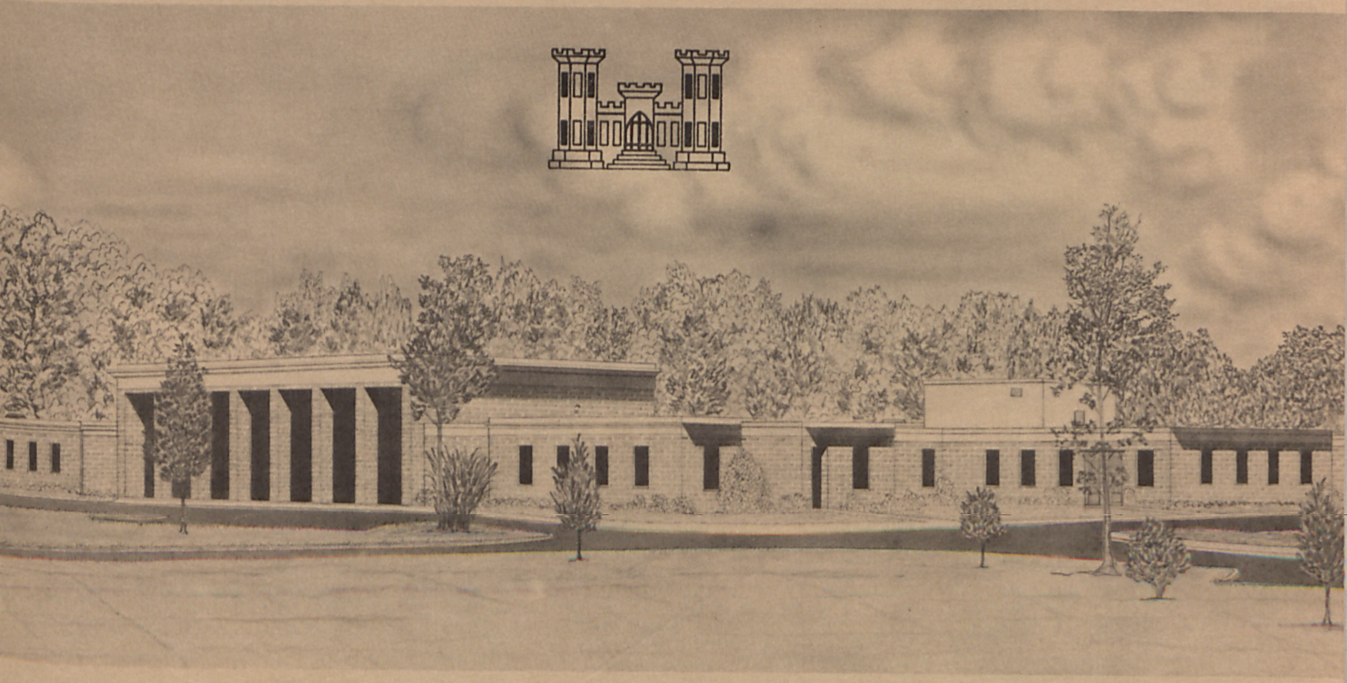
MISCELLANEOUS PAPER S-71-19

INVESTIGATION OF FIBER GLASS REINFORCED RESINS FOR STABILIZATION OF MISSILE LAUNCHING SITES

by

G. W. Leese



June 1971

Sponsored by Research and Development Directorate, U. S. Army Materiel Command

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

The general authorization for this investigation is contained in Research and Development Project 1T062103A046, "Trafficability and Mobility Research," Task 05, "Expedient Surfacings Materiel Research." This investigation was performed under the sponsorship of the Research, Development, and Engineering Directorate, U. S. Army Materiel Command.

The study reported herein was conducted during the period August 1967-February 1968 by personnel of the U. S. Army Engineer Waterways Experiment Station (WES) Soils Division, under the general supervision of Messrs. W. J. Turnbull, A. A. Maxwell, and W. L. McInnis, and under the direct supervision of Mr. G. W. Leese. The field tests reported herein were conducted at the White Sands Missile Range (WSMR), N. Mex., with coordination through the U. S. Army Missile Command (USAMICOM), Redstone Arsenal, Ala. This report was prepared by Mr. Leese.

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

Acknowledgment is made to Messrs. W. Johnson and M. Denning of USAMICOM, and Mr. J. Keosoff of WSMR for their assistance and cooperation in the performance of the field test phase of this study.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

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

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles	1.609344	kilometers
square yards	0.836127	square meters
gallons (U. S.)	3.785412	cubic decimeters
pounds	0.45359237	kilograms
pounds per square foot	4.88243	kilograms per square meter
ounces per square yard	0.03391	kilograms per square meter
feet per second	0.3048	meters per second
Fahrenheit degrees	5/9	Celsius or Kelvin degrees*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

SUMMARY

Experience with Army tactical rockets and missiles has shown that during launchings over unprotected soil surfaces, the motor blast produces dust clouds that could reveal the firing location to the enemy and causes soil erosion in the launch area detrimental to reloading and operating conditions. As the tactical missiles and rockets are used as artillery and antiaircraft weapons in close support of forward-area ground operations, attenuation of dust clouds and control of ground erosion are considered essential for personnel and equipment protection and for camouflage and concealment.

Tests using small rocket motors were made at the U. S. Army Engineer Waterways Experiment Station on blast-resistant materials and combinations of materials at exposure temperatures up to 3800 F to select the most favorable combination of materials for field testing. Field tests of materials were conducted with the Honest John and Little John rockets, both operational weapons, at the White Sands Missile Range, N. Mex.

Based on results obtained in this investigation, the following conclusions are believed warranted:

a. A ground cover constructed of high-heat-resistant polyester resin reinforced with glass will withstand the direct blast from the motor of the Little John rocket.

b. The use of a fence around two sides and along the rear edge of the firing pad will substantially reduce the areal extent of ground protection required for alleviating dust cloud formation during launch.

INVESTIGATION OF FIBER GLASS REINFORCED RESINS FOR STABILIZATION OF MISSILE LAUNCHING SITES

PART I: INTRODUCTION

The Problem

1. The firing of tactical missiles and rockets from mobile launchers emplaced on unprotected areas creates undesirable soil erosion and dust clouds caused by the motor exhaust gases impinging on the exposed ground surface. Since missiles and rockets are used as artillery and antiaircraft weapons in close support of forward-area ground operations, motor exhaust blast control to prevent undesirable soil erosion conditions and dust cloud formation is considered essential for personnel and equipment protection, launcher stability, and camouflage and concealment. Thus, blast-resistant materials suitable for use in the exhaust-blast impingement area are needed to prevent these undesirable blast effects.

Purpose and Scope of Investigation

2. The purpose of this investigation was to determine the ability of a high-heat-resistant polyester resin reinforced with glass to withstand the direct blast of tactical Army rocket engines and to determine the ability of a vertical fence around the launch area to deflect the ground wash upward to alleviate dust cloud formation. The objectives were accomplished by a series of small rocket engine firings on a number of polyester resin, glass-fiber-reinforced panels in the Surface Effects Blast Facility (SEBF) of the U. S. Army Engineer Waterways Experiment Station (WES) and full-scale launchings of the Honest John and Little John rockets at the White Sands Missile Range (WSMR), N. Mex., on selected items.

3. Polyester resins that possessed high-temperature resistance, good strength under heat, burn and abrasion resistance, and suitable properties for field application were subjected to the exhaust blasts of both liquid- and solid-propellant rocket motors at the WES to determine the most suitable material for field testing at WSMR. The WES tests consisted of exposing the glass-fiber-reinforced, polyester resin specimens to the exhaust blast of the rocket motors at exposure temperatures up to 3800 F* for about 5 sec at several angles of blast impingement.

Small Rocket Motors

Liquid-propellant rocket motor

4. The small liquid-propellant rocket motor (fig. 1) used to produce blast velocities, pressures, and temperatures on the test specimens was fabricated in the WES machine shop. The motor has a nominal thrust of 500 lb, an exhaust velocity (characteristic) of about 5200 fps, an exhaust gas temperature capable of exceeding 4000 F, and an expansion ratio (throat area to nozzle exit area) of 1:8. It uses RP-1 and liquid oxygen as fuel and oxidizer, respectively, and is cooled by water circulating under high pressures between the copper combustion chamber and the carbon steel water jacket. The motor is ignited by injecting triethylaluminum (TEA) into the combustion chamber, followed immediately by the RP-1 fuel.

Solid-propellant rocket motors

5. The solid-propellant rocket motors (fig. 2) used were procured from the Thiokol Chemical Company. The motors have a nominal thrust of 325 lb, an exhaust velocity of about 5000 fps, exit gas temperatures exceeding 4000 F, and an expansion ratio of 1:5; expel 35 percent solids (by weight) in the exhaust gases; and burn for about 5 sec. Ignition is attained by using an electrical igniter placed within the combustion chamber.

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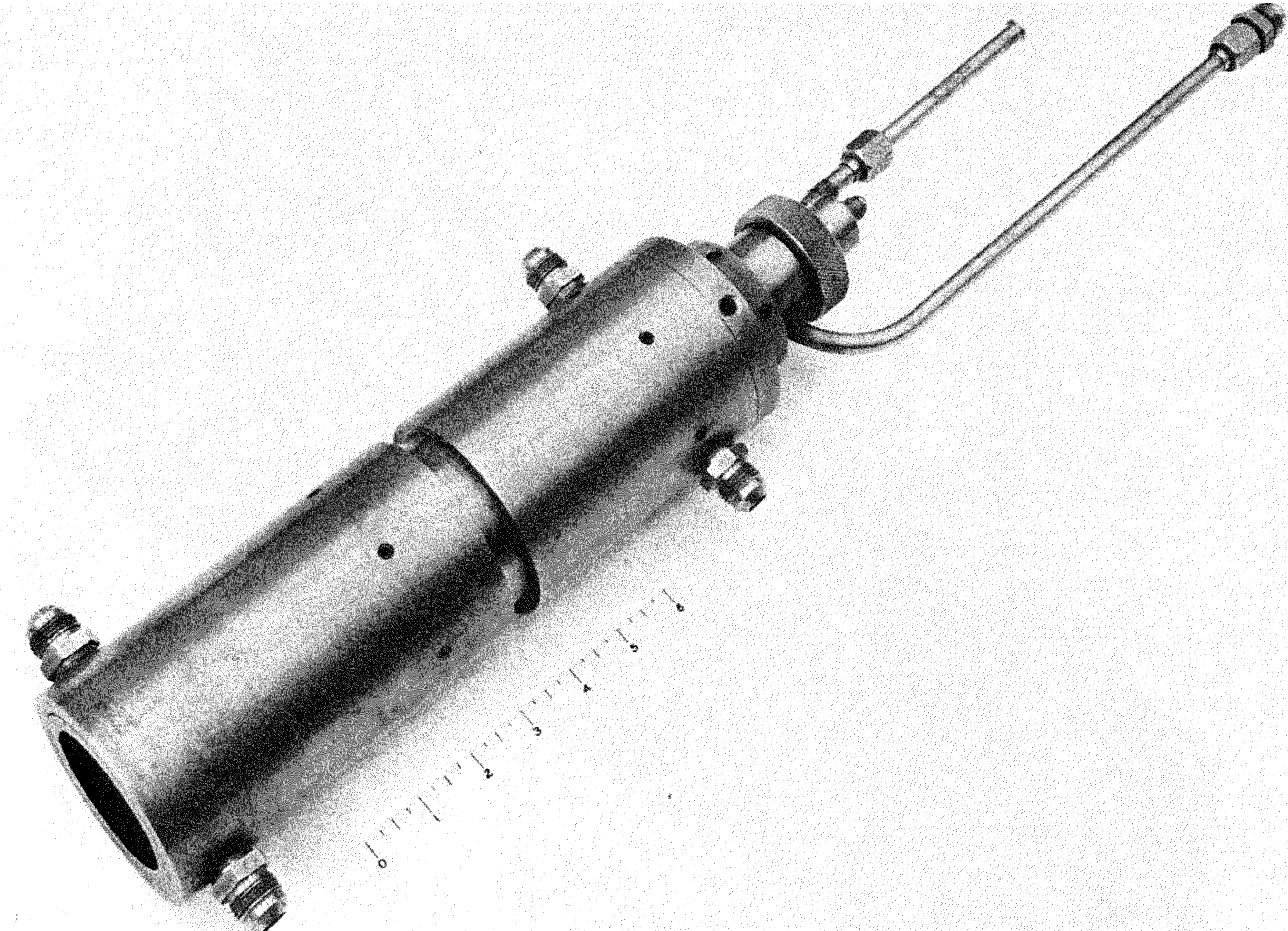
* A table of factors for converting British units of measurement to metric units is presented on page ix.



S549-80

Fig. 1. Liquid-propellant rocket motor

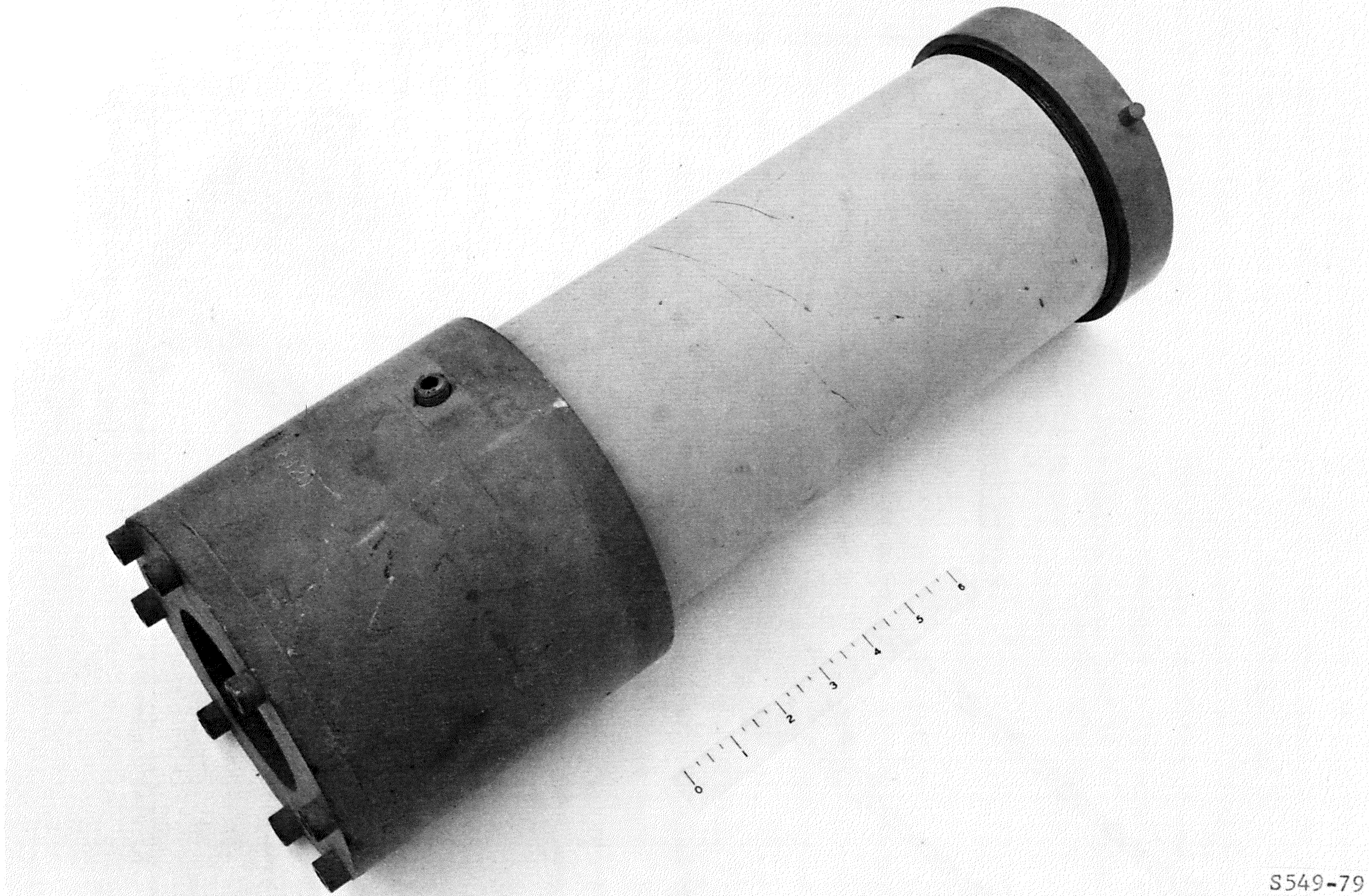


Fig. 2. Solid-propellant rocket motor

Instrumentation

6. Instrumentation used to record test data during the small rocket motor tests consisted of load cells for measuring motor thrust, an infrared radiometer for determining the surface temperature of the materials during tests, and motion picture cameras to record the test results in order that a detailed study could be made of each material tested.

Polyester Resin Test Specimens

Polyester resins

7. Polyester resins, chosen from a literature search, that appeared to have desirable characteristics for missile site protection were Reichhold STF 73A, Hooker Chemical Corporation Hetron 24806, Atlas Chemical Industries, Inc., 382FRD-05A, and Silmar Chemical Corporation S-346.

Glass-fiber reinforcement

8. The glass-fiber reinforcement used to fabricate the test specimens consisted of 13.5-oz-per-sq-yd nondirectional mat and 18.5-oz-per-sq-yd woven roving. Alternate layers of the mat and roving were used (mat placed on the top and bottom to obtain a relatively smooth surface) for reinforcement to achieve a glass-fiber content of approximately 17.5 percent by weight. The glass mat and roving were supplied by Coast Manufacturing and Supply Company of Dallas, Texas.

Test specimen preparation

9. Test specimens were prepared using the polyester resins obtained from the manufacturers. The resins were mixed in the recommended ratio with catalyst and promoter. Also, several specimens were prepared in which boric acid powder was mixed with the resin to determine its ability to increase the heat resistance of the resin. Antimony trioxide was also added to some specimens to provide self-extinguishing capability to the resin should it start burning.

10. The blended, catalyzed, and promoted resin was cast in alternate layers with the glass reinforcement in a 4- by 4-ft-, 3/4-in.-deep mold;

the finished test specimens were about 1/2 in. thick. Although cure time was about 30 min, the specimens were allowed to cure for at least 24 hr. Just prior to testing in the exhaust blast of a rocket motor, the test specimens were weighed and measured for thickness.

Small Rocket Motor Blast Tests and Results

11. The test specimen was placed on a table beneath the rocket motor and securely fastened to the table top. Because the motor was fixed at a 45-deg angle, the table top was positioned to provide the impingement angle desired for the specific test. As the exhaust temperature pattern was known for the rocket motors, exposure temperatures on the test specimens were controlled by placing the specimens at specified distances under the motor, as shown in tables 1 and 2. Photograph 1 shows the test area and photograph 2 shows a test in progress in which the liquid-propellant motor is being used.

Reichhold STF 73A

12. Two test specimens were prepared using Reichhold STF 73A resin. This resin was blended with 30 percent boric acid powder and 3.5 percent antimony trioxide by weight. The finished panels contained 17 percent glass fibers. One specimen was subjected to two firings of the solid-propellant motor at distances of 5 and 3 ft for approximately 4.5 sec each. The second specimen was subjected to six firings of the liquid-propellant motor at distances of 5 ft for a total exposure time of 34.3 sec. Photograph 3 shows a specimen before testing.

13. The first solid-propellant motor test on the specimen at a distance of 5 ft eroded very little of the material (photograph 4). The specimen was then subjected to the exhaust blast of the solid-propellant motor at a distance of 3 ft, with an exposure temperature of about 3700 F; this exposure eroded a hole through the specimen, as can be seen in photograph 5.

14. The liquid-propellant motor test series was conducted with a distance of 5 ft between the specimen and the motor nozzle. This test series was conducted with the exhaust blast impinging on the specimen at

angles of 30, 45, 60, 75, and 90 deg. The specimen then was positioned back to the 45-deg impingement angle and exposed to the blast for about 6.3 sec. Total exposure time was 34.3 sec, during which time 9 lb of material was ablated, with the depth of loss of material in the impingement area being 0.122 in. Photograph 6 shows this specimen after completion of tests.

Hetron 24806

15. Two 4- by 4-ft specimens were prepared using Hooker Hetron 24806 resin. One specimen was mixed with 30 percent boric acid powder and without the antimony trioxide, and the other specimen contained no boric acid powder or antimony trioxide. The finished specimens contained about 15 percent glass fiber. The first panel was exposed to two solid-propellant motor firings of approximately 4.5 sec each at distances of 5 and 3 ft. The second specimen was subjected to seven firings of the liquid-propellant motor at distances specified in table 2 for a total exposure time of 38.6 sec. Photograph 7 shows a specimen before solid-propellant rocket tests.

16. The solid-propellant rocket motor test on the first specimen at a distance of 5 ft (2800 F exposure temperature) resulted in the erosion of very little material (photograph 8). The depth of material loss was not measured as the char would have had to be removed. Then the specimen was placed 3 ft from the exhaust nozzle of a solid-propellant rocket engine and subjected to its blast for 4.7 sec at an exposure temperature of 3700 F. Photograph 9 shows the approximately 0.45-in.-deep depression eroded in the specimen. The second panel was subjected to 38.6-sec exposure with the liquid-propellant rocket motor at distances shown in table 2 with little material being removed (photograph 10). The surface cracks and loose portion shown in the upper section of the panel (photograph 10) were caused by thermal shock.

Atlac 382FRD-05A

17. One Atlac 382FRD-05A specimen was prepared that contained 30 percent boric acid, 17 percent glass fibers, and no antimony trioxide. Because of trouble in mixing and casting the second specimen and the limited resin available, no test specimen was available for the liquid-propellant rocket motor tests. Photograph 11 shows the specimen before testing.

18. The specimen was placed 5 ft from the nozzle of the solid-propellant rocket engine and subjected to its blast for 4.85 sec, during which time the panel lost 2-3/8 lb of material by ablation, which left an approximately 0.05-in.-deep depression at the impingement point (photograph 12).

Silmar Chemical
Corporation S-346

19. Silmar S-346 test specimens were prepared using 30 percent boric acid, 3.5 percent antimony trioxide, and 17 percent glass fibers. These specimens were subjected to two tests with the solid-propellant rocket motor at distances of 5 and 3 ft from the exit nozzle of the motor. Photograph 13 shows one of the specimens before tests.

20. When subjected to 4.9 sec of the exhaust blast at a 5-ft distance, the material developed a slight soft char, with very little material being ablated (photograph 14). When tested at a 3-ft distance, a hole burned through the panel in 4.5-sec exposure time (photograph 15).

Discussion of results

21. Based on the results of the tests described above, the Hooker Hetron 24806 resin was chosen for field tests at WSMR. This resin appeared to have the most favorable abrasion and high-heat-resistant properties as well as handling properties and glass wetting abilities. The use of boric acid to fill the resin to increase its heat resistance did not show any increased benefit when compared with unfilled resin.

22. Field tests in which the Honest John and Little John rockets were launched from pads constructed of polyester resin and fiber glass were conducted at WSMR.

Rockets and Launchers

Honest John
rocket and launcher

23. The Honest John rocket is a surface-to-surface, free-flight, solid-propellant rocket with a range equivalent to that of medium- to long-range artillery (18-20 miles). It is approximately 27 ft long and 2.5 ft in diameter and is intended to be used tactically to provide close fire support to ground combat operations. The rocket is fired from a mobile, self-propelled launcher (fig. 3) and can be armed with either an atomic or high-explosive warhead.

Little John
rocket and launcher

24. The Little John rocket is a surface-to-surface, free-flight, solid-propellant rocket with a range equivalent to that of medium-range artillery (10 miles or more). It is approximately 15 ft long and 1.4 ft in diameter and is intended to be used tactically to provide close fire support to ground combat operations. The rocket is fired from a mobile, towed trailer launcher (fig. 4) and can be armed with either nuclear or conventional warheads.

Application Equipment

25. The application equipment was developed to apply either dust alleviators or polyester resin from the UH-1 helicopter. This equipment was truck-mounted with the spray bar on one side of the truck so that the truck would not have to track on previously placed material (fig. 5). The spray unit contains a 200-gal resin tank and a 5-gal catalyst tank. The

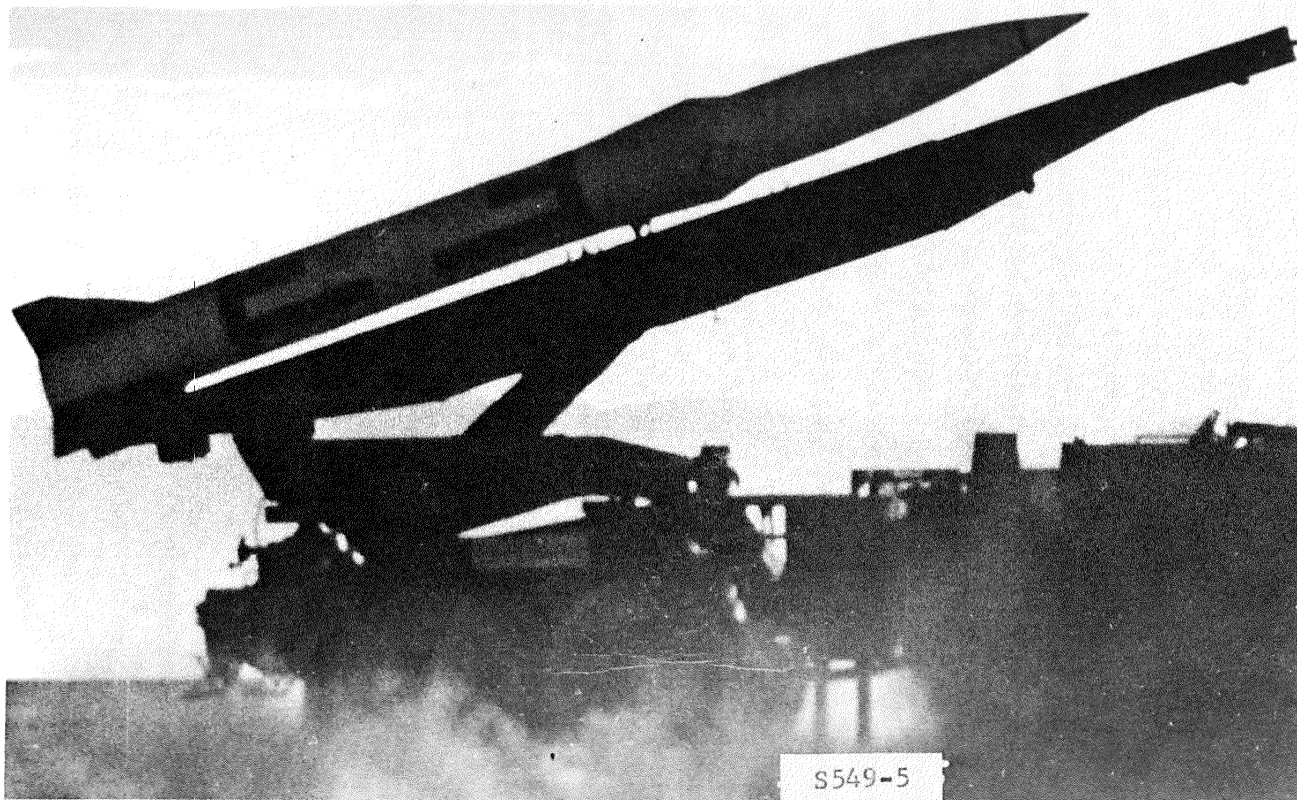


Fig. 3. Honest John rocket and launcher

Fig. 4. Little John rocket and launcher

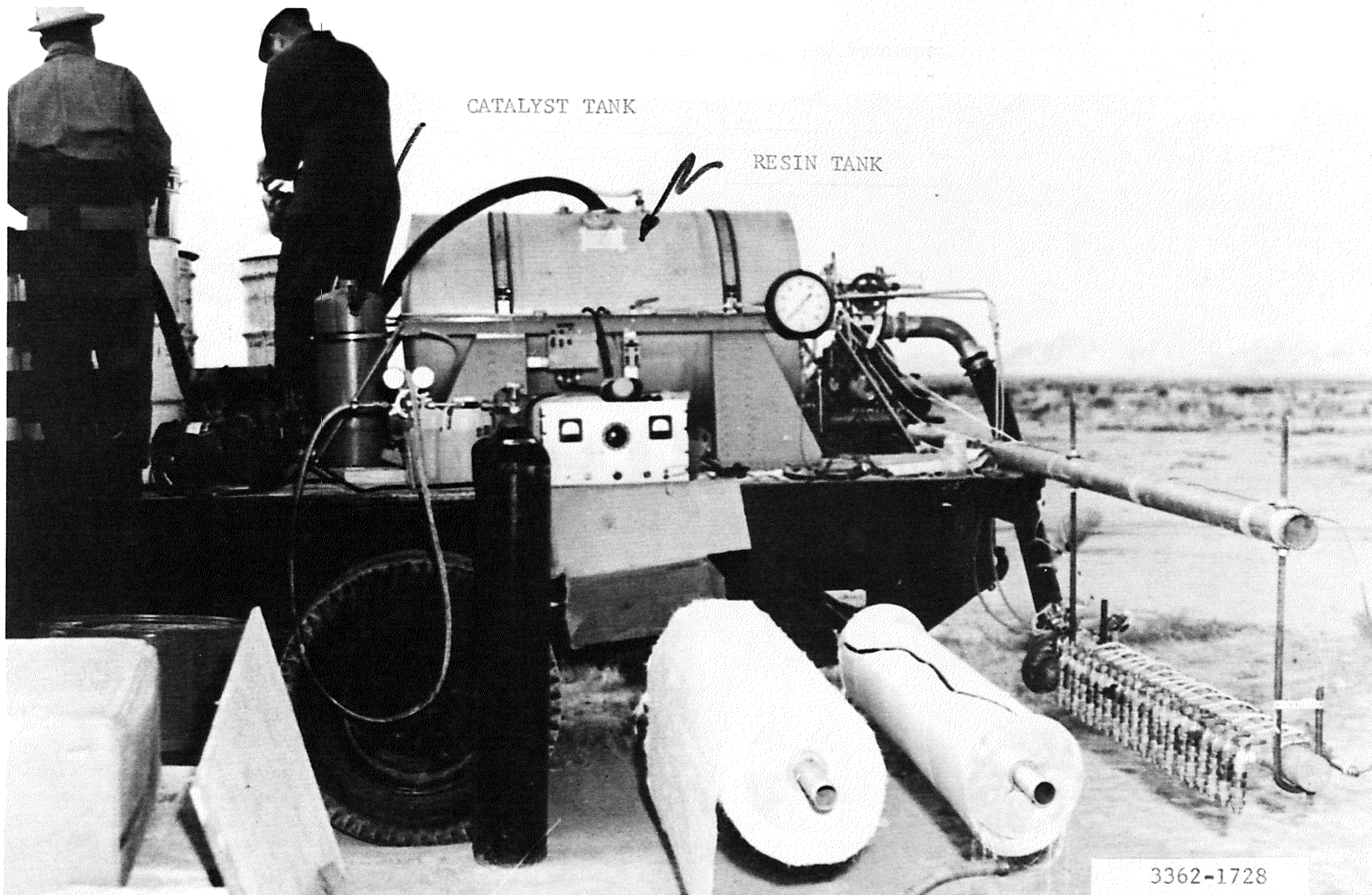


Fig. 5. Truck-mounted sprayer

pumps for the resin and catalyst are tied together so that at any motor speed (revolutions per minute), the proper ratio is pumped through the spray bar to provide good curing properties. Rolls of glass mat and woven roving were suspended alongside the spray bar so that the resin sprayed from the bar saturated the glass fabric before it was laid on the ground surface. This had a tendency to "work" the resin within the fibers of the glass and gave better wetting of the glass fabric. Resin cure time was 15 min.

Honest John Test

26. The Honest John launch site selected for this test was about 65 miles north of the WSMR headquarters. The area had been used previously for rocket launches, and large holes covered the area. A motor grader was used to fill these holes; no compaction effort was applied to the loose sandy soil. Photograph 16 shows the test area prior to initiation of application of the polyester resin and glass fiber.

Test site construction

27. Spray application equipment was assembled at the site, and the drums of resin were stirred to ensure no settlement of the boric acid powder before transferring the resin to the spray equipment tank. Hooker Chemical Company's Hetron 24806 resin with 30 percent boric acid powder, 3.5 percent antimony trioxide, 1 percent cobalt napthenate, and 0.075 percent methylethylketone (MEK) in peroxide was used. The boric-acid-filled resin was selected for this first test based on results of studies with the rocket motors at the WES.

28. Construction of the 50- by 100-ft launch pad was started by placing the glass fibers and resin in a center-line strip, 5 ft wide and 100 ft long, down the launch area. The desired pad thickness was obtained by varying the amount of overlap on succeeding runs and by selecting single or double layers per run of the 13.5-oz-per-sq-yd mat and the 18.5-oz-per-sq-yd woven roving. This can be seen in photograph 17, where the second run is being placed using only woven roving and a 3-1/2-ft overlap. The thickness of the finished pad varied as follows: 1/2 in. over a 10- by 50-ft section in the blast-impingement area, 5/16 in. at the front and rear of the

impingement area, 1/4 in. in 10-ft-wide strips on each side of the impingement area, and 3/16 in. on each side of the launch pad (fig. 6). The weight of the material in the 1/2-in.-thick blast-impingement area was about 5 psf; the 5/16-in. section, 3.1 psf; the 1/4-in. section, 2.5 psf; and the 3/16-in. section, 1.8 psf. Average weight of the finished launch protection pad was 2.2 psf. To conserve filled material, the outer 10 ft of each side of the pad was placed using unfilled resin. The unfilled resin wetted the glass fiber better and required less hand touch-up than those sections placed with the filled resin. Photograph 18 shows the finished resin pad.

29. Computations indicated that an area 300 ft wide and 250 ft long would be needed to alleviate dust cloud formation in the exhaust blast of the Honest John rocket. Therefore, a 24-in.-high fence constructed of back-braced sections of T100 extruded aluminum landing mat (photograph 19) was placed on each side and at the rear edge of the pad to raise the high-velocity gases to a sufficient height above the ground surface so as not to raise dust. Resin and glass mat were then placed at the bottom edge of the landing mat panels to prevent high-velocity gases from passing under the panels (photograph 20); this tied the mat panels to the launch pad. Also, UCAR-131 dust alleviator was placed around the outer edges (photograph 21) as a preventative measure in case the exhaust blast should extend over the edges during flyaway. Pad placement time was 48 man-hours with the equipment described in paragraph 25. Photograph 22 shows the completed launch pad prior to emplacement of the rocket launcher.

Launch test and results

30. The truck-mounted Honest John launcher was placed on the launch pads so the rear wheels would be on the forward edge; the launch angle of about 16 deg gave a predicted impingement point about 30 ft back from the forward edge. As the rocket left the launch rail, the polyester resin pad appeared to part and lay to one side; this exposed the soil beneath, causing dust. Inspection of the area after the launch revealed that the pad had separated at about one-third points across the pad (photograph 23). One side parted about half the length of the pad, while the other side of the polyester pad parted completely and was blown over the vertical wall. As the pad was fastened to the fence, one section of the landing mat fence was

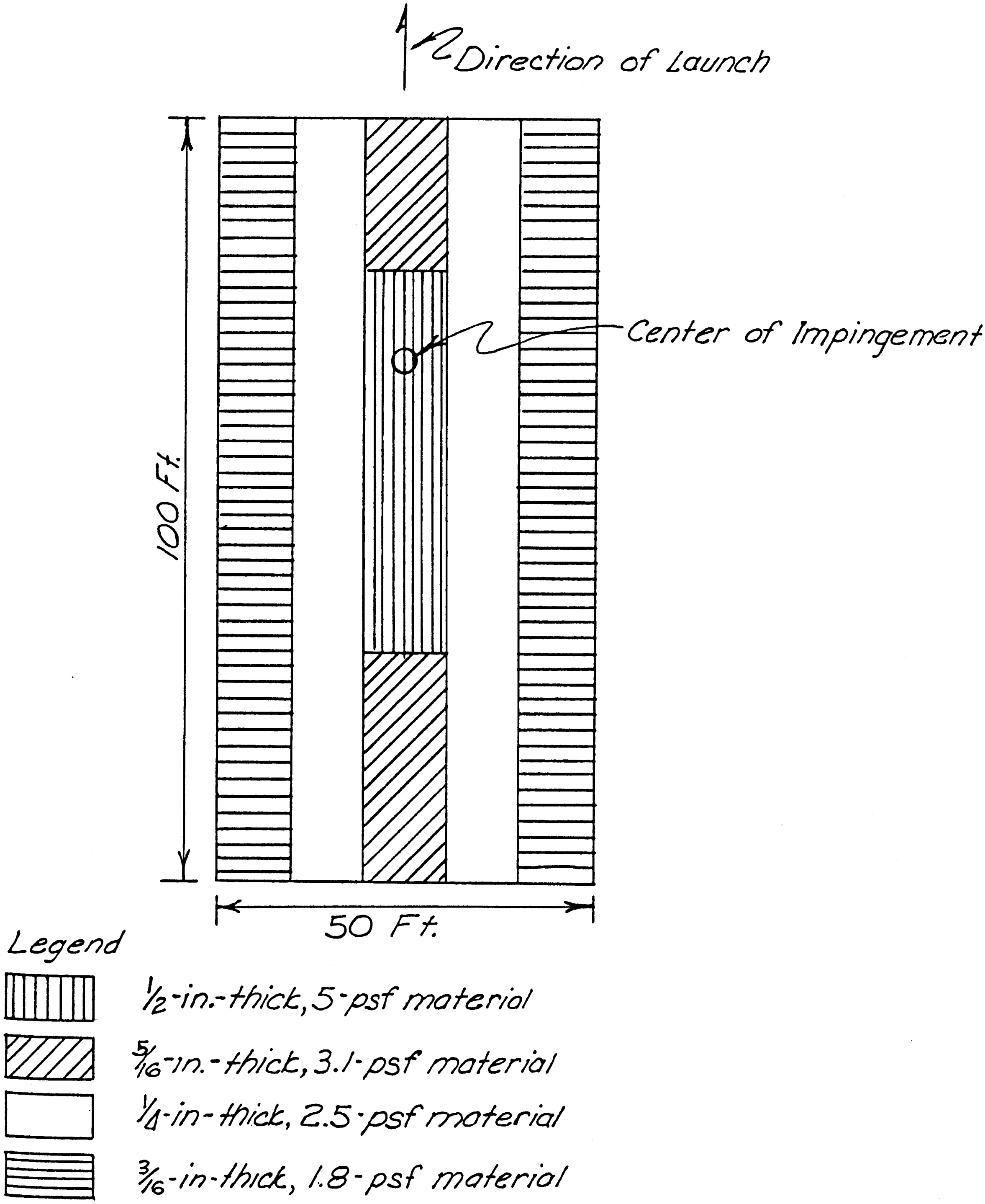


Fig. 6. Fiber glass-polyester resin launch pad, Honest John rocket

blown out. Close inspection of the failed area revealed incomplete cure of the resin had caused extremely weak joints in the fiber glass reinforcement. The impingement area showed only discolorations from the burned rocket fuel (photograph 24). The UCAR-131 dust alleviator, although extremely thin (1/2 gal per sq yd), alleviated the dust somewhat. Photograph 25 shows the UCAR-131 coating forward of the pad after launching.

Little John Rocket Test

31. The test site for the Little John rocket launch pad test was the same as that used during the Honest John rocket test. Procedures and resin additives were changed, and minor modifications were made to the spray application equipment prior to placing the Little John test pad. Based on additional test information and the Honest John rocket test, unfilled Hetron 24806 resin containing 0.5 percent cobalt napthenate and 1.0 percent MEK peroxide was selected for the Little John rocket test pad. To ensure flow of MEK peroxide catalyst to provide complete cure of the resin, the spray bar was modified to provide an external mix system rather than the internal mix system used during the Honest John rocket pad construction (fig. 7). This allowed the operator to observe MEK peroxide flow continuously and to make any necessary corrections. The direction of placement of the runs was changed from parallel to the launch direction as used in the Honest John rocket test pad to perpendicular for the Little John rocket test pad; this gave a shingle effect that would cause the blast gases to flow over a joint rather than against it.

Test site construction

32. Construction of the 36- by 75-ft launch pad was started from the rear edge of the pad by placing a 5-ft width of 13.5-oz-per-sq-yd glass mat and resin for a distance of 36 ft. This procedure was continued, varying overlap to obtain the 1/8-in. thickness desired. After a length of 22-1/2 ft had been covered, 18.5-oz-per-sq-yd woven glass-fiber roving was added to the glass mat to increase the thickness to 1/4 in. (photograph 26). As the impingement area was approached, the thickness was increased to 3/8 in., then to 7/16 in., with the 7/16-in. thickness being carried the last 22-1/2 ft (fig.

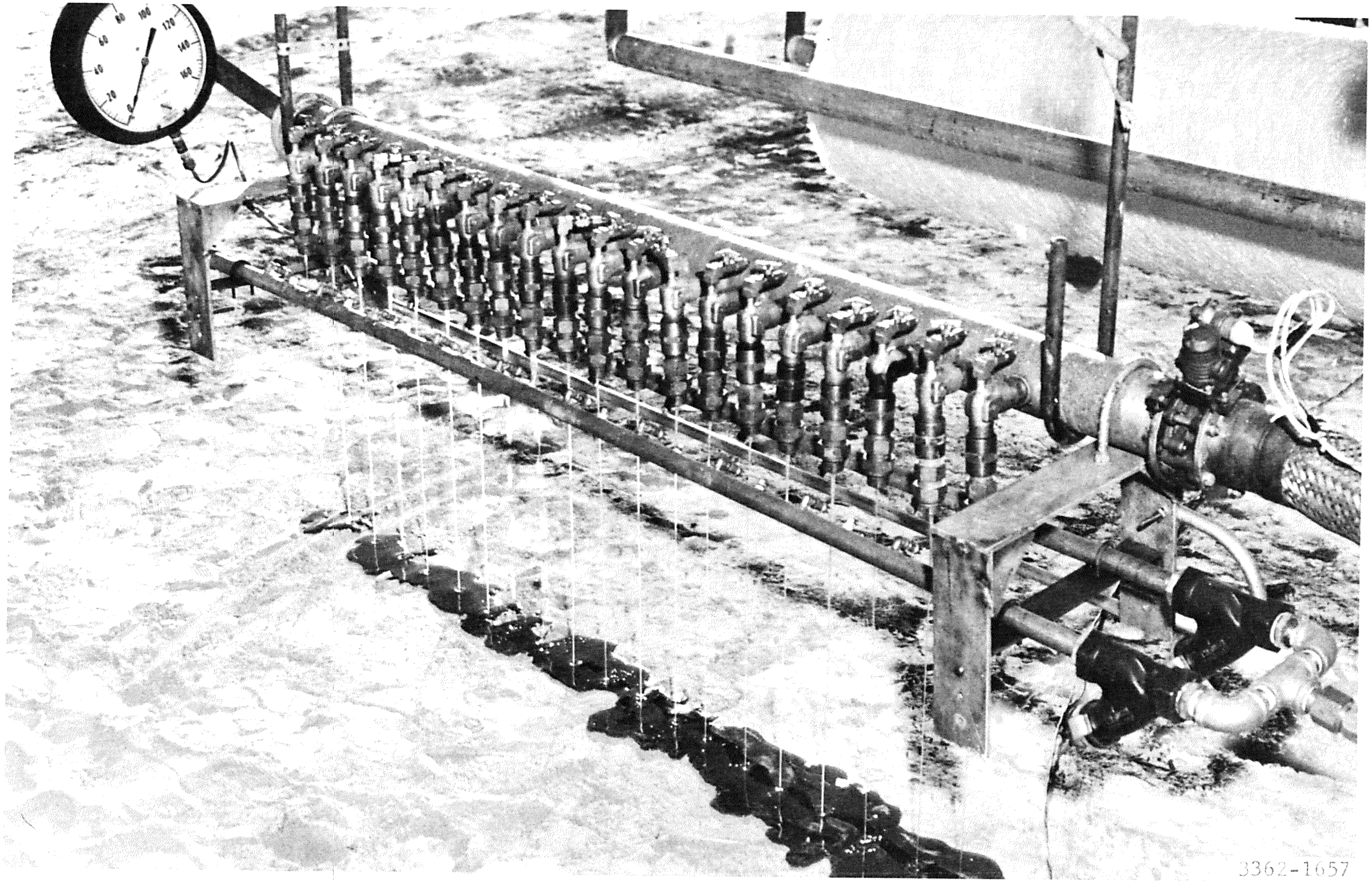


Fig. 7. Modified spray bar

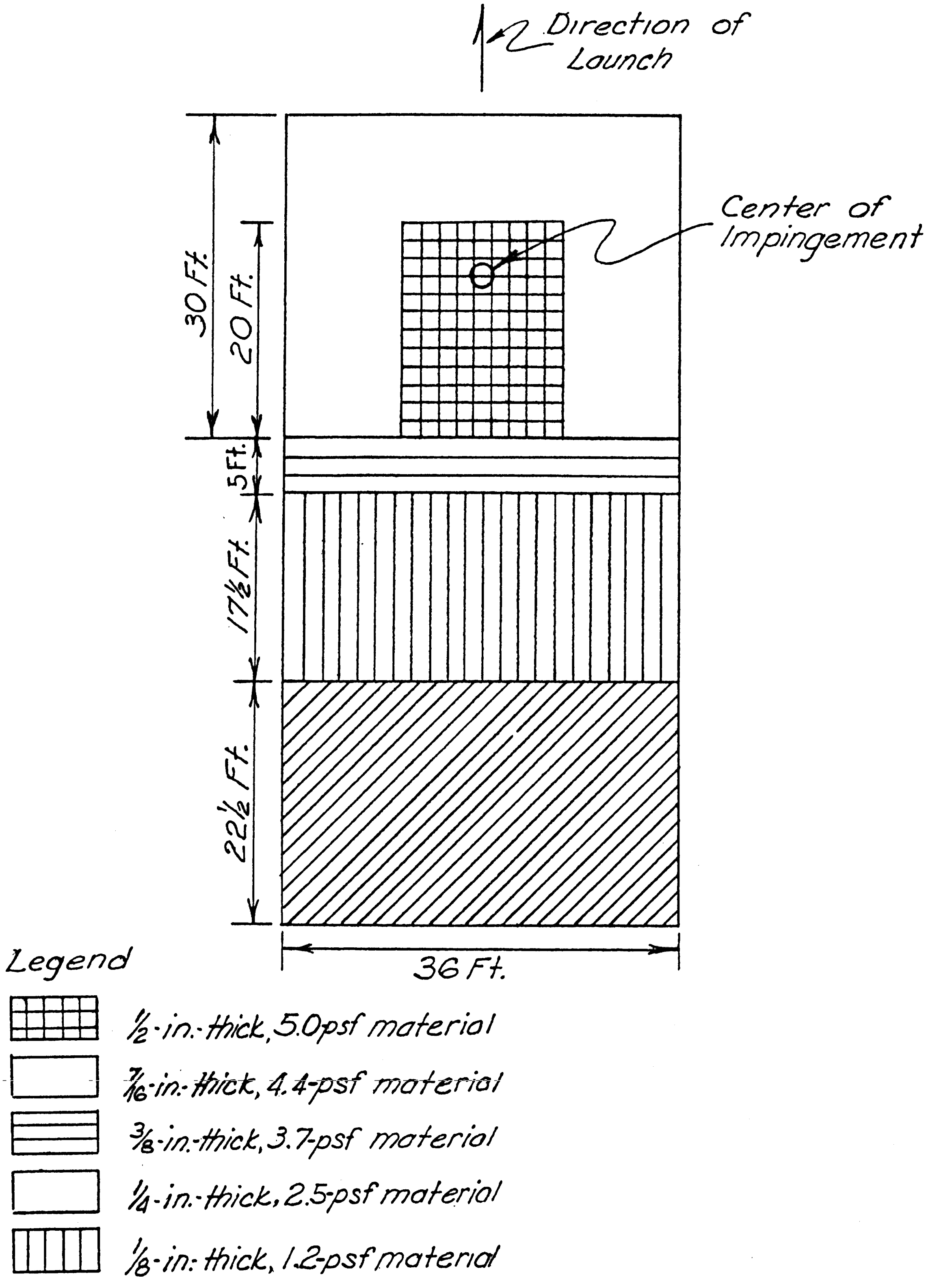


Fig. 8. Fiber glass-polyester resin launch pad, Little John rocket

To even up the sides of the launch pad, one layer of glass mat and resin was placed around the pad (photograph 27). As an added precaution, the direct impingement area was covered with an additional layer of glass mat saturated with resin (photograph 28). This added layer was placed by hand, using paint rollers to roll in the premixed resins.

33. A vertical fence 16 in. high was used on each side and on the rear edge of the launch pad to raise the high-velocity gases above the unprotected dusty ground surface. This fence was made from three plies of 1/2-in.-thick plywood laminated to provide a tongue-and-groove end joint and a fence thickness of 1-1/2 in. The fence was back-braced and anchored (photograph 29). Triangular braces were used across the rear and one-third the distance up each side, and angle iron stakes were used on the remainder of the fence. Photograph 30 shows the completed launch pad. Pad placement time was 24 man-hours utilizing the previously described spray equipment.

Launch test and results

34. The trailer-towed Little John rocket launcher was placed on the launch pad (photograph 31). This launcher places the rocket's exhaust nozzle very close to the launch pad. The rocket was launched at a quadrant elevation (QE) of about 16 deg. Practically no dust was observed around the sides or to the rear of the launch area; however, some dusting occurred forward of the area where the exhaust gases flowed over the unprotected ground surface.

35. Examination of the launch pad immediately after the launching indicated no appreciable damage to the area (photograph 32). The impingement area was discolored by burned motor fuel but had no char (photograph 33).

PART IV: CONCLUSIONS

37. Based on results obtained in this investigation, the following conclusions are believed warranted:

a. A ground cover constructed of high-heat-resistant polyester resin reinforced with glass fiber will withstand the direct blast from the motor of the Little John rocket fired at a QE of about 16 deg.

b. The use of a 16-in.-high plywood fence around two sides and the rear of the firing pad will substantially reduce the areal extent of ground protection required for alleviating dust cloud formation during launch.

Table 1

SOLID-PROPELLANT ROCKET TEST RESULTS

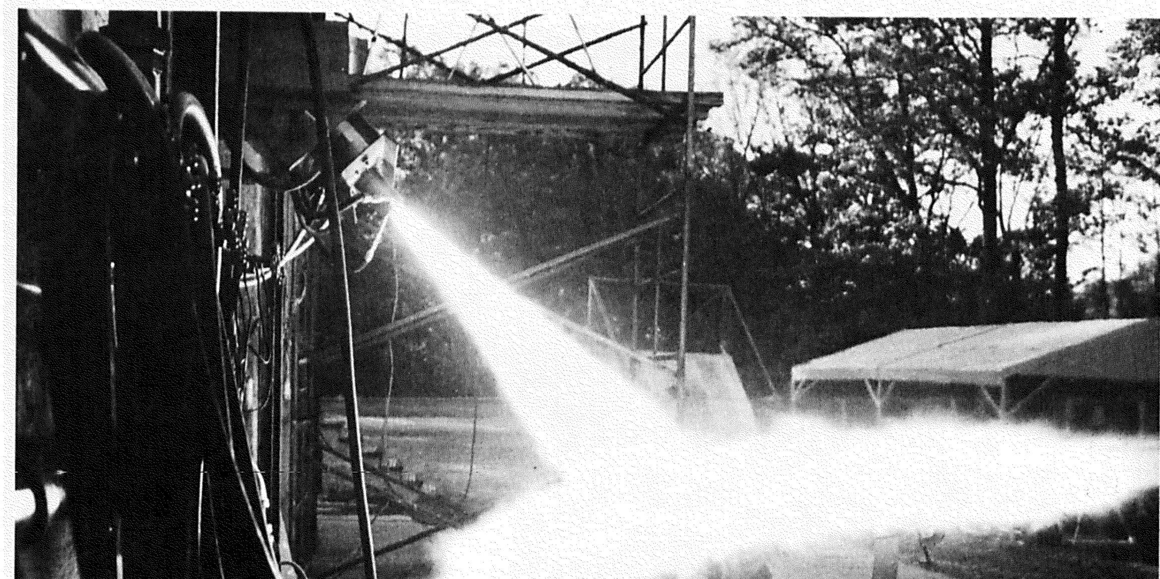
Type of Material	Test No.	Nozzle Distance ft	Impingement Angle Deg	Exposure Temperature deg F	Exposure Time Sec	Remarks
Reichhold STF 73A	1	5	45	2800	4.2	Slight erosion
	2	3	45	3700	4.5	Hole eroded through specimen
Hetron 24806	1	5	45	2800	4.85	Slight erosion
	2	3	45	3700	4.7	Hole eroded through 90 percent of specimen thickness
Atlac 382FRD-05A	1	5	45	2800	4.85	Slight erosion
Silmar S-346	1	5	45	2800	4.9	Slight char formed; very little erosion
	2	3	45	3700	4.5	Hole eroded through specimen

Table 2

LIQUID-PROPELLANT ROCKET TEST RESULTS

Type of Material	Test No.	Nozzle Distance ft	Impingement Angle Deg	Exposure Temperature deg F	Exposure Time Sec	Remarks
Reichhold STF 73A	1	5	30	2800	5.5	Slight erosion
	2	5	45	2800	5.1	No change
	3	5	60	2800	6.0	Erosion increased
	4	5	75	2800	6.0	Erosion increased
	5	5	90	2800	5.4	Little change
	6	5	45	2800	6.3	Hole eroded 90 percent through specimen
Hetron 24806	1	6.12	90	2300	4.0	Very slight erosion
	2	6.12	90	2300	6.0	Surface cracks formed
	3	6.0	90	2400	10.1	Little change
	4	5	90	2800	4.6	Erosion increased
	5	5	90	2800	5.2	Little change
	6	2.75	75	3800	3.3	Erosion increased
	7	2.75	75	3800	5.4	Surface cracks deepened; hole eroded 80 percent through specimen

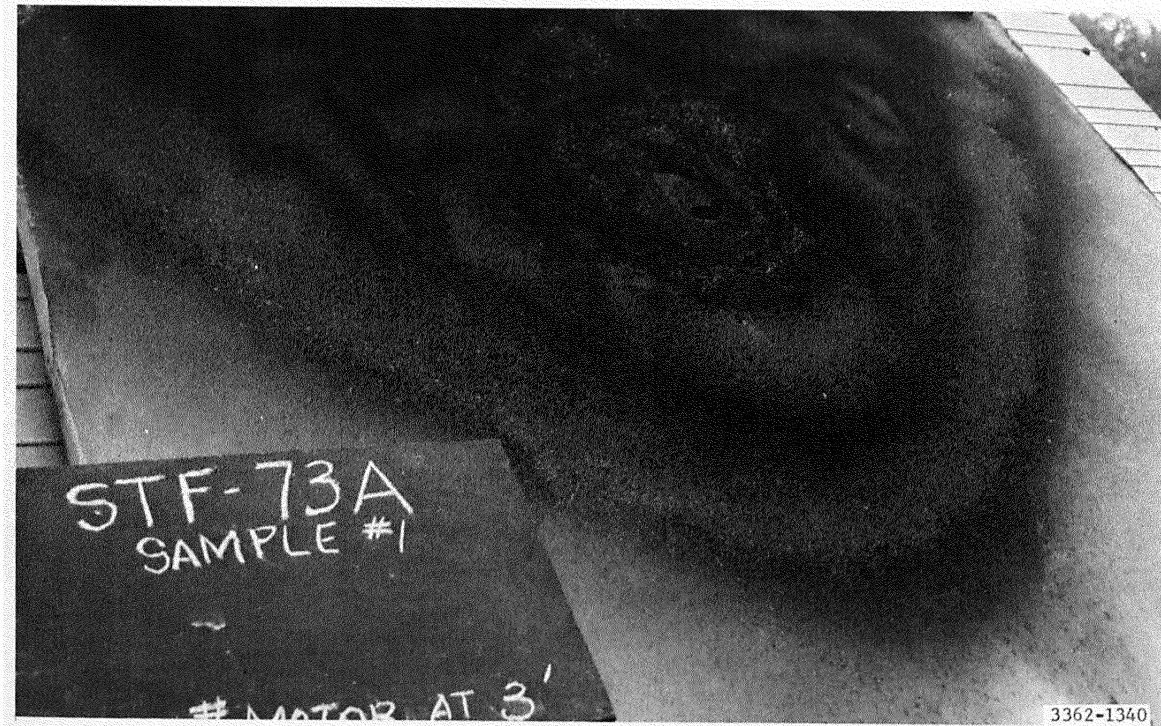
Photograph 1. General view of test area



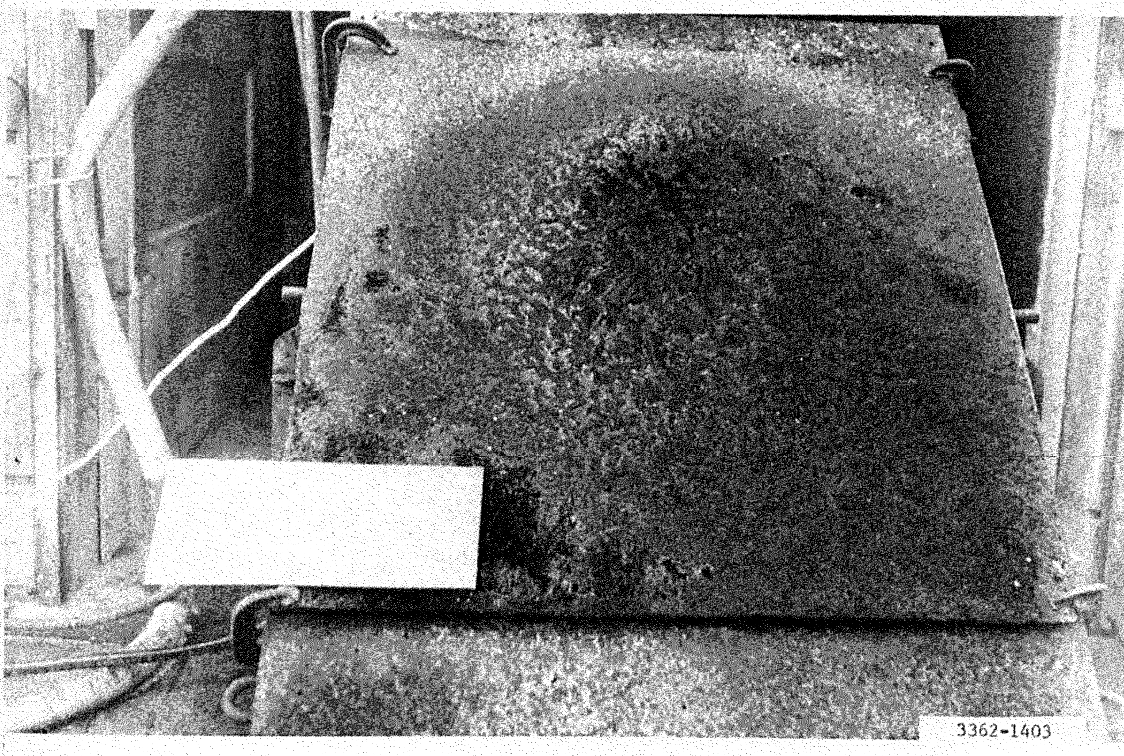
Photograph 2. View of test in progress

Photograph 3. Reichhold STF 73A specimen before tests

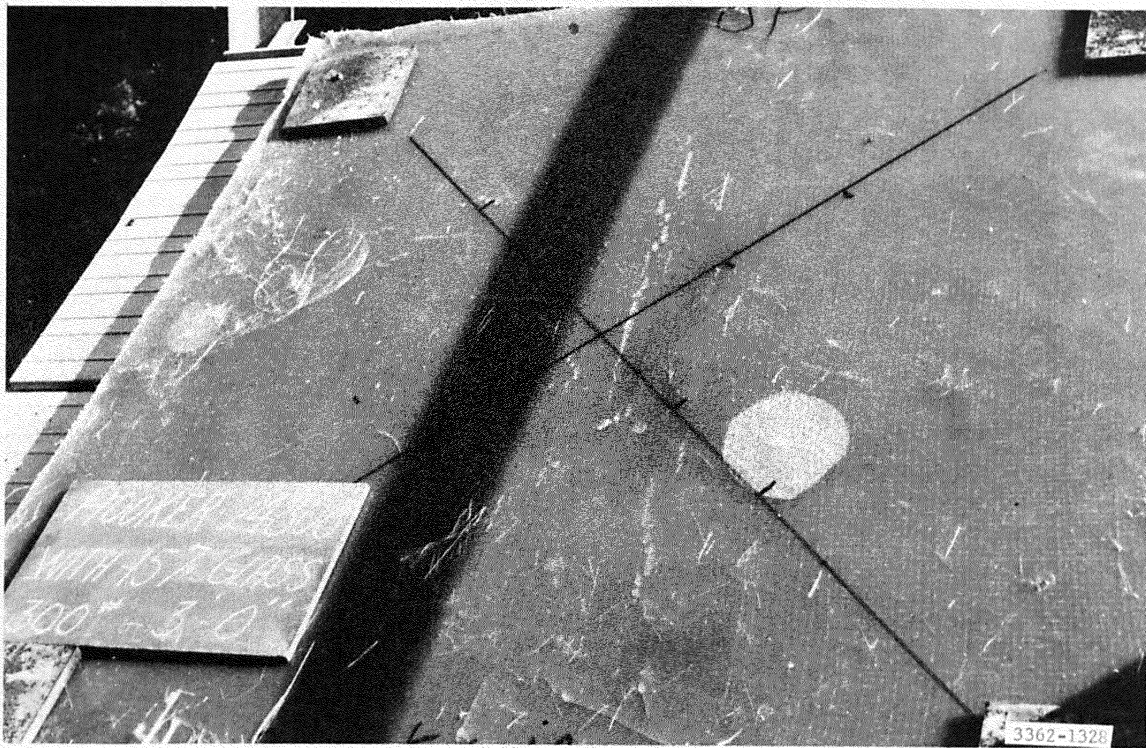
Photograph 4. Reichhold STF 73A specimen after 5-ft-distance, solid-propellant motor test at exposure temperature of 2800 F



Photograph 5. Reichhold STF 73A specimen after 3-ft-distance, solid-propellant motor test at exposure temperature of 3700 F

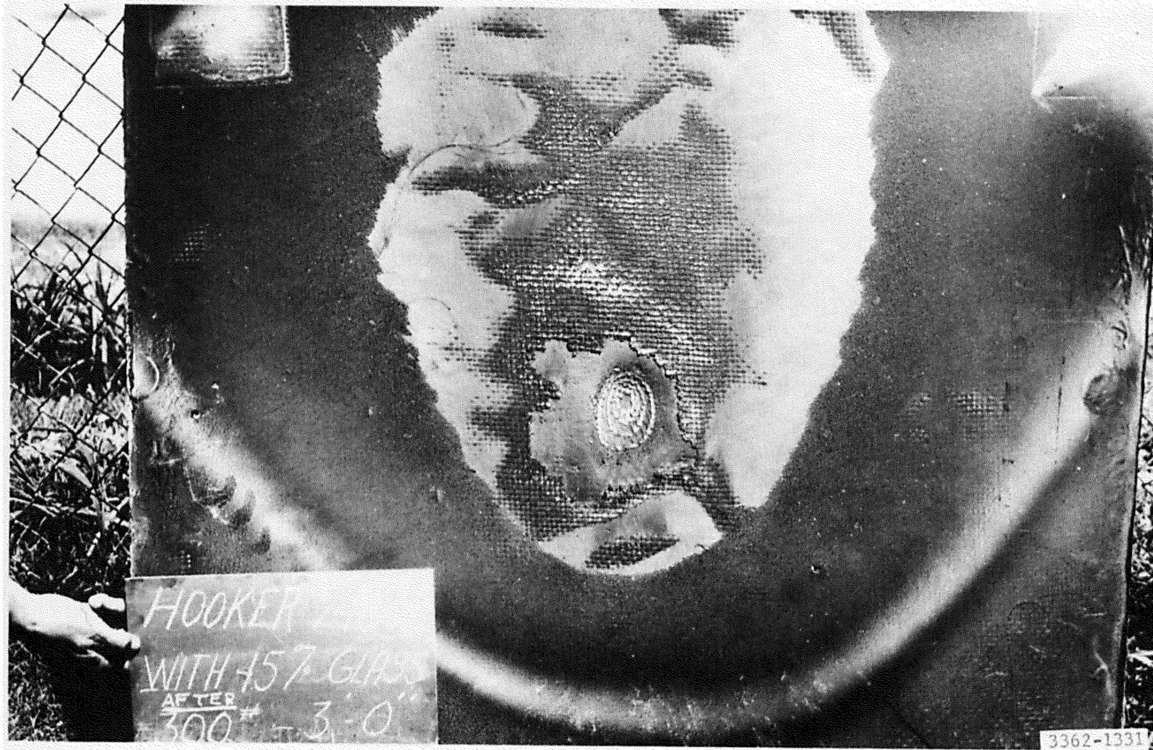


Photograph 6. Reichhold STF 73A specimen after series of exposures to liquid-propellant motor exhausts

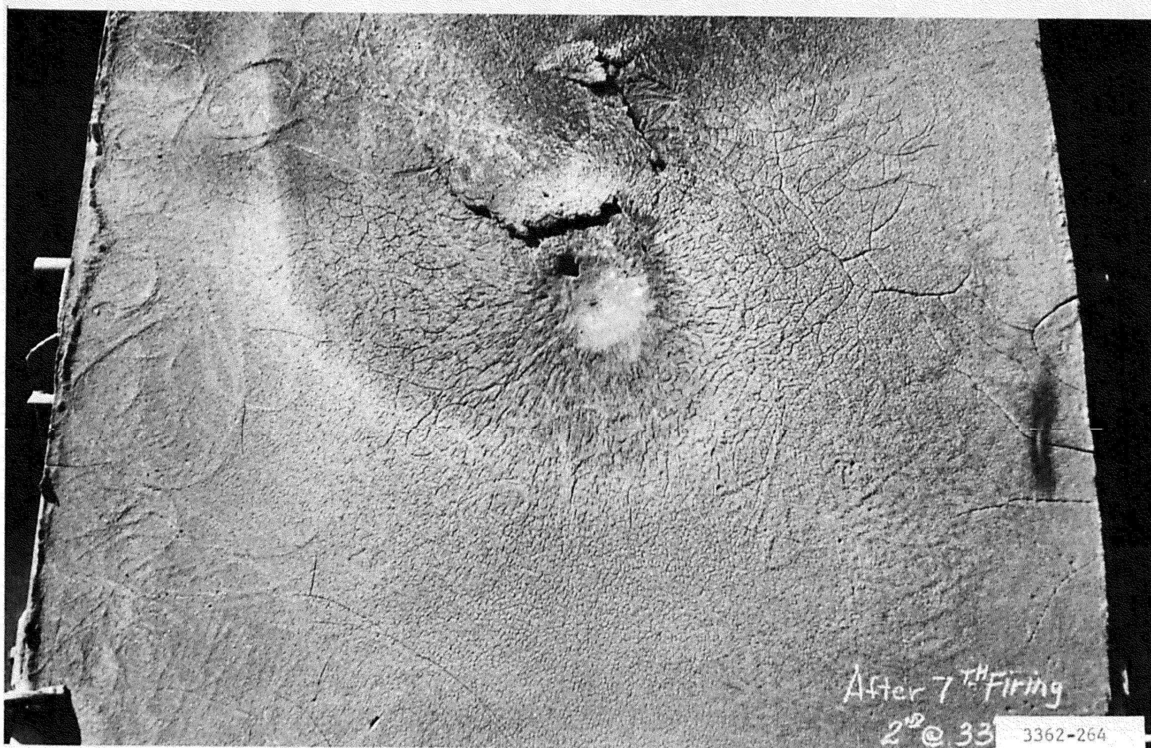


Photograph 7. Hetron 24806 specimen before tests

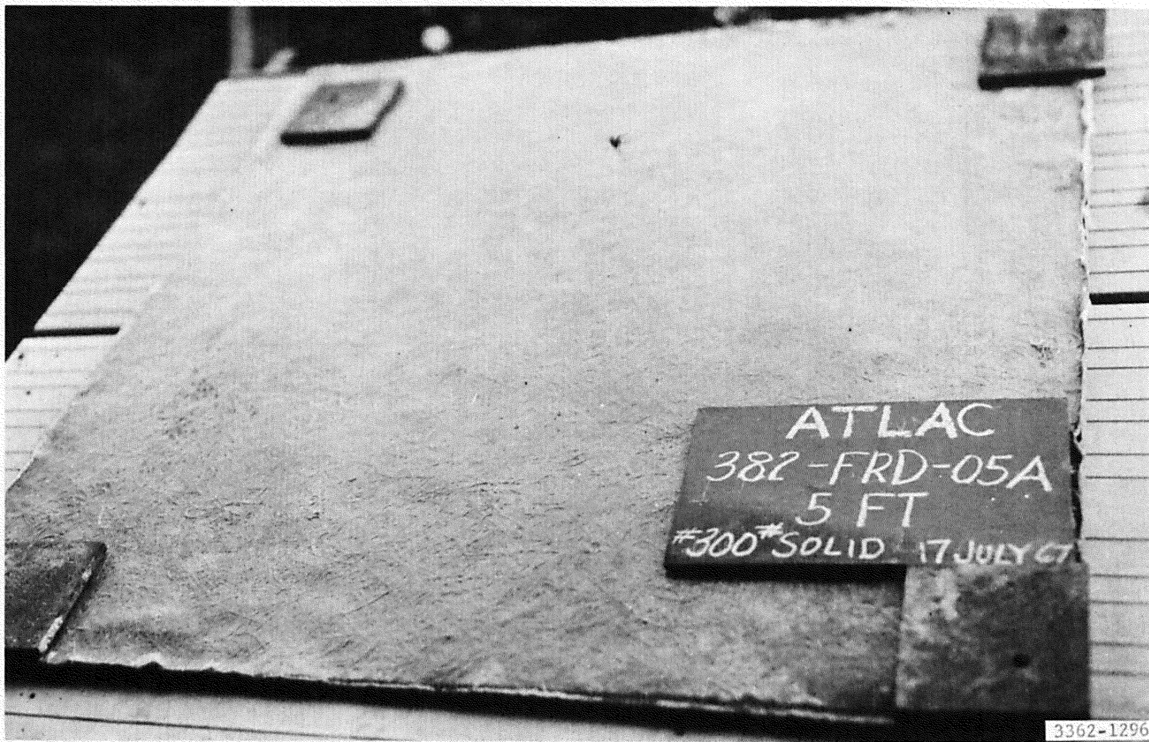
Photograph 8. Hetron 24806 specimen after 5-ft-distance, solid-propellant motor test



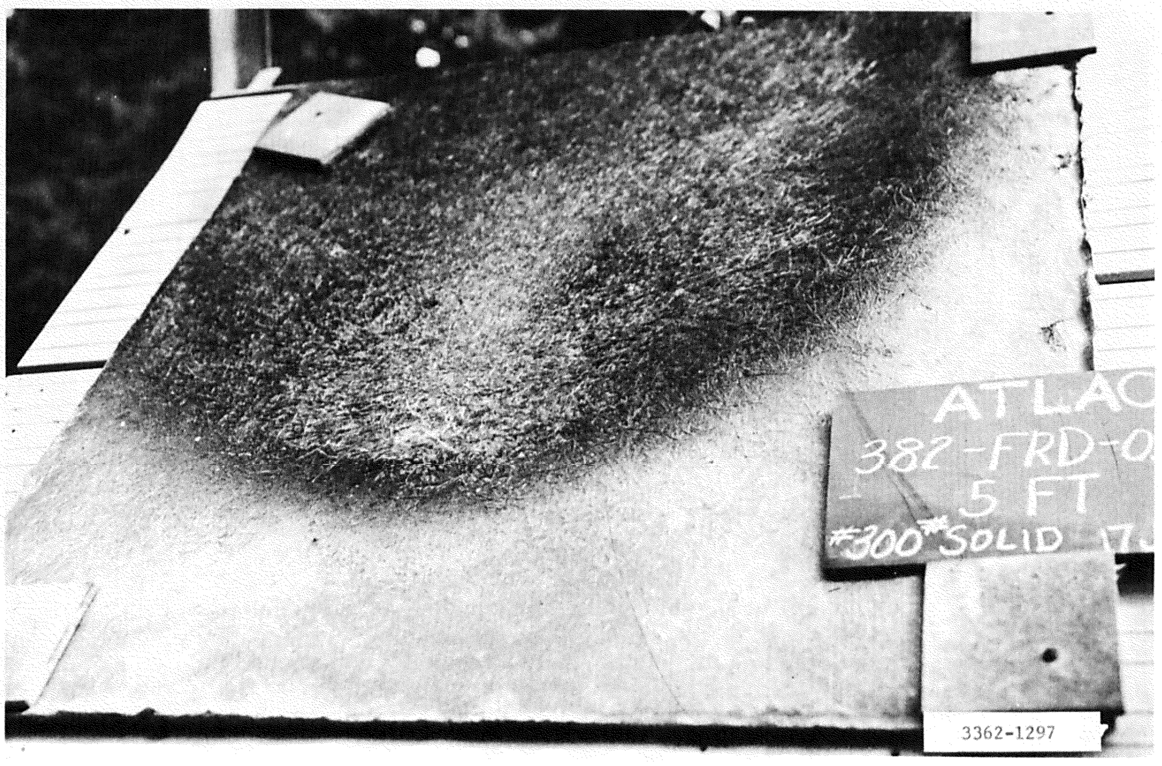
Photograph 9. Hetron 24806 specimen after 3-ft-distance, solid-propellant motor test



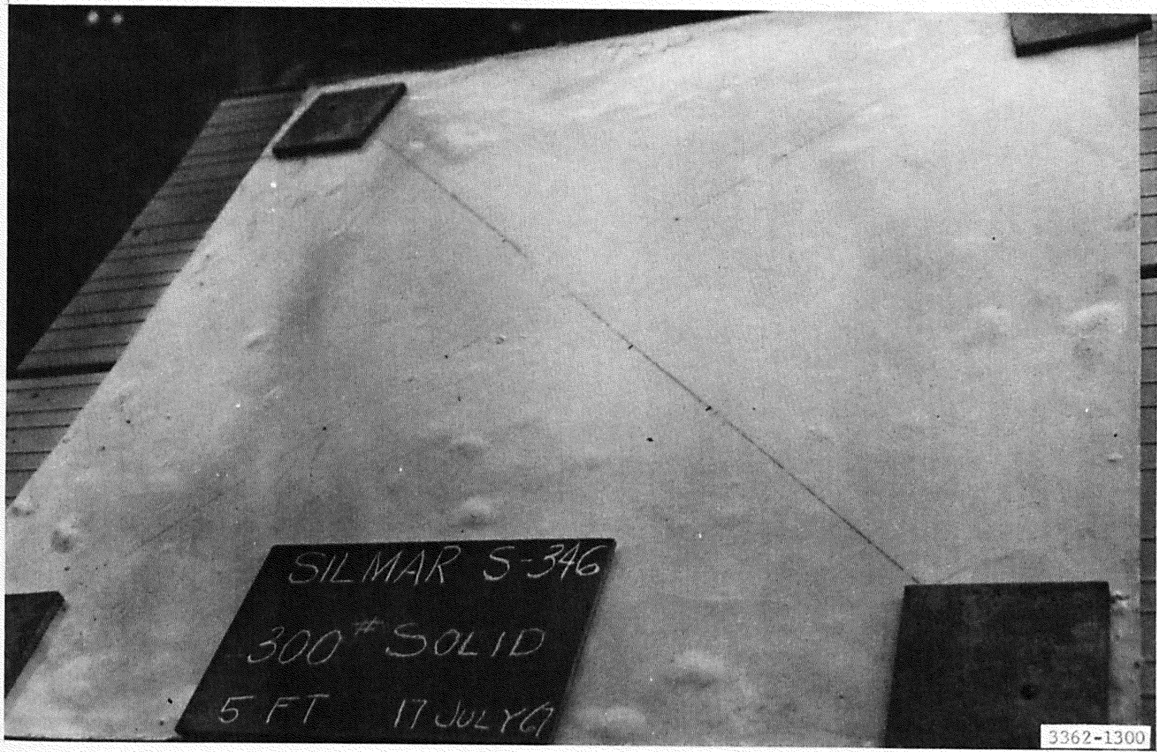
Photograph 10. Hetron 24806 specimen after series of exposures to liquid-propellant motor exhausts



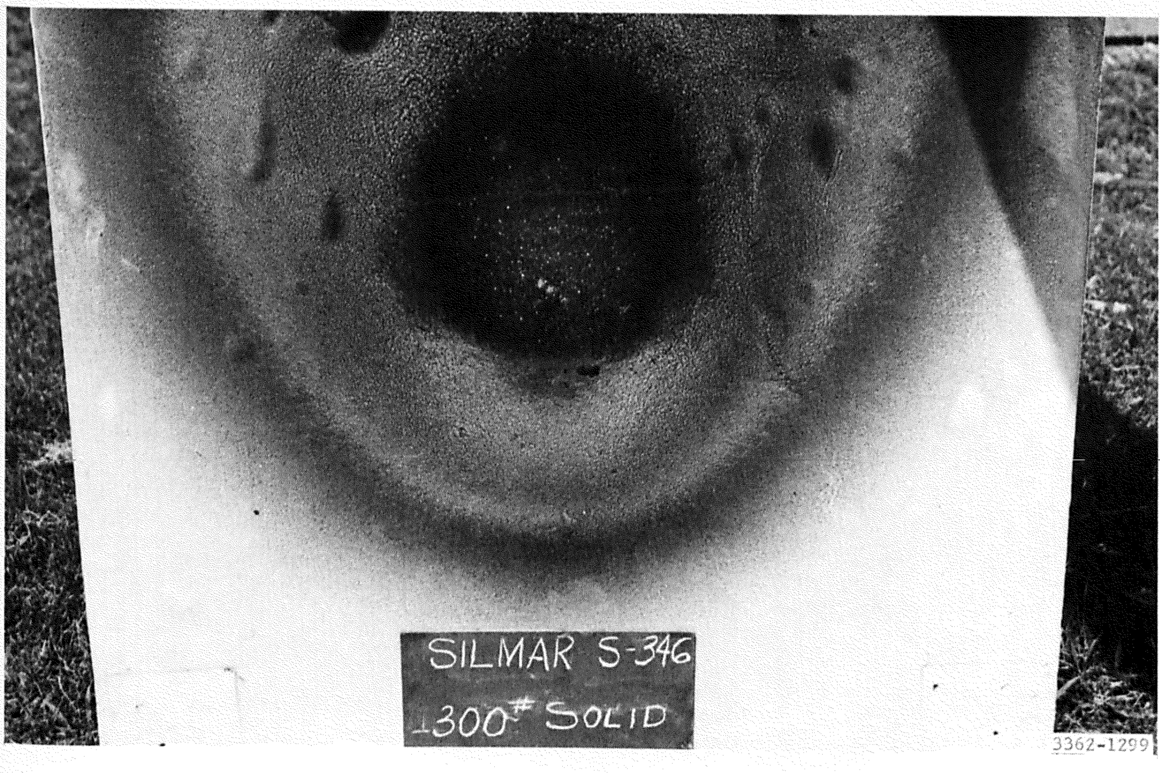
Photograph 11. Atlac 382FRD-05A specimen before tests



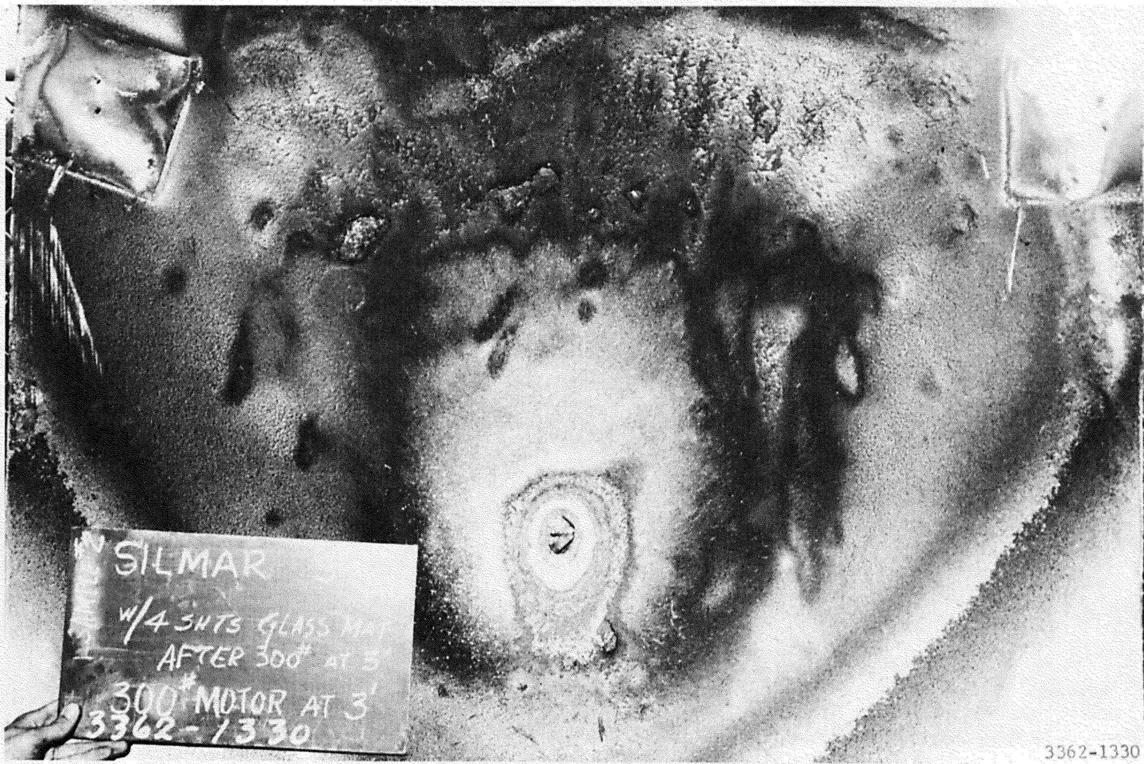
Photograph 12. Atlac 382FRD-05A specimen after 5-ft-distance, solid-propellant motor test



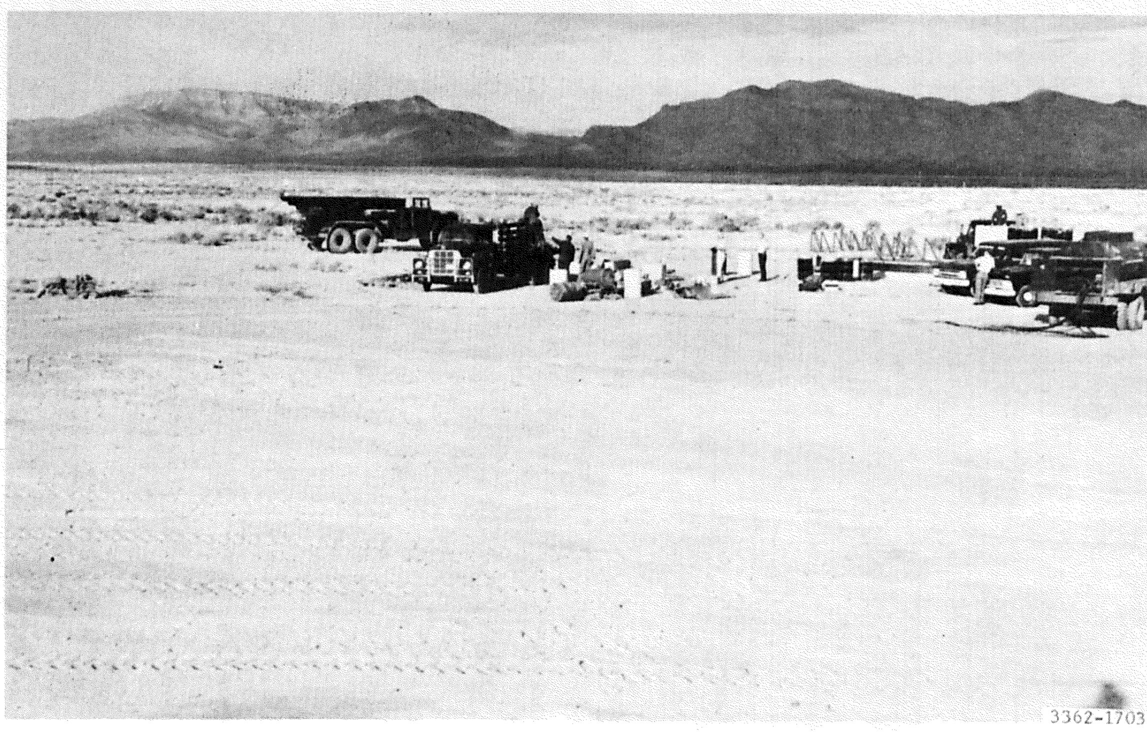
Photograph 13. Silmar S-346 specimen before tests



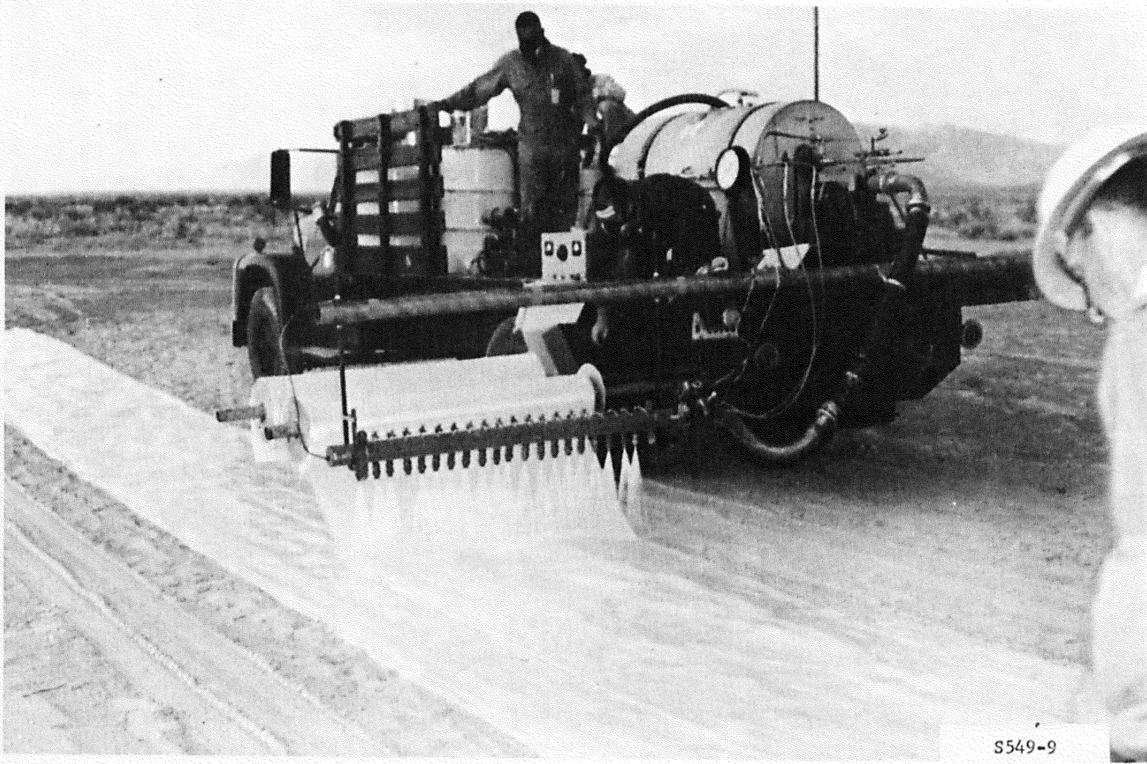
Photograph 14. Silmar S-346 specimen after 5-ft-distance, solid-propellant motor test



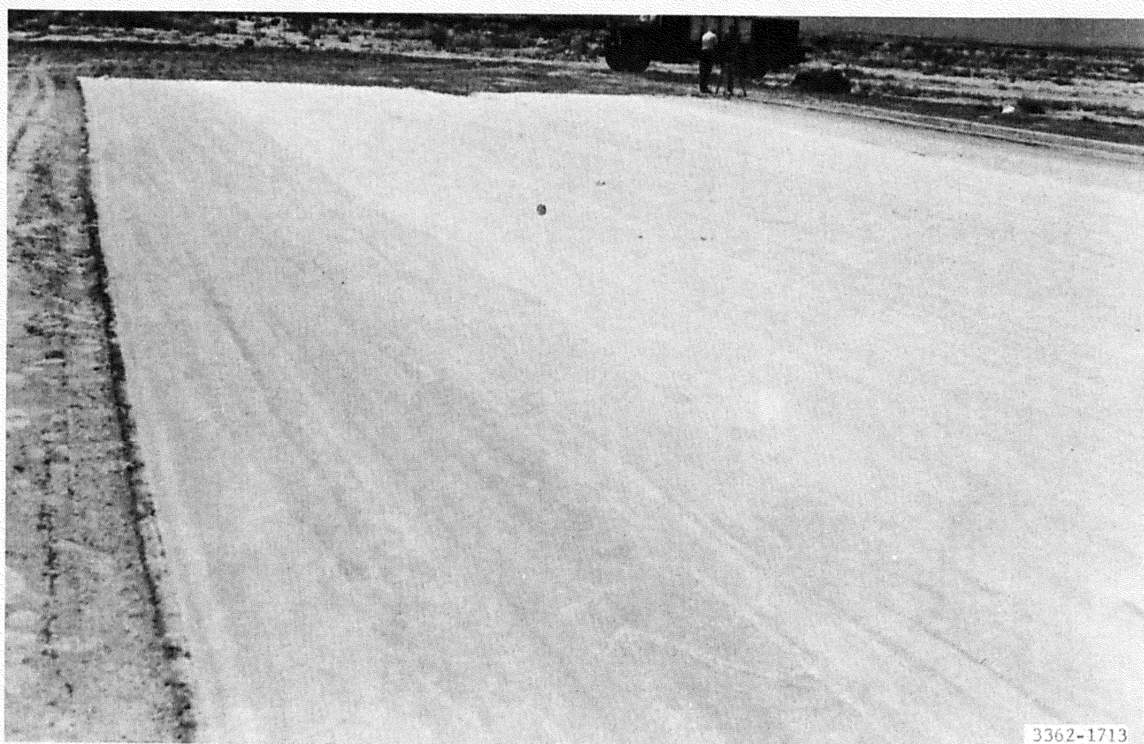
Photograph 15. Silmar S-346 specimen after tests



Photograph 16. View of field test area

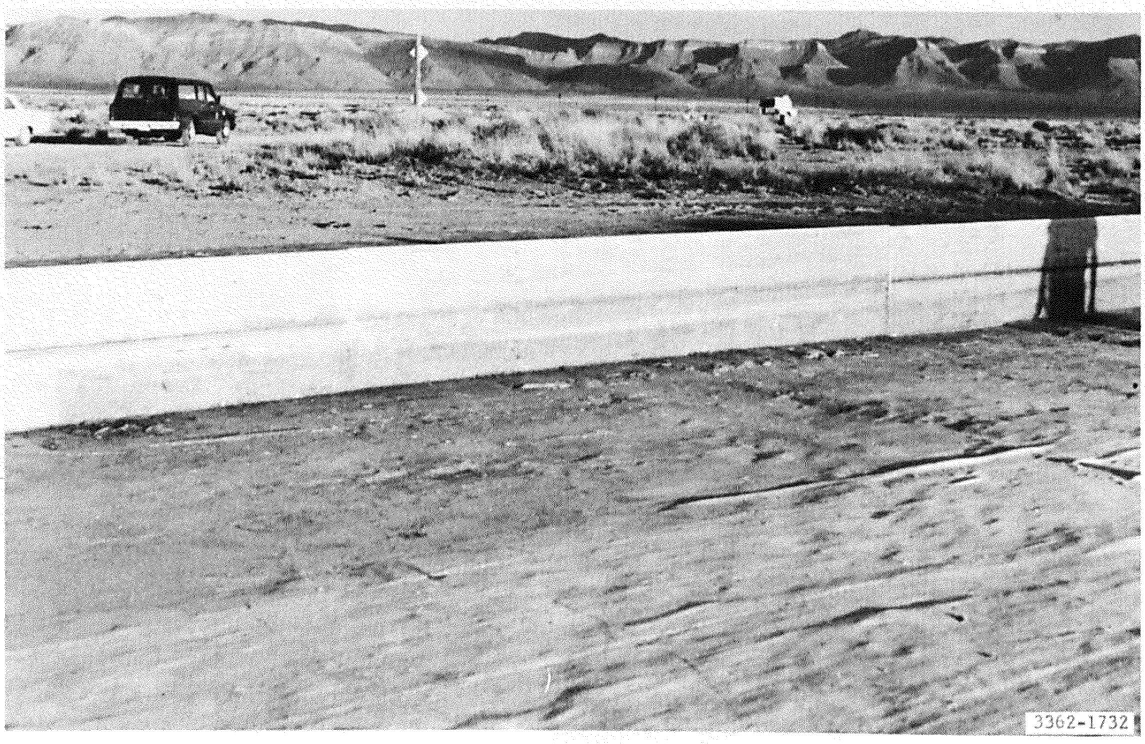


Photograph 17. Placing glass fabric and resin

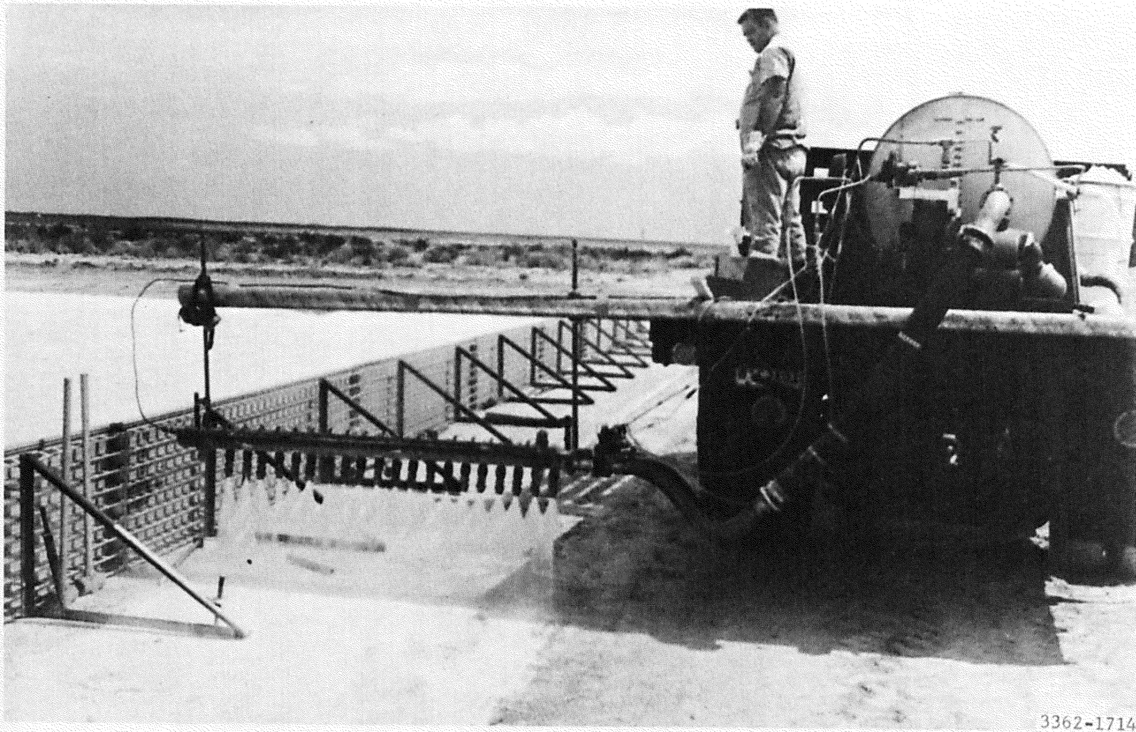


Photograph 18. Completed fiber glass-polyester resin area

Photograph 19. Anchorage of vertical fence



Photograph 20. Inside view of vertical wall



Photograph 21. Applying UCAR-131 outside the blast fence

Photograph 22. Completed Honest John launch area

Photograph 23. Area after launch of Honest John rocket

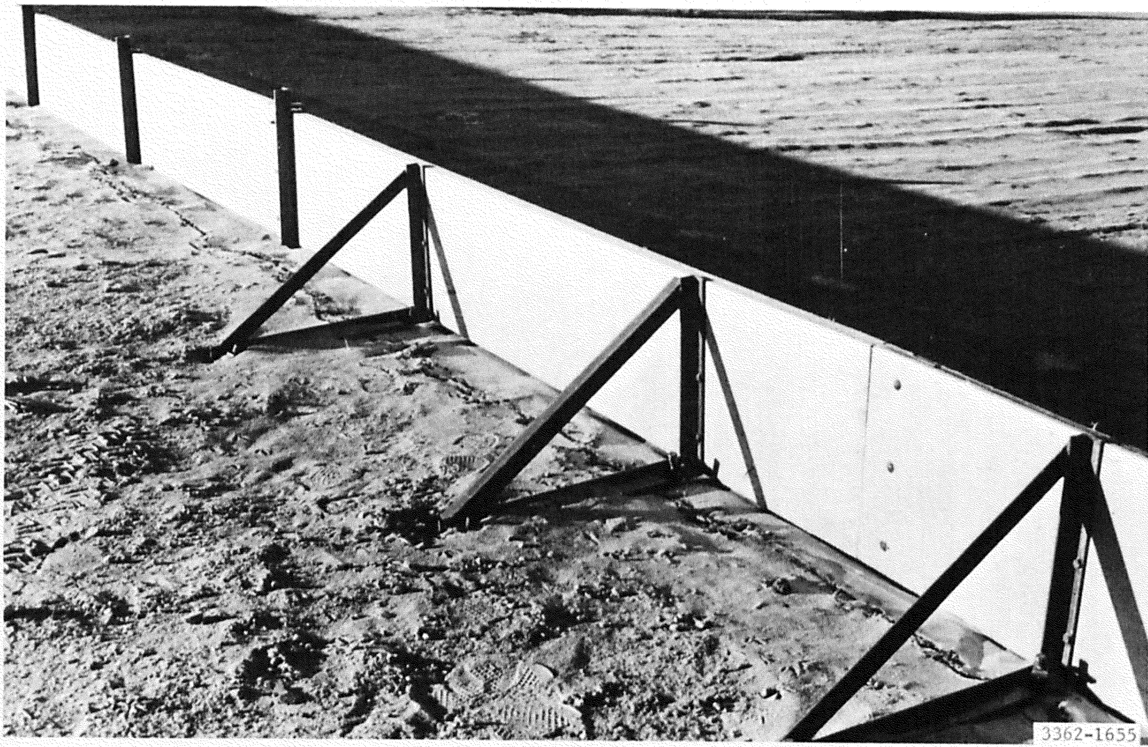
Photograph 24. Impingement area after launch of Honest John rocket

Photograph 25. UCAR coating forward of launch area

Photograph 26. Placing material in Little John rocket launch pad

Photograph 27. Placing border of glass fiber and resin

Photograph 28. Buildup in impingement area



Photograph 29. Blast-deflecting fence placement

Photograph 30. Completed Little John rocket launch area

Photograph 31. Placing Little John rocket launcher on pad

Photograph 32. Little John rocket pad after launch

Photograph 33. Little John rocket blast-impingement area

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13. ABSTRACT Experience with Army tactical rockets and missiles has shown that during launchings over unprotected soil surfaces, the motor blast produces dust clouds that could reveal the firing location to the enemy and causes soil erosion in the launch area detrimental to reloading and operating conditions. As the tactical missiles and rockets are used as artillery and antiaircraft weapons in close support of forward-area ground operations, attenuation of dust clouds and control of ground erosion are considered essential for personnel and equipment protection and for camouflage and concealment. Tests using small rocket motors were made at the U. S. Army Engineer Waterways Experiment Station on blast-resistant materials and combinations of materials at exposure temperatures up to 3800 F to select the most favorable combination of materials for field testing. Field tests of materials were conducted with the Honest John and Little John rockets, both operational weapons, at the White Sands Missile Range, N. Mex. Based on results obtained in this investigation, the following conclusions are believed warranted: a. A ground cover constructed of high-heat-resistant polyester resin reinforced with glass will withstand the direct blast from the motor of the Little John rocket, and b. The use of a fence around two sides and along the rear edge of the firing pad will substantially reduce the areal extent of ground protection required for alleviating dust cloud formation during launch.

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Erosion control						
Fiber glass reinforced plastics						
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Missile launching sites						
Soil stabilization						
Synthetic resins						

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