h. Repeat this procedure for the third and final location.

i. Six points now should be marked around the crater. Locate these points, and record them on Data Sheet 15.

2. Intermediate Measurement

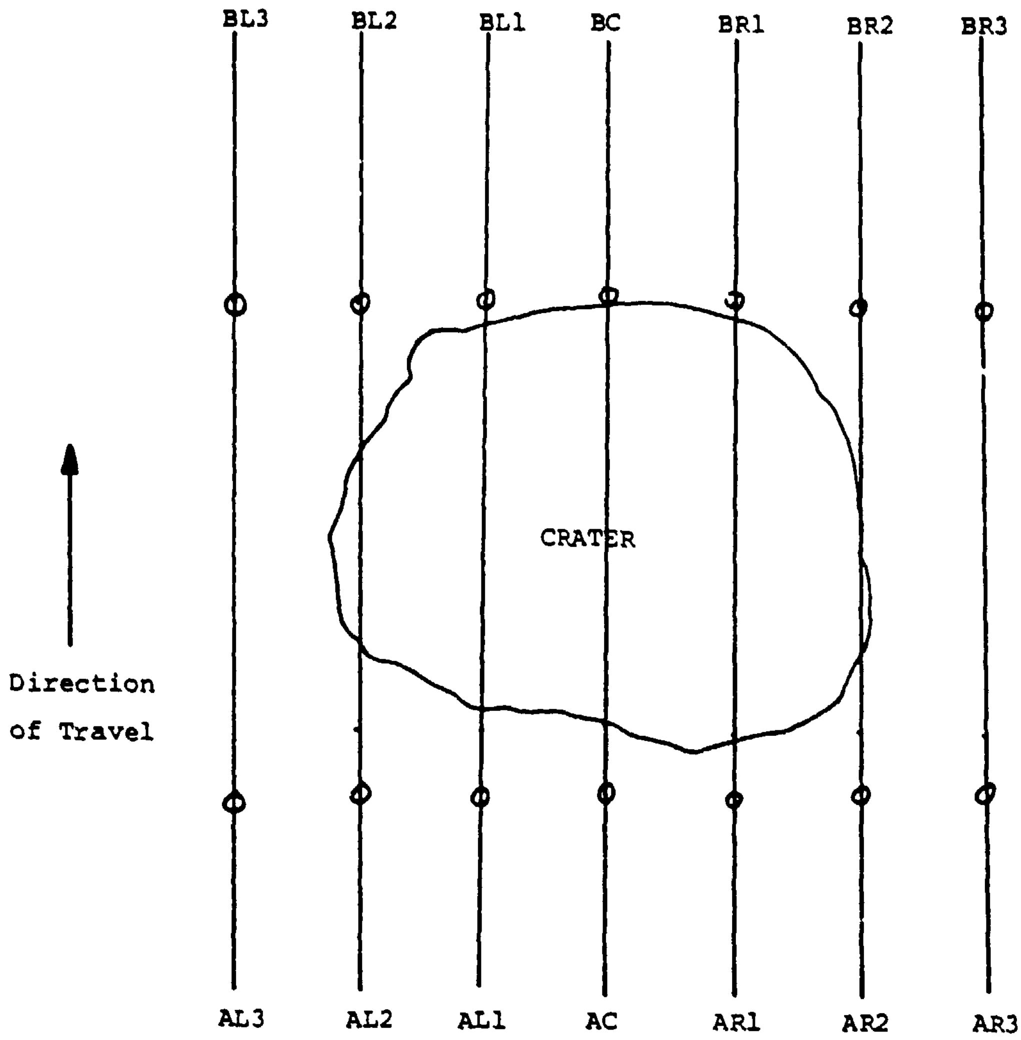
a. At the test director's signal, begin timing the following test team actions.

(1) Assume a direction for the MOS.

(2) Measure the crater width perpendicular to this direction.

(3) Take the measurement either with the tape measure across the crater or by pacing (using one pace = approximately 3 feet) outside the crater. This measurement does not have to be precise (nearest foot is fine), as long as the measurements used are consistent. The measurement is the crater width, W.

b. Locate the crater's centerline (in the assumed travel direction) by measuring 1/2 W from one crater edge (see Figure B-2). (Pacing the distances is fine.)



O - Traffic Cone

Figure B-2. Intermediate Measurement Layout for the Stringline and Dipstick

(1) Mark the centerline with a cone on both sides of the crater.

(2) Six lines (three to the right and three to the left of the centerline) then are marked parallel to this line.

(3) The distance between each line is 1/4 W (see Figure B-2). Indicate these lines with traffic cones.

(4) After the final cone has been placed, stop the stopwatch.

c. On Data Sheet 17, record the elapsed time required to complete the above measurement (intermediate layout time).

d. At the test director's signal, start the stopwatch to time the event. (The test team will have 60 feet of cable already unwound from the initial measurement. If the crater is more than 20 feet in diameter, unwind an additional length of cable so at least three times the crater width can be checked for upheaval. If the crater is less than 20 feet in diameter, use the 60-foot length.)

(1) Place a modified stringline base at each end of the centerline.

(2) Attach the free cable end to the hook base.

e. Adjust each stanchion's height so the cable clears all remaining debris, as well as the crater lip. Each stanchion must remain the same height above the pavement at each end. The vertical box on each base adjusts upward and has markings spaced 1 inch apart.

(1) If necessary, adjust the boxes the same distance upward to assure crater clearance.

(2) Stand one person on each base.

(3) Winch the cable taut until one base slips along the pavement. If the base slips, retighten the cable as much as possible.

(4) Stop the stopwatch when the test team signals that the bases are in place.

f. On Data Sheet 17, record the cable's height from the ground at each end, the weight of each person standing on the baseplates, and the setup time.

g. At the test director's signal, start the stopwatch (from 0 elapsed time), and begin measuring upheaval.

(1) With the aluminum measuring bar in hand, measure the distance from the cable to the pavement at the indicated upheaval start point. (All following reference distances will be based on a 12-inch stanchion

height. If this distance is 11 1/2 inches (±1/8 inch), the upheaval has been marked correctly. If this distance is less than 11 1/2 inches, the upheaval has been marked incorrectly. The real upheaval point is between the indicated upheaval point and the baseplate.

(2) Move one half the distance to the baseplate.

(3) Measure the cable-to-pavement distance. If it is 11 1/2 inches (±1/8 inch), mark the location as the correct start of upheaval. If it is less than 11 1/2 inches, again move one half the distance to the baseplate and remeasure.

(4) Repeat this procedure until the exact start of the upheaval is found and marked with a traffic cone.

(5) Once signaled that the initial upheaval start point is correct or that the new start point has been marked with a traffic cone, stop timing.

(6) Record the time to find this point on Data Sheet 17.

h. Move to the other side of the crater and repeat Paragraph g.

i. Move the baseplates 1/4 W, and repeat the procedures in Paragraphs d through h. Repeat this procedure for the other five lines.

j. When the extent of crater upheaval has been checked, record, on Data Sheet 15, the location of the upheaval markers (traffic cones), as was done for the initial measurement.

3. Quality Control Measurement

a. Once the crater has been repaired, and at the test director's signal, start the stopwatch, and begin the quality control measurement. (The test team already will have unwound 100 feet of cable.)

(1) Locate the previously marked centerline parallel to the assumed travel direction.

(2) Position the bases across the crater along the assumed centerline.

(3) Set the stanchion height to 12 inches.

(4) Attach the cable to the hooked end.

(5) Winch the cable taut until one baseplate slips.

(6) Retighten the cable as much as possible before the baseplate moves again.

(7) Once the test team signals that the bases are in position, stop the stopwatch.

b. On Data Sheet 17, record the grid line number, the cable height at the winch and at the hook end, the weight of each individual standing on the bases, the total cable length, and the time required to set up.

c. At the test director's signal, start the stopwatch (from 0 elapsed time) and begin to measure.

(1) Starting at one base, measure the distance between the cable and the pavement/repaired crater at 10-foot intervals.

(2) The test team member taking the measurement will call out the measurements for recording on Data Sheet 18.

(3) Record the time required to take the measurements.

(4) Repeat this procedure for the other six profile lines.

F. DIPSTICK PROCEDURES

1. Initial Measurement

a. In this process, the procedure for finding the lines on which to measure is identical to that described in Paragraphs E.2.a and b for the intermediate stringline measurement, and therefore, will not be repeated.

b. At the test director's signal, start timing the event.

(1) Obtain readings along the previously marked centerline by starting at the crater edge and moving away from the crater.

(2) Record the readings on Data Sheet 19 as the operator calls them out. Both individuals will annotate this set of readings as AC (Figure B-1).

(3) Continues taking readings until the change between two subsequent readings is less than -.1 inch for five reading pairs. When this difference is reached, the start of upheaval is located at the first reading pair.

(4) Mark the start of upheaval with a traffic cone.

(5) On Data Sheet 19, record the time required to mark the upheaval along this line.

d. Repeat this procedure for the centerline on the crater's other side. Annotate this line as BC (Figure B-1).

e. Move 1/4 W, and repeat the above procedure on the lines annotated as AR1, BR1, etc. (See Figure B-2). Continue with lines AL1, BL1, AR2, BR2, etc.

f. After outlining the upheaval, record the traffic cones' position, with respect to the crater, on Data Sheet 15.

2. Intermediate Measurement

At the test director's signal, start timing this event.

(1) Set up the Radio Shack PC-2 computer to run the data analysis program for each data set.

(2) Play back the tape recording of the profile measurements.

(3) Input the numbers to the program.

(4) Obtain a hard copy profile printout for each data set.

(5) From this printout, determine the start of upheaval.

(6) For each profile, record the distance away from the crater lip that upheaval occurs.

(7) Use this distance to locate the start of upheaval.

(8) Remark the correct start of upheaval, as necessary.

(9) On Data Sheet 19, record the time required to get the hardcopy profiles.

(10) On Data Sheet 15, record the upheaval's revised location and the time to obtain the profiles.

3. Quality Control

After the crater has been repaired, begin quality control measurements. At the test director's signal, start timing the grid lines' profile through the crater in the travel direction.

(1) For this test, take profile readings of all previous profile lines by recording the data and readings on Data Sheet 14.

(2) Start the profiling 10 feet from the indicated start of the upheaval (away from the crater).

(3) Reduce the data into profiles using the PC-2 computer.

(4) On Data Sheet 14, record the time required to complete each profile. Use a separate data sheet for each profile.

G. POSTTEST ACTIVITIES

Periodically during the flight operations, the upheaval measurement teams will measure the repair quality against the established surface roughness criteria.

ANNEX C

DEBRIS CLEARANCE PROCEDURES

A. PROCEDURES

Debris density measurements will be taken after crater formation, immediately after crater repair, after the first equipment pass, and when the FSO designates the runway operational for peacetime use. Using the procedures in Subsection C, measure the debris density around each crater immediately after crater formation. Repeat the debris density measurement immediately after each crater repair.

On the MOS designated for sweeping, perform the following actions after both craters are repaired:

_____1. Start sweeping the entire designated MOS area with one pass of the towed broom, if debris is dry and loose. Otherwise, start with a simple pass of the regenerative sweeper. (Start sweeping time).

_____2. After one complete coverage by each equipment piece, record debris distribution and density. (Data collection time-out)

_____3. Repeat towed broom and sweeper coverages until the SOF indicates that the runway is acceptable for operations. Record the number of passes for each equipment type.

_____4. Stop the clearance operation when the SOF approves runway cleanliness. (Stop sweeping time).

B. DATA COLLECTION PROCEDURES

Sweeping procedures will be timed and recorded on videotape. Debris density and distribution will be collected at the times indicated above.

C. DEBRIS DENSITY

Required equipment includes a theodolite, a Philadelphia rod, a compass, tape measures (100-foot and 50-foot), a push broom, dust pans, sample bags and tags, and a 35 mm camera.

Density measurements will be taken on a minimum of eight radials from the crater's center. Four of these radials will be aligned along the cardinal headings or along lines parallel and perpendicular to the runway heading. The remaining four radials will bisect the first four. Should an uneven distribution of ejecta occur, additional measurements will be taken along two radials defining the areas of heaviest ejecta concentration and along a radial bisecting these two radials.

_____1. Establish measurement radials before craters are exploded.

_____2. Determine sampling distances (after seeing the crater).

3. At each sample point

_____a. Place a 2- by 2-foot wooden frame over sample point.

_____b. Collect all debris within the wooden frame, down to the finest particle and place in sample bags. Tag each sample bag.

_____c. Record the distances and number of large rocks which may not lie on a sample location. Rocks should fall within the following categories (based on maximum rock dimension):

(1) Rocks larger than 12 inches

(2) Rocks larger than 9 inches, but smaller than 12 inches

(3) Rocks larger than 6 inches, but smaller than 9 inches

(4) Rocks larger than 3 inches, but smaller than 6 inches

(5) Rocks larger than 2 inches, but smaller than 3 inches

(6) Rocks larger than 1 inch, but smaller than 2 inches

_____d. Photograph each radial from the crater's edge looking out onto the debris. (Indicate, on the picture, which radial was photographed.)

_____e. Take several photographs looking toward the crater.

_____f. Photograph the sample points along a representative radial.

4. After sampling

Perform a sieve analysis on each sample, in accordance with ASTM C136. Determine the total sample weight, then sieve the entire sample. Each sample will be sieved through 1.5 inch, 1.0 inch, 0.75 inch, 0.5 inch, 0.25 inch, Number 4, Number 40, Number 60, Number 100, and Number 200 standard sieves. For individual rocks too large for the sieve analysis, record the rock's weight and its three major dimensions.

D. POSTTEST

Additional runway sweeping may be required because of the time between the final crater repair and the start of aircraft operations. The additional sweeping is not part of the data collection effort.

ANNEX D

SOILS TESTS AND CRATER REPAIR SURVEY PROCEDURES

A. SURVEYING PROCEDURES

1. Initial Runway Survey

An initial runway survey has been conducted by AFESC. The team, using a rod and level, surveyed along five lines, 12.5 feet apart, with the first survey line 25 feet from the runway's north edge and the last survey line on the existing runway centerline. The lines extend from the intersection of Runway 09/27 and the north-south taxiway out a minimum of 4000 feet. Elevations were taken for the corners of each runway slab within the survey area. Benchmarks are identified by paint on the pavement.

2. Crater Profile

After crater formation, the AFESC survey team will profile each crater. For each crater, the team will measure elevations along predetermined profile lines using a rod and level or theodolite.

To compare the results of the super stringline and dipstick methods of upheaval determination, pattern the profile lines parallel to the traffic direction. Proceed as follows:

_____a. Take a profile along the crater centerline in the traffic direction.

_____(1) Begin the profile at least 25 feet from the crater's edge.

_____(2) Take a survey at 1-foot intervals.

_____(3) Shoot all elevations from a permanent or temporary benchmark.

_____(4) Continue the profile across the crater, to a minimum of 25 feet past the crater's edge.

_____b. Repeat Profile Instruction (1) along a line parallel to the centerline. Offset the remaining profile lines 5 feet from each other to cover the crater.

_____c. Run three profiles, according to Instruction (1), perpendicular to the traffic line. One profile should be taken across the crater's center and the remaining profile at the crater's edge.

_____d. Benchmarks must be recorded on the data sheets.

3. Sixteen-Point Survey

A 16-point elevation survey will be taken by AFESC at various times during each crater repair (see Annex A for the time to employ the 16-point survey). The purpose of a 16-point survey is to monitor the crater's structure during the repair without resorting to a field profile. Elevations are measured with rod and levels using the following procedure:

_____a. Define 16 data points on the repair surface. The 16 data points should be arranged in a 4- by -4 grid with each point 10 feet from the adjacent point in the row and each row 10 feet from adjacent rows. Data point location should be measured from a reference point outside the crater, since elevation and soil sampling will occur at the same 16 points on the crushed stone surface layer.

_____b. Beginning at the first designated point,

_____(1) Shoot the elevations from a permanent or temporary benchmark.

_____(2) Record benchmark and elevation on the data sheet.

_____(3) Reduce all elevations to true elevation.

_____c. Repeat Step b for each of the 16 data points.

The 16 data points also will represent locations for soils measurements to be made during the repair (see Section B of this Annex). Variations to the 16-point pattern must be approved by the test director.

4. Repair Profiles

After each crater repair and at the end of each day's trafficking, the AFESC survey team will profile the repair to determine the final surface elevation. For each crater, the team, using a rod and level, will measure and record elevations along a minimum of six profile lines. In addition, upheaval measurement teams will record the repair's profile for comparison with the rod and level profiles.

The profiles will be taken parallel to the crater's centerline in the traffic direction. Profile lines will extend a minimum of 25 feet beyond each crater edge. Elevations will be recorded at 1-foot intervals. Mat surface elevations will be recorded under load (use a pickup truck to depress the mat). Profile results will include benchmark measurements.

B. SOILS TEST

1. Moisture Density

The two methods of measuring moisture content and density of the crushed stone material during the crater repair test are the Troxler nuclear moisture density gauge and the sand cone method. Use of the Troxler gauge

(Model 3411B) is preferred because of the sampling speed. Sand cone readings will be taken at the test director's discretion, in accordance with ASTM-Test Designation D-1556. Moisture and density values will be recorded during each crater repair. For the Troxler gauge method, 16 data points will be recorded for each measurement series. Data points will correspond to the 16-point elevation survey (Subsection A.3. of this annex). Location of the sand cone measurement points will be specified by the test director. The test director must approve any deviations to the data collection procedures.

2. Airfield Index Procedure

Before crater repair begins (see Annex A), airfield cone penetrometer readings within the crater subgrade will be recorded. Sixteen locations, corresponding to the 16-point elevation survey (Subsection A.3), will be selected.

3. Proctor Test

A minimum of two 5-point proctor tests will be conducted on the crushed stone material, in accordance with ASTM-D 1557, Method A.

4. Grain Size Analysis and Soil Classification

Before crater repair, natural subgrade soil samples will be collected and classified, in accordance with ASTM D2487, to include complete grain size analyses and Atterberg limits. A minimum of two samples shall be taken from each crater.

Before testing, all aggregate materials, including spall aggregate, ballast rock, chipped stone, and crushed stone shall be tested for grain size distribution, in accordance with ASTM C-136, D-422, and C-702. A minimum of two tests shall be run or one for each 100 tons of purchased material.

5. Sieve Analysis

Sieve analyses will be conducted in accordance with ASTM Test Designation D-422.

6. Void Ratio Determination

Specific gravity tests will be conducted in accordance with ASTM D-853.

D. REPAIR SAG DETERMINATION (STRINGLINE)

For expendiency between aircraft passes, repair monitors will measure repair sag using the conventional stringline method (Interim Guidance). If time permits, the upheaval measurement teams also will record sag using the super stringline and the dipstick.

ANNEX E

GROUND TEAM PROCEDURES DURING AIRCRAFT OPERATIONS

A. PRETEST ACTIVITIES

Each day, before aircraft operations, the ground team will perform the following actions:

1. Verify communications' operability.

2. Verify video recorders' operability.

3. Verify mat instrumentation.

4. Inspect for FOD and sweep the main runway, Runway 09/27, and taxiways, if required.

5. Collect aircraft weight and servicing data.

B. PROCEDURES DURING AIRCRAFT OPERATIONS

1. Repair Checks

After every aircraft taxi pass, for at least the first three passes, and every 10th pass thereafter, the repair monitors will examine each crater and spall closely for FOD and excessive sag. The monitors will measure the craters with a stringline to ensure adherence to surface roughness criteria. Also, the monitors will check the anchor bolts' tightness on each mat. If the bolts can be turned by hand, they must be retorqued and the loose bolt's location indicated on the data sheet.

2. Jet-Blast Event

The repair will be inspected after each jet-blast event.

3. Hot Brakes Prevention

Aircraft will be monitored for hot brakes after initial landing and between test events. Optical pyrometer measurements will be taken in the designated hot brake area (See Figure 5). During pyrometer readings, the aircraft wheels will be chocked and the brakes released. If the test temperature limits are approached, the tires and brakes will be cooled by blower.

4. Vehicle Authorization

To preclude FOD during aircraft trafficking, only designated "clean" vehicles will be authorized on pavement surfaces in the test area. Authorized vehicles will be identified by a temporary ID issued by the test director.

ANNEX G

CRATER AND SPALL FORMATION PROCEDURES

A. CRATER FORMATION

An Operating Instruction (OI) for explosive crater formation will be developed by the 823 CESHR and approved by the Wing Safety Officer at Charleston AFB, SC.

B. SPALL FORMATION

A total of 175 spalls will be jackhammered into Runway 09/27 before the test start. Before the test, the project officer in charge of the spall repair system development will identify spall sizes and locations on the pavement using spray paint. Spalls will be numbered and sizes recorded. Each spall, as it is formed, will be filled with water and checked for leaks. Leaking spalls (losing greater than or equal to 0.5 inch of water in 5 minutes) will not be used as test spalls and will be repaired by other means.

Following training and one spall test event, some repaired spalls will be jackhammered out to create additional spalls for completing the spall test. Solid polymer will be disposed of in a designated location.

ANNEX H

TEST LOGISTICS

This section details the resources required for the test. Included are lists of equipment, materials, and manpower required for each test; an overall summary; and an indication of the resource source.

TABLE H-1. MAJOR TEST EQUIPMENT

ITEM	QTY	OPR	SOURCE	NOTE
A. Crater Repair				
RRR Excavator	1	AFESC/RDCO	AFESC/DEY	
2 1/2 yd^3 FEL	2	BDM	Rental	With forks
10-ton Vib. Roller	1	AFESC/RDCO	AFESC/RDCO	
Pickup Truck	1	AFESC/RDCO	AFESC/RDCO	
Air Compressor	1	AFESC/RDCO	AFESC/RDCO	
Anchoring Kit	1	BDM	Inventory	See detailed equipment list
2 1/2 yd FEL	1	AFESC/RDCO	AFESC/RDCO	
8 yd^3 Dump Truck	1	N. Field	N. Field	Substitute three 5-ton trucks
Dump Truck	1	BDM	Rental	
FEL Forklift Attachment	1	AFESC/RDCO	AFESC/RDCO	
7 1/2-ton Tractor	1	AFESC/RDCO	AFESC/RDCO	
22-ton Trailer	1	AFESC/RDCO	AFESC/RDCO	
Water Truck/Trailer	1	AFESC/DEY	437 ABG/DEM	
Grader	1	N. Field	N. Field	
Line Truck With Auger	1	AFESC/DEY	437 ABG/DEM	
Generator, Portable 5 kw		AFESC/RDCO	AFESC/RDCO	
Misc. Equipment		BDM	Various	See detailed list
B. Upheaval Measurement				
Dipstick	1	BDM	AFESC/DEY	
Improved Stringline (Set)	1	BDM	AFESC/DEY	
Stringline (Set)	1	BDM	AFESC/DEY	
C. Runway Debris Clearance				
Grader	1	N. Field	N. Field	From A above
Regenerative (Vacuum) Sweeper	1	AFESC/DEY	437 ABG/DEM	TEMKO sweeper
Towed Broom	1	AFESC/RDCO	AFESC/RDCO	

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TABLE H-1. MAJOR TEST EQUIPMENT (CONCLUDED)

ITEM	QTY	OPR	SOURCE	NOTE
D. Spall Repair				
Pickup Truck (1/2 ton)	1	AFESC/DEY	AFESC/DEY	
Utility Trailer (2 ton)	1	AFESC/DEY	AFESC/DEY	
Air Compressor and Hose	1	BDM	Rental	
with Spall-cleaning Nozzle	1	AFESC/DEY	AFESC/DEY	
Drum Dispensing Hardware (Set)	4	BDM	AFESC/RDCO	Per field manual
Dump Truck	1	N. FIELD	N. FIELD	Same as in Section A
Spall Repair Equipment Set	1	BDM	Various	See Spall Repair Procedures Document
E. MOS Marking				
Paint Striper	1	AFESC/DEY	AFESC/DEY	
Pickup Truck	1	AFESC/RDCO	AFESC/RDCO	With pintle hook (Same as Sec. A)
MOS Marker Trailer	1	AFESC/DEY	AFESC/DEY	Utility trailer with side gates
Edge Markers	100	BDM	BDM	
Distance-to-go Markers	18	BDM	BDM	
Station Markers (Reference)	340	BDM	BDM	
Additional MOS Marking Equip.		BDM	Various	See MOS marking procedures
F. Aircraft Operations				
Portable TACAN	1	240 CCS	240 CCS	
VASI	1	823 CESHR	823 CESHR	
Arresting Barrier	1	823 CESHR	823 CESHR	
Blower	2	AFESC/DEY	437 ABG/DEM	

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TABLE H-2. TEST MATERIALS

ITEM	QTY	OPR	SOURCE	NOTE
A. Crater Repair				
Folded Mats (30 by 54 feet)	6	AFESC/DEY	AFESC/DEY	Polyester
Anchor Bolts, Regular	250	BDM	Inventory/ Purchase	
Anchor Bushings, Regular	200	BDM	Inventory/ Purchase	
Anchor Bolts, Modified	250	BDM	Purchase	
Anchor Bushings, Modified	200	BDM	Purchase	
Crater Fill Material:				
Crushed Stone (tons)	350	AFESC/DEY	Local	
Ballast Rock (tons)	400	AFESC/DEY	Local	
B. Upheaval Measurement				
Miscellaneous Items		BDM	BDM	See detail list
C. Runway Debris Clearance				
NONE				
D. Spall Repair				
Polyurethane Kits	13	BDM	Ashland	
Catalyst (gal.)	20	BDM	Ashland	
Aggregate, ASTM No. 6 (ton)	20	AFESC/DEY	Local	Washed
Catalyst Measuring Bottles	5/kit	AFESC/DEY	AFESC/DEY	
Sand Bags		AFESC/RDCO	AFESC/RDCO	For aggregate

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TABLE H-2. TEST MATERIALS (CONCLUDED)

ITEM	QTY	OPR	SOURCE	NOTE
E. MOS Marking				
Paint, Yellow (gal.)	150	BDM	BDM	
Paint, White (gal.)	1100	BDM	BDM	
Paint, Black (gal.)	550	BDM	BDM	
Solvents (gal.)	220	BDM	BDM	
Glass Beads (lb.)	6000	AFESC/DEY	AFESC/DEY	
F. Support				
Diesel Fuel for Equipment	As Req.	BDM	Local	
Aircraft Fuel	As Req.	USAFTAWC	9th AF	

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TABLE H-3. SUPPORT EQUIPMENT

	ITEM	QTY	OPR	SOURCE	NOTE
A.	Loadcart, F-15	1	AFESC/RDCO	AFESC/RDCO	
B.	Hazardous Waste Disposal				
	55-gal. Drum	3	BDM	BDM	
	Overpack Drum	3	BDM	BDM	
	Absorbant Material (Overpack drum)	1	BDM	BDM	
C.	Safety				
	Ear Protectors	23	AFESC/RDCO	AFESC/RDCO	FOR DATA COLLECTORS
	Optical Pyrometer	1	USAFTAWC	3246 TZPT	
	Full-face Respirators with Organic Vapor Filter	6	BDM	AFESC/RDCO	
D.	Area Lighting Kit	1	BDM	Rental	
E.	Mil van (or Trailer)	1	AFESC/RDCO	AFESC/RDCO	
	Tractor	1	AFESC/RDCO	AFESC/RDCO	
F.	Headset Radios with Extra Batteries	6	BDM	AFESC/RDCO	
G.	Chemical Toilets	3	AFESC/DEY	AFESC/DEY	

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TABLE H-4. DATA COLLECTION EQUIPMENT

ITEM	QTY	OPR	SOURCE	NOTE
A. Test Observation				
Towers (Scaffolding)	2	BDM	Rental	Approximately 20 feet high
High-Speed Video	2	3246 TZPT	3246 TZPT	No contract for shipping
High-Speed Cameras	3	3246 TZPT	3246 TZPT	
Video Recorders (set)	3	BDM	AFESC/RDCO	Set includes camera, recorder, and tripod two active, one spare
Binoculars	6 (min)	BDM	BDM	
Stopwatches	4	BDM	BDM	
String check devices	3	BDM	BDM	
Data Forms	1 Box	BDM	BDM	
Surveying Equipment		BDM	AFESC/RDCO	
Torque Wrenches	4	BDM		For anchor bolt torques
B. Test Communications				
Radios, FM, Portable with chargers	8	BDM	AFESC/RDCO	
C. Data Analysis				
Video Monitor	1	BDM	AFESC/RDCO	
Video Tuner	1	BDM	AFESC/RDCO	
Portable Computer	1	BDM	BDM	
Printer	1	BDM	BDM	

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TABLE H-4. DATA COLLECTION EQUIPMENT (CONCLUDED)

ITEM	QTY	O.R	SOURCE	NOTE
D. Soils-Testing Equipment				
Nuclear Moisture Density Gauge	1	BDM	AFESC/RDCO	Troxler
Airfield Penetrometer	1 set	BDM	AFESC/RDCO	
Tape measure (100 ft and 50 ft)	4 ea	BDM	AFESC/RDCO	
E. Miscellaneous Equipment		BDM	AFESC/RDCO	See detailed list
F. Support				
Photocopy Machine	1	BDM	Rental	
Weather Station	1	AFESC/DEY	AFESC/DEY	Onsite
G. Instrumentation				
Van	1	AFESC/RDCO	AFESC/RDCO	
Instrumented Bolts and Bushings	50	BDM	Purchase	
Wire	15,000 ft	BDM	Purchase	
Strain Gauges	80	AFESC/RDCO	AFESC/RDCO	

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TABLE H-5. MANPOWER REQUIREMENTS - PRETEST WEEK

AFSC	TOTAL	FUNCTION	SOURCE
55171	1	Supervisor	9th AF
5515x	2	Dump Truck Operators/ Water Truck/Tractor Trailer	9th AF
Any	6	Spall Repair/Upheaval Measurement	9th AF
	9		

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TABLE H-6. MANPOWER REQUIREMENTS - TEST WEEK 1

AFSC	TOTAL	FUNCTION	SOURCE
55171	1	Supervisor	9th AF
	1	Supervisor	AFESC/RDCO
5515x	1	Excavator Operator	AFESC/RDCO
	1	4 yd^3 Loader Operator	AFESC/RDCO
	2	2 1/2 yd^3 Loader Operator	9th AF
	2	Dump Operators/Water Truck/Tractor Trailer	9th AF
	1	Grader Operat[illegible]/Debris Clearance	9th AF
	2	Sweeper [illegible]/Debris Clearance	9th AF
	1	Roller Op[illegible]/Loa[illegible] Operator	AFESC/RDCO
55350	3	Upheaval Measurement/Mat Anchor/Laborers	9th AF
553xx	2	MOS Marking	9th AF
55250	2	Paint Machine Operator	9th AF
Any	6	Spall Repair/Crater Repair Helpers	9th AF
	2	MOS Marking	9th AF
	2	Instrumentation Specialists	AFESC/RDCO
	29		

NOTE: This table excludes data collectors. See Annex F for data collection manpower requirements.

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TABLE H-7. MANPOWER REQUIREMENTS - TEST WEEK 2

AFSC	TOTAL	FUNCTION	SOURCE
55171	1	Supervisor	9th AF
	1	Supervisor	AFESC/RDCO
5515x	1	Grader Operator	9th AF
		4 yd^3 FEL Operator	9th AF
	1	Roller Operator/Loadcart Operator	AFESC/RDCO
	2	Sweeper Operator	AFESC/RDCO
553xx	1	MOS Marking	9th AF
55250	1	Paint Machine Operator	9th AF
Any	1	MOS Marking	9th AF
	2	Instrumentation Specialists	AFESC/RDCO
	11		

NOTE: This table excludes data collectors. See Annex F for data collection manpower requirements.

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ANNEX I

TEST SCHEDULE

Figure I-1 illustrates the detailed test schedule. Figure I-2 illustrates key pretest support activities, and Figure I-3 illustrates posttest support activities. Runway restoration is scheduled for the 2 months following the last test event.

The test director will contact 437 ABG/DOTX daily to obtain the scheduled North Field missions. Runway 09/27 will be closed until restoration is completed; however, this should not impact normal North Field operations.

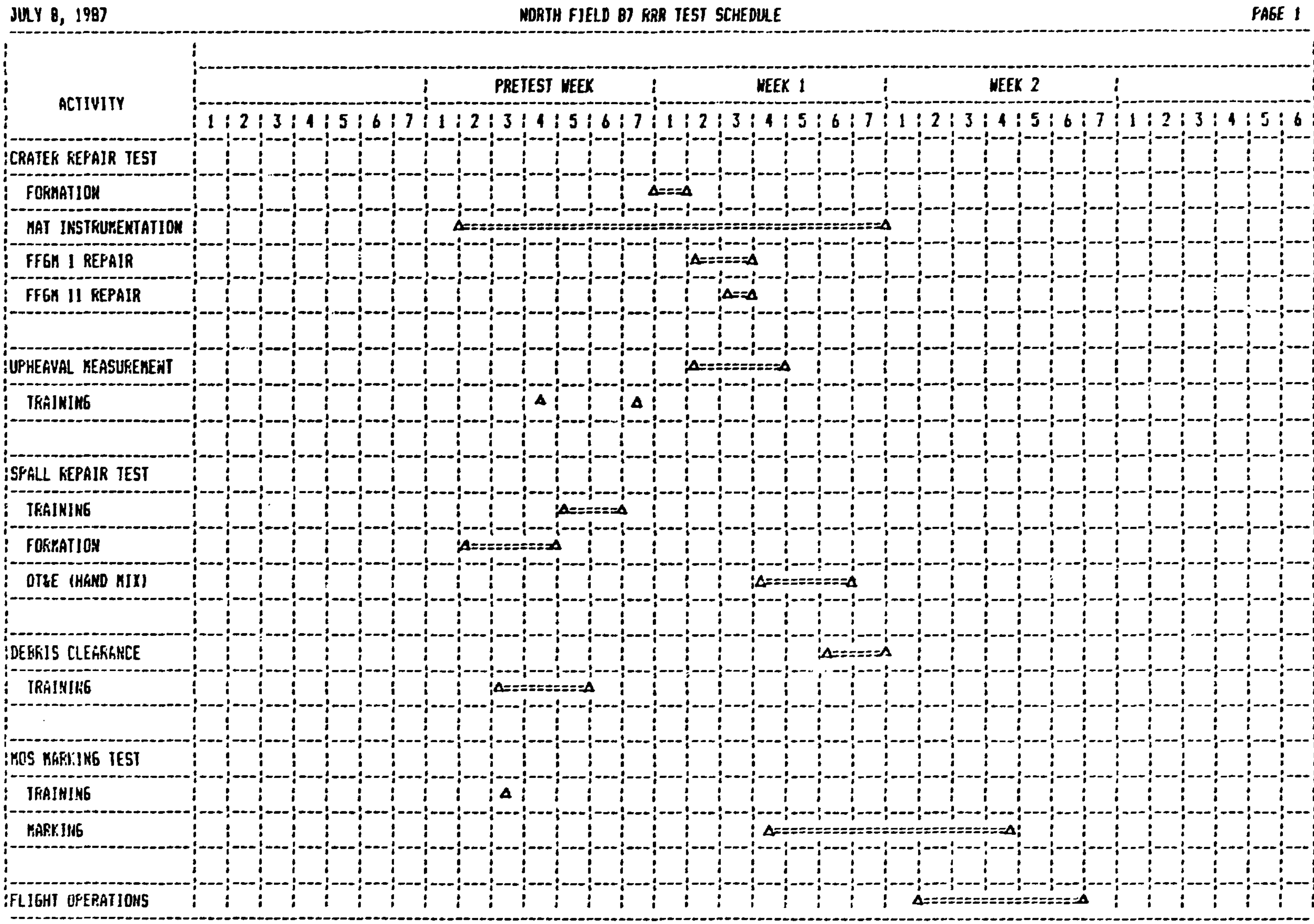

Figure I-1. North Field 87 RRR Test Schedule

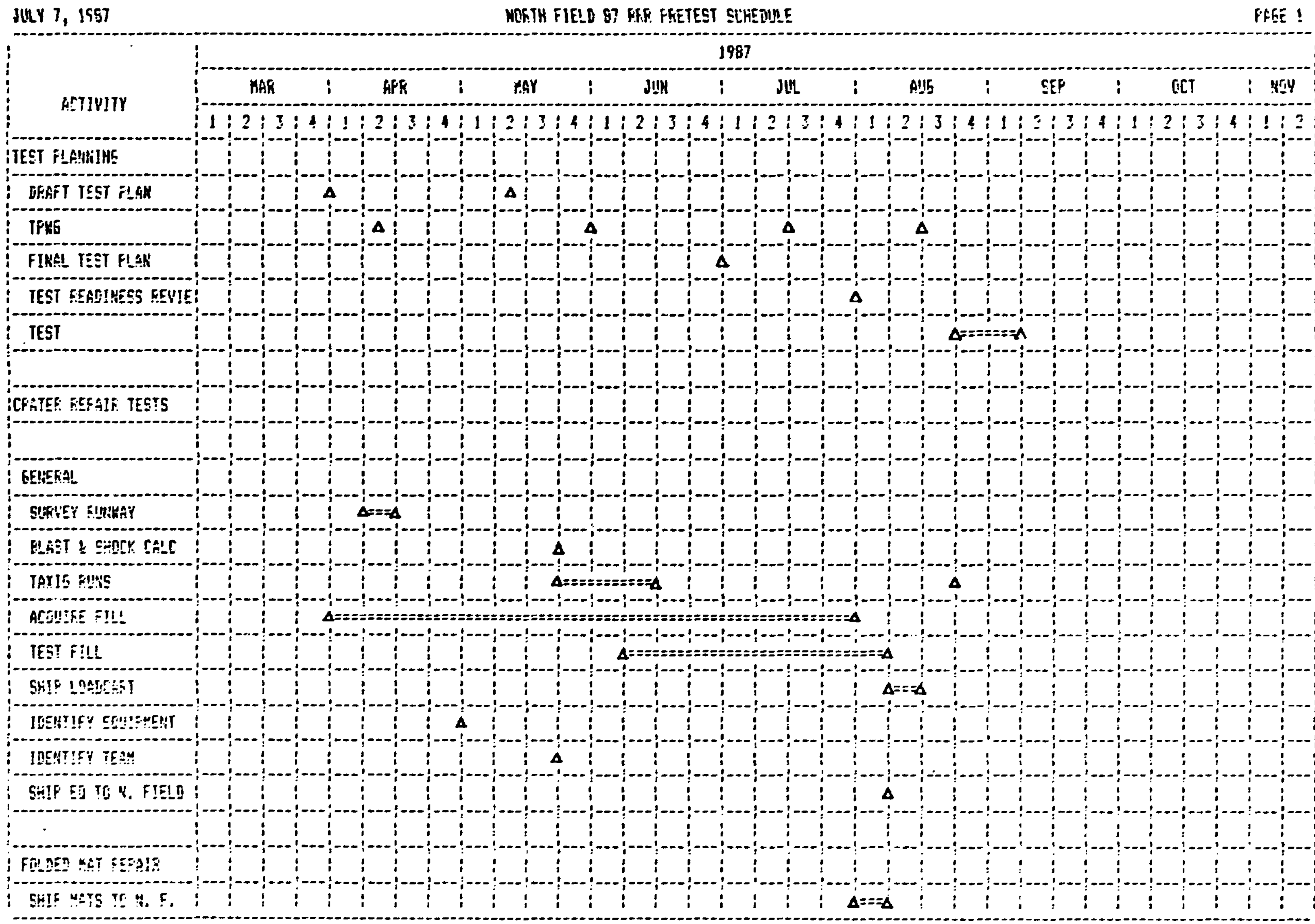

Figure I-2. North Field 87 RRR Pretest Schedule

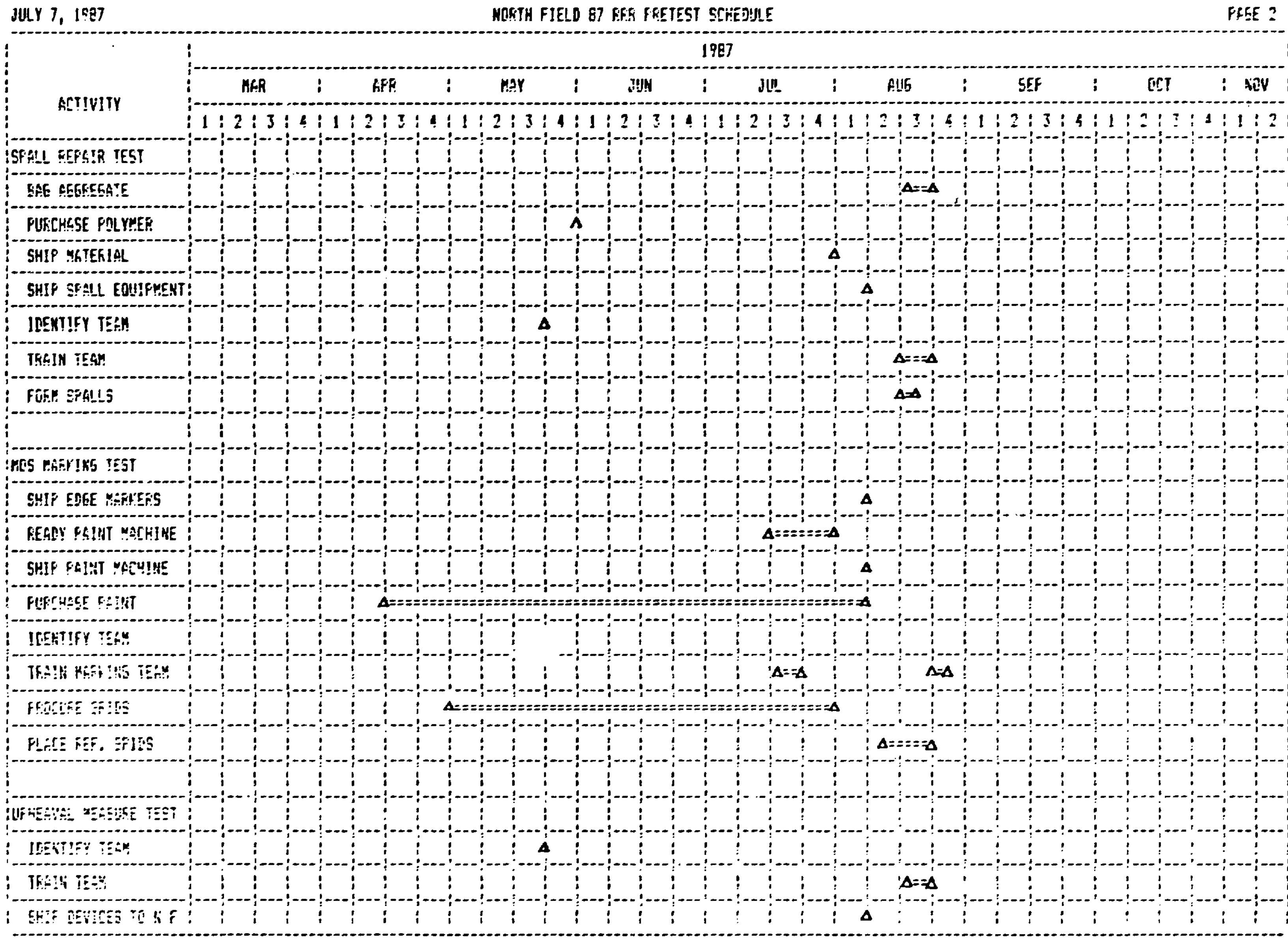

Figure I-2. North Field 87 RRR Pretest Schedule (Continued)

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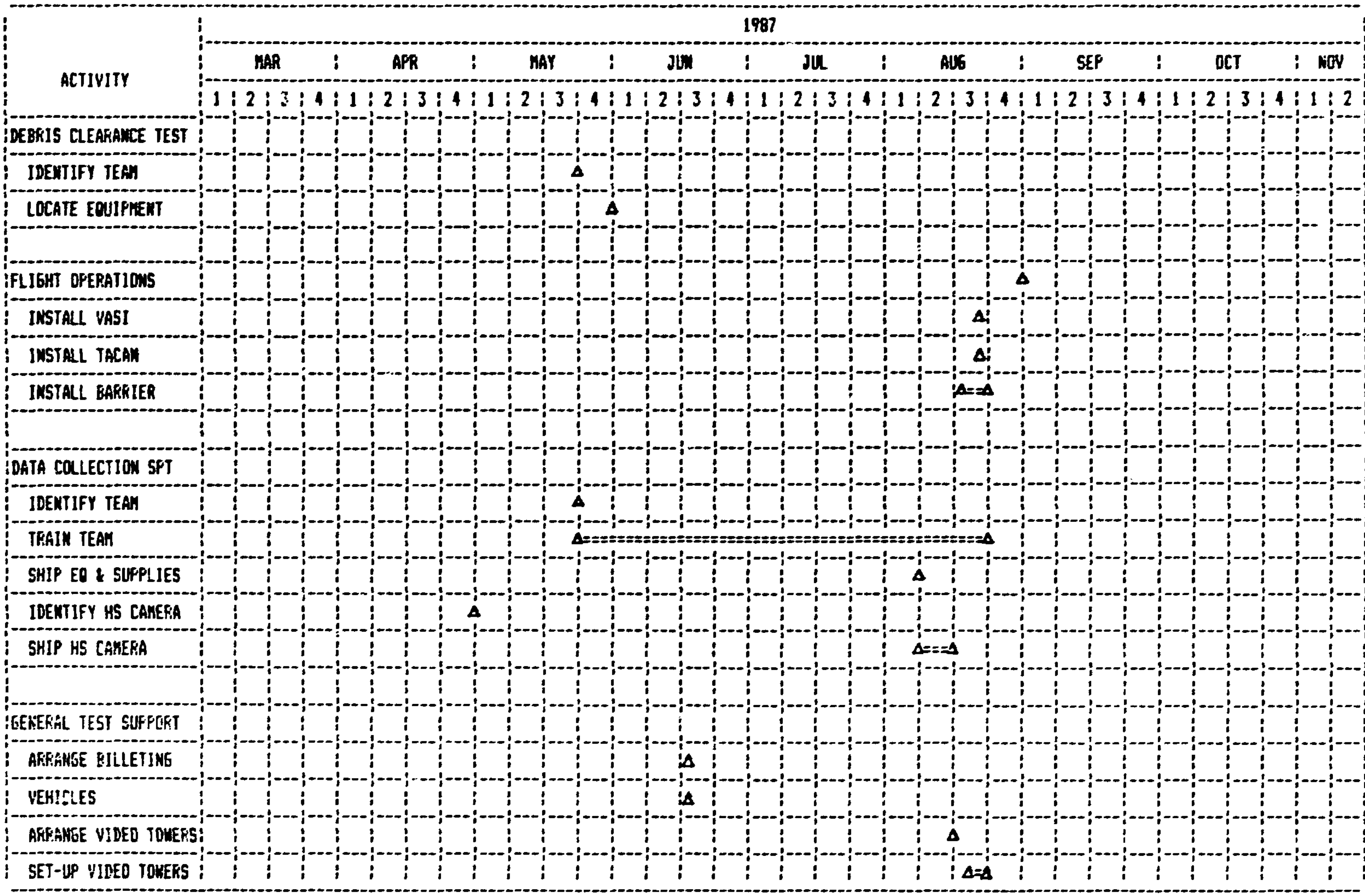

Figure I-2. North Field 87 RRR Pretest Schedule (Concluded)

JULY 7, 1987 NORTH FIELD 87 POSTTEST SCHEDULE PAGE 1

	1987																				1988													
ACTIVITY	AUG				SEP				OCT				NOV				DEC				JAN				FEB				MAR				APR	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
NORTH FIELD TEST				Δ===	===Δ																													
BRIEF RESULTS								Δ																										
DRAFT TEST REPORT																		Δ																
SHIP EQUIPMENT						Δ===	===Δ																											
SHIP HAZARDOUS WASTE						Δ==Δ																												
RESTORE AIRFIELD						Δ===	===	===	===	===	===	===	===Δ																					

Figure I-3. North Field 87 RRR Posttest Schedule

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ANNEX J

MAT INSTRUMENTATION

To measure mat deformation and anchor bolt loads during aircraft trafficking, the polyester FFGM, covering Crater 1, will be instrumented. This annex contains details of the instrumentation system.

A. INSTRUMENTATION SYSTEM DESCRIPTION

The mat instrumentation system consists of the strain gauge array on the FFGM, instrumented anchor bolts, instrumentation cables, and an AFESC/RDCO-provided instrumentation van containing conditioning amplifiers and a data acquistion system. The mat sensors are connected to the instrumentation van by a detachable, 200-foot instrumentation cable. Figure J-1 illustrates the functional diagram of the instrumentation system. A maximum of 50 channels will be monitored, according to the designation shown in Table J-1.

1. Mat Sensors

The FFGM will be instrumented, as shown in Figure J-2. Rossettes and axial gauges (350 and 1000 ohm) will be used for instrumentation. The gauges and mat instrumentation cables will be installed on site during the pretest week. Gauge and mat instrumentation cable installation will be carried out in accordance with the manufacturer's recommendations (severe environment) and the results of the field preparation tests. The instrumented mat will be anchored in position following the anchor bolt calibration tests.

In addition tc the FFGM-mounted strain gauges, instrumented anchor bolts will be installed, as indicated in Figure J-2. The instrumented anchor bolts consist of oversized bolts instrumented with three axial gauges and field-installed, as shown in Figure J-3. The anchor bolts will be placed after Crater 1 is proofrolled.

2. Instrumentation Van

For this test series, the van will be configured with a 96-channel data acquistion system, 50 single-channel conditioning amplifiers, a 14-channel analog tape recorder, a dual-channel digital oscilloscope, a plotter, a dot-matrix printer, a voltmeter, and miscellaneous instrumentation equipment (cables, adapters, etc.). The tape recorder will serve as a backup to the data acquistion system. During the monitoring of aircraft trafficking, the instrumentation van will be located approximately 200 feet south of Crater 1. During MAC scheduled air drops, the instrumentation van will be disconnected from the mat sensors and relocated to the equipment staging area.

3. Main Instrumentation Cable

The instrumented mat will be connected to the van by the main instrumentation cable. The cable will be constructed before the field event and will consist of 50 dual-twisted pairs of individual cables (200 feet).

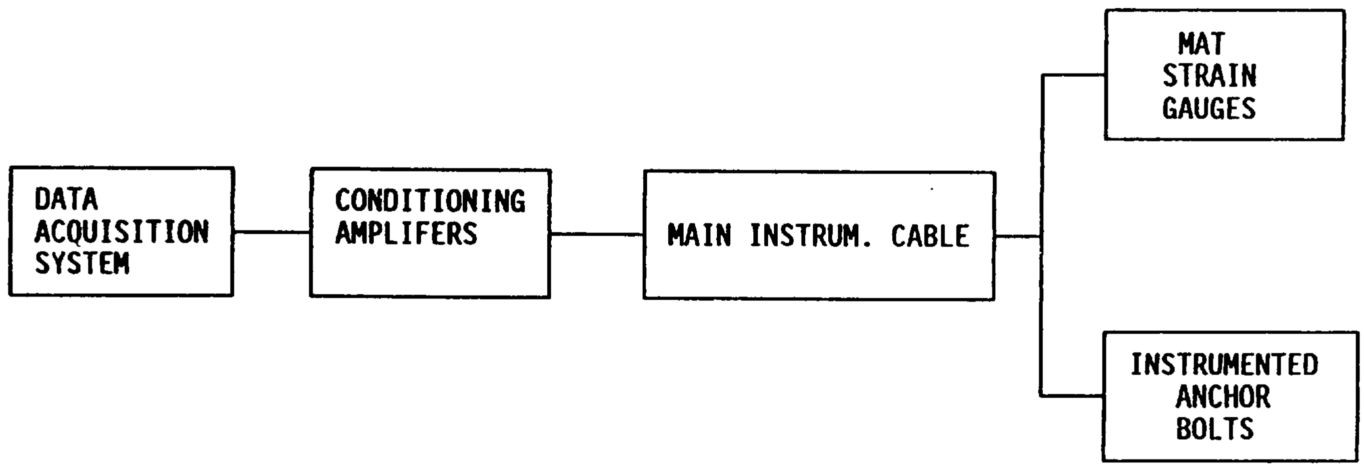

FIGURE J-1. INSTRUMENTATION SYSTEM CONFIGURATION

TABLE J-1. MAT INSTRUMENTATION CHANNEL

CHANNEL	FUNCTION	SENSOR	DESCRIPTON/LOCATION	RANGE
1				
2				
3				
4				
5				
6				
7				
8	Details of Mat Instrumentation will be determined during			
9	pretest analysis.			
10				
11				
12				
13				
14				
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24				
25				
26				
27				
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29				
30				
31				
32				
33				
34				
35				
36				
37				

TABLE J-1. MAT INSTRUMENTATION CHANNEL (CONCLUDED)

CHANNEL	FUNCTION	SENSOR	DESCRIPTON/LOCATION	RANGE
38				
39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				

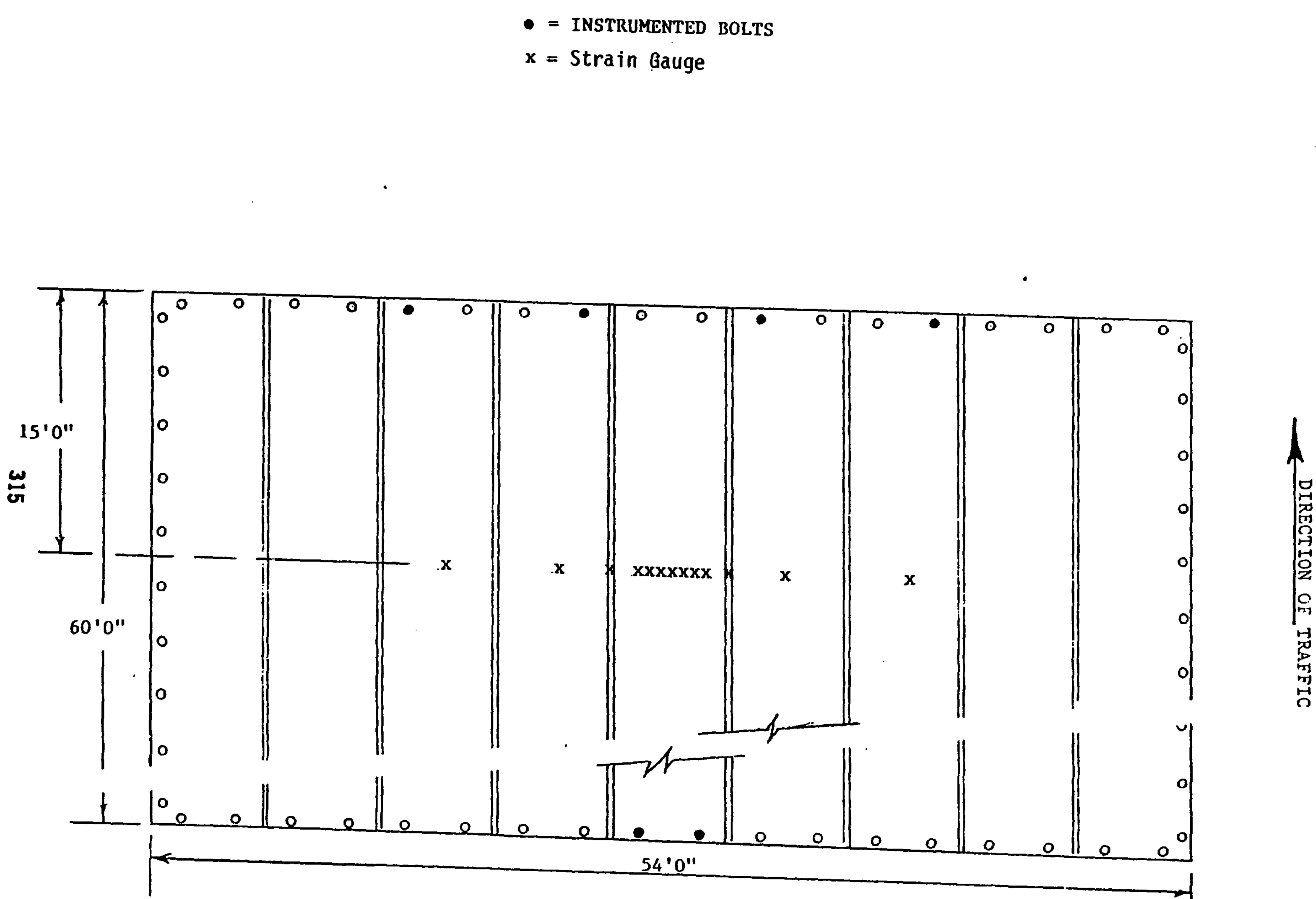
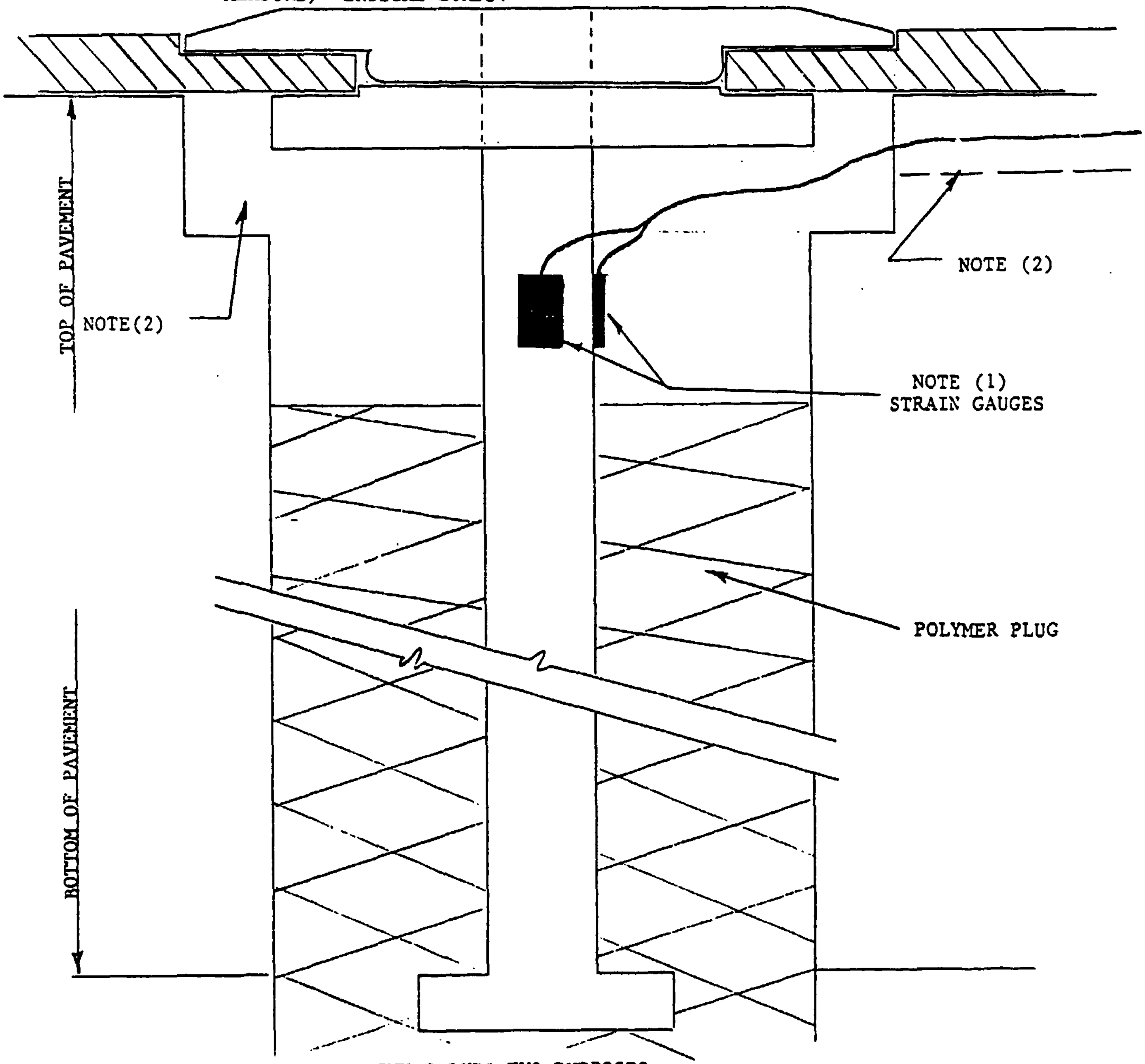


Figure J-2. Strain Gauge and Instrumented Bolt Locations

NOTES: (1) BUSHINGS ACT AS JAM NUTS AND HOLD MAT SECURELY TO BOLT BUT DO NOT PIN MAT TO THE PAVEMENT. SLIDING FORCE FROM MAT IS CARRIED BY THE BOLT WHICH BENDS ELASTICALLY. BENDING CAN BE CONVERTED, THROUGH CALIBRATION, TO HORIZONTAL FORCE. A SECOND STRAIN GAUGE 180° AWAY AND AT THE SAME LEVEL MIGHT MAKE IT POSSIBLE TO SUBTRACT OUT (AND MEASURE) VERTICAL LOADS.



(2) THIS COUNTERSINK SERVES TWO PURPOSES:
(A) PREVENTS BOLT FROM CONTACTING PAVEMENT SURFACE WHEN BENT.
(B) PROVIDES CLEARANCE FOR WIRES WHICH CAN STAY UNDER MAT AND RUN THRU A GROOVE CUT IN CONCRETE ALONG UNDER MAT EDGE. FILL GROOVE WITH POLYMER

Figure J-3. Instrumented Bolt Installation

Each twisted pair will be shielded individually. The main cable will terminate to the instrumentation van with 50 MS-type connectors into the individual conditioning amplifiers. The instrumented mat end of the main cable will consist of four connectors: two for the instrumented anchor bolt lines and two in support of the mat instrumentation channels. All quick-disconnects will be shielded and moisture proofed. The main instrumentation cable will be protected by mat splice panels anchored to the runway.

B. INSTRUMENTATION CALIBRATION PROCEDURES

Instrumentation calibration is composed of equipment calibration/checkout and sensor calibration. All instrumentation equipment used in this test series will be calibrated and/or checked at the RDCO instrumentation shop before transportation to the test site. The mat strain gauges and instrumented bolts will be field-calibrated using test setup and procedures established during the field preparation tests. The anchor bolt calibration will be conducted before instrumenting mat anchors. The mat strain gauge calibration tests will be conducted immediately following the anchoring of the mat leading edge. Field calibration will be repeated, as required, and within testing constraints.

C. TEST DATA COLLECTION

The mat gauges and instrumented bolts will be monitored during aircraft trafficking events. A minimum of 10 and a maximum of 20 events will be recorded. Other nonrecorded events will be used to evaluate the operational status of the sensor array. The test director and instrumentation team will decide which events will be recorded. Preliminary test results and operational status of the instrumentation system will be reported at the end-of-the-day briefing. Repairs to the instrumentation system will not interfere with the aircraft operational schedule.

D. OPERATIONAL PRECAUTIONS

1. The instrumented mat will be cleared manually with leaf blowers to prevent damage to the mat sensors from the sweepers and towed broom.

2. During the MOS marking test, the paint machine operator must raise the paint machine broom to avoid damaging the instrumentation system.

3. The instrumented mat, main cable, and instrumentation van will be off limits to all unescorted personnel and equipment except the test director and instrumentation team.

ANNEX K

RELIABILITY AND MAINTAINABILITY EVALUATION PLAN

A Joint Reliability and Maintainability Evaluation Team (JRMET) will be established to evaluate the reliability and maintainability (R&M) of the MOS marking system, the bucket-mixed polymer spall repair system, the dipstick, the super stringline, and the fiberglass mats. JRMET is a review counsel established for system acquisition to assist in collecting, analyzing, evaluating, and validating R&M data. This team is chaired by the program office with representatives from the operating and support commands, OT&E and DT&E staffs, contractors, and other staff members from the program office. The JRMET promotes joint and independent use and evaluation of R&M data, thus reducing duplication.

A. NORTH FIELD 87 TEST R&M OBJECTIVES

During the North Field Test, the following critical components will be monitored:

1. OT&E Tests

a. MOS Marking (Paint Machine)

(1) Engine

(2) Transmission

(3) Paint Heaters

(4) Paint Guns

(5) Pumps

(6) Valves

(7) Broom

(8) Broom Hoist

(9) Broom Wheels

(10) Electronics

(11) Steering

b. MOS Markers

(1) Edge Markers

(2) Distance-to-go Markers

(3) Barrier Markers

c. Bucket-Mix Spall Repair

(1) Valves

(2) Buckets

(3) Drums

(4) Gloves

2. DT&E Tests

a. Crater Upheaval Measurement Devices

(1) Dipstick

(a) Computer/Printer

(b) Cassette Tape

(c) Printer Paper

(d) Printer Pens

(e) Batteries

(2) Super Stringline

(a) Stringline

(b) Stringline Winch

(c) Measurement Platform

(d) Measurement Rod

b. Folded Fiberglass Mat

(1) Mat

(2) Hardware

(3) Support Tools

B. R&M DATA COLLECTION

R&M data will be collected on the data forms found in Section E. Procedures for data collection are the same as described in Annex H. All data will be returned to the designated test data manager following JRMET review.

C. JRMET DATA REVIEW PROCESS

At the end of each day, the JRMET and data collectors will review collected R&M data. Questionable R&M data entries will be clarified or modified to the JRMET's satisfaction.

When the JRMET is satisfied that the R&M data factually portray the event, it will certify data accuracy for R&M analysis. As with other test data, R&M data will not be released to anyone except those persons responsible for collection, analysis, evaluation, and calculation, until the R&M analysis has been completed by AFESC and USAFTAWC. Only certified R&M data will be used by AFESC and USAFTAWC to analyze the tested items' R&M elements.

D. ITEM FAILURE REPORTING

If, during the R&M data evaluation and certification process, a potential critical deficiency is identified, it will be reported in accordance with TO-00-35D-54.

E. R&M DATA FORMS

R&M data forms are found on the following pages.

INITIAL DISTRIBUTION LIST

HQ USAF/LEE	1	HQ USCENTAF/LGDE	1
HQ USAF/LEEX	1	AD/YQ	1
HQ USAF/XOORB	1	AD/AFATL/DL (TECH LIB)	1
HQ AFESC/DEO	1	AFWL/NTE	1
HQ AFESC/TST (LIBRARY)	1	AFWAL/FIES/CDIC	1
HQ AFESC/RDC/RDCP	1	AFWAL/FIEM	1
HQ PACAF/DEO	1	DTIC/DDA	1
HQ PACAF/DOUP	1	USAFTAWC/TC	2
HQ TAC/DED	1	USA CORPS OF ENG SCHOOL/ATZA-CDO	1
HQ TAC/DRP	1	WATERWAYS EXPERIMENT STATION/GP	1
HQ TAC/DEMM	1	20 NAVAL CONST REGIMENT 20NCR/R24	1
HQ USAFE/DEM/DES	1	COMCBLANT	1
SAF/AQPN	1	USN CIV ENG LAB/L03AB	1

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