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HOT DESTRUCT TEST OF THE THIRD-STAGE ATHENA/H SOLID ROCKET MOTOR

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AIR FORCE ROCKET PROPULSION LABORATORY
DIRECTOR OF LABORATORIES
AIR FORCE SYSTEMS COMMAND
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EDWARDS, CALIFORNIA

32

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The Athena Destruct Test was conducted at the Air Force Rocket Propulsion Laboratory on 22 April 1971 with a third-stage Athena/H (Alcor JB/23KS11000) solid propellant rocket motor. The objective of the test was to demonstrate that the Third-Stage Athena/H destruct hardware would terminate the thrust of a burning Alcor IB motor without resulting in "high-order" detonation. A secondary test objective was to attempt estimating the initial velocities of debris and fragments using high-speed photography. All test objectives were successfully accomplished.

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The Athena Destruct Test was conducted at the Air Force Rocket Propulsion Laboratory on 22 April 1971 with a third-stage Athena/H (Alcor JB/23KS11000) solid propellant rocket motor. The objective of the test was to demonstrate that the Third-Stage Athena/H destruct hardware would terminate the thrust of a burning Alcor IB motor without resulting in "high-order" detonation. A secondary test objective was to attempt estimating the initial velocities of debris and fragments using high-speed photography. All test objectives were successfuly accomplished.

FOREWORD

The destruct test described was conducted by the Air Force Rocket Propulsion Laboratory (AFRPL) in support of SAMSO, the Advanced Ballistic Re-entry Systems (ABRES) Program (627A), Contract F04701-68-C-0046. Project direction was provided by the Motor Development Branch under Project 627A00AMT, Athena Destruct Test, which covered the period of 27 February 1971 to 23 April 1971. Project Engineer for the project was Lt Richard M. Seibel, III, AFRPL (MKMC).

Individuals who made significant contributions to the success of the test program include: Mr. G. L. Wellman, Test Division (TSBB); Mr. T. C. Glaze, Test and Support Division (TSBB); and Mr. G. A. Kopinsky, Test Division (TSBB).

This technical report has been reviewed and is approved.

CHARLES R. COOKE
Chief, Solid Rocket Division
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION 1

INTRODUCTION

This report contains a discussion of the Athena Destruct Test conducted at the Air Force Rocket Propulsion Laboratory (AFRPL) on 22 April 1971. The blast hazards test facility and the test results are discussed.

A. OBJECTIVE

The primary objective of this test was to demonstrate that the Atlantic Research Corporation (ARC)-designed Third-Stage Athena/H destruct system would render a thrusting Third-Stage Athena/H propulsion subsystem (Alcor IB/23KS11000) nonpropulsive. Technically, this is achieved if the destruct system ruptures the motor pressure vessel without propellant "high-order" detonation.

A secondary objective was to provide motor debris dispersion data to facilitate the estimation of ground hazard radius resulting from an in-flight command destruct.

B. TEST ARTICLE DESCRIPTION

The test motor was an operational Third-Stage Athena/H (Alcor IB/23KS11000) solid propellant rocket motor manufactured by Aerojet General Corporation. The destruct system consisted of a linear shaped charge (LSC), a safe and arm device (S&A), and a detonation block (det block) which transferred the detonation shock from the S&A to the LSC.

C. TEST CONFIGURATION

The Athena Destruct Test was conducted at the AFRPL Test Area 1-36D, on 22 April 1971. The destruct system was activated 7.5 seconds after motor ignition while the motor was restrained in a horizontal position. High-speed (Fastax) cameras were positioned to record initial LSC penetration and motor fragment dispersion. Documentary cameras were positioned to record the test and the debris hazard radius. Motor chamber pressure was redundantly monitored and recorded on FM tape, and initial motor thrust was indicated by a breakwire secured across the nozzle exit cone.

With the intent of simulating flight operation, pressure switches were electrically wired to the destruct electrical circuit and mechanically connected to the pressure tap in the igniter. These switches were required to actuate on ignition pressure, thereby completing the destruct electrical circuit and maintaining continuity until the command destruct signal occurred.

D. TEST RESULTS

The destruct test successfully terminated the thrust of the Alcor IB motor as programmed. The pressure switches actuated on ignition, permitting the destruct signal to activate the destruct system 7.5 seconds after motor ignition. Upon command destruct, the motor case ruptured along the length of the LSC, the adjacent propellant ignited, a 1-pound piece of the forward dome blew off, and the motor thrust terminated. After the relatively nonviolent destruct, the motor remained basically intact. However, flames were observed through the slot in the side of the case, the forward dome and nozzle for 100 seconds after command destruct as a result of propellant burning at ambient pressures. These flames melted approximately half the case (Figure 1).* The maximum radius of debris was 700 feet (debris was recovered to a 450-foot radius).

* Figures and tables are presented sequentially beginning on pages 14 and 24, respectively.

SECTION II

TEST FACILITY DESCRIPTION

The Athena Destruct Test was conducted at Test Area 1-36D, a remote blast hazards area sited for 1-million pounds of TNT. The test pad is located 2750 feet above sea level in a shallow valley; the surrounding terrain rises to an altitude of 2800 feet above sea level at a distance of 1000 feet from the test pad. Figure 2 is a schematic of the general layout of Test Area 1-36D.

A. CAMERA COVERAGE

Two Fastax cameras set for 4000 frames per second (fps) operation and 100 pulses per second (pps) timing were positioned 800 feet in front of the motor. The purpose of these cameras was to view the overall test pad and motor fragments, thereby aiding the assessment of initial fragment velocities. To facilitate the estimation of fragment velocities, the longitudinal axis of the motor was pointed directly at the station six camera, and markers were placed 20 feet apart for 120 feet on both sides of the motor in a row perpendicular to that axis. The station seven camera was used as a backup (Figure 3).

Two documentary cameras set for 24 fps operation and 100 pps timing were positioned 800 and 1200 feet from the motor. The purposes of these cameras were to document the test and to record the maximum debris radius. Experience with destruct tests of pressurized motors indicated a potential hazard radius of 3000 feet. Therefore, wide-angle lenses were chosen to give the station three and station eight cameras horizontal fields of view of 2500 feet.

A Fastax camera (station five) set for 8000 fps operation and 1000 pps timing was located 85 feet from the motor. Viewing the motor and the test stand, the camera was intended to record the destruct system activation and the initial termination of motor thrust. A high-speed flash bulb wired to the destruct electrical circuit was placed on the test stand to establish a time reference on the Fastax film.

B. INSTRUMENTATION

All data were recorded on a wideband FM tape recorder (PI 400) at 40 inches per second tape speed.

Motor chamber pressure was redundantly monitored with two 1000 psi pressure transducers. Initial motor thrust was monitored by a breakwire secured across the nozzle exit cone (Figure 4). The initiation and magnitude of the igniter and safe and arm currents were monitored and recorded. The initial activations of the Fastax cameras were recorded.

Two pressure switches manufactured by Custom Components, Inc., were electrically connected in series with the destruct ordnance circuit (Figure 5). They were set to actuate, thereby completing continuity of the destruct circuit, when motor chamber pressure increased to 165 ±5 psi. An automatic override switch was programmed as a backup system to complete the destruct circuit 0.4 second after initiation of the destruct pulse.*

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* "Test procedures for Project Athena," Countdown No. CD-1-36D-1, Air Force Rocket Propulsion Laboratory, April 1971.

SECTION III

INSTRUMENTATION CALIBRATION

All pressure transducers and amplifiers were removed from the system and individually calibrated. This operation established the sensitivity of each transducer and gain of each amplifier. With the system in operational configuration, an end-to-end calibration was performed on both pressure channels. This was accomplished by applying a known pressure to the transducers in the field and comparing the known value to the measured FM tape value. The current measurements for the fire signal (ignitor) and the destruct signal were calibrated in similar fashion. The pressure switches were calibrated to show both off, one on and both on readings. The breakwire, 4000 fps camera, and 8000 fps camera also registered on or off the FM tape.

SECTION IV

MOTOR DESCRIPTION

The hot destruct test was conducted with a third-stage Athena/H (Alcor IB/23KS11000) solid propellant rocket motor (S/N STV 181). The motor was manufactured by the Aerojet General Corporation. The destruct system was manufactured by the Atlantic Research Corporation.

The operational Alcor motor was horizontally restrained and secured to the test stand at the forward and aft interface skirts (Figure 6). The linear shaped charge (LSC) and the detonation transfer block were bonded to the motor. The safe and arm device was bolted to the det block and restrained further with a nylon strap that was wrapped around the motor and over the safe and arm device (Figures 7 and 8).

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SECTION V

TEST RESULTS

A. POST-TEST OBSERVATIONS

Examination of the camera films revealed that the LSC split the motor case along the complete length of the charge. Motor thrust from the nozzle was terminated within 10 milliseconds after command destruct. After destruct, the motor remained intact except that flames were observed through the slot in the side of the case, the forward dome and nozzle. The only thrust being developed was that resulting from mass flow produced from propellant burning at ambient pressures. The observation of surging, pulsating flames through the forward dome opening and side slot is evidence supporting the fact that the propellant was burning at ambient pressures. Analysis of the documentary cameras indicated that flames were protruding from the motor for approximately 96 seconds after command destruct.

Examination of the remains of the motor revealed that the flames had melted approximately half the case (Figure 9). All of the bolts used to secure the motor to the test stand, with the exception of one at the head end and five at the aft end, had been stripped from the motor and test stand.

The maximum radius of debris which was recovered was approximately 450 feet. Figure 10 is a map of the debris location and weights.

B. DATA RESULTS

Table I summarizes the data from the 40 inches per second oscillographic trace of the event. Only one of the chamber pressure transducers gave readable data during the motor firing. Immediately after the destruct signal, the chamber pressure signal did not register until it was stabilized at essentially zero psi, 15 milliseconds later. This time correlates well with the time delay noted in film analysis.

C. FILM ANALYSIS

Table II summarizes the film from the 8000 frames per second camera at station 5. Chamber pressure instantly decreased (signified by a reduction in the plume) upon application of destruct current. The delay between the two events was less than 0.5 millisecond. As support for this conclusion, the analysis of camera 5 film indicated destruct occurred prior to the observation of light from the flash bulb wired into the destruct circuit. Although the flash bulb was located directly behind a pole, which prevented immediate observation of initial light, a very faint indication of the flash bulb can be observed in the same frame that destruct initially occurs. The time interval between flash bulb light and a definite reduction in the plume (indicating a decrease in chamber pressure) was estimated at 10 milliseconds. This estimate incorporates the assumption that the camera is operating at approximately 5300 frames per second at this early phase. After 400 frames, it became apparent that the flames flickered at regular intervals of approximately 28 milliseconds. This pulsating flame was viewed from all cameras.

Cameras 3, 6, 7 and 8 recorded the ejection of two pieces of burning propellant from the motor. The landing locations of these propellant pieces were not determined at the test site. However, analysis of the station 8 documentary camera film indicated that one of the pieces landed between 600 and 700 feet from the motor and 25 to 35 degrees east of north. An effort to determine the propellant velocity by analysis of the film indicated that immediately after the propellant became visible above the cloud of debris, its velocity was in excess of 60 feet per second.

SECTION VI

CONCLUSIONS

The Athena Destruct Test was completely successful. The destruct system with the incorporation of the pressure switches performed as planned. The motor case was ruptured, the forward dome blew off, and thrust from the nozzle was terminated in less than 10 milliseconds after destruct. The pressure switches closed upon motor pressurization completing an electrical circuit through which the destruct current passed. The thrust breakwire could serve as a backup means to activate destruct. Propellant did not detonate and only two pieces of burning propellant ejected from the motor were observed on cameras 3, 6, 7 and 8. The maximum radius of debris was between 600 and 700 feet.

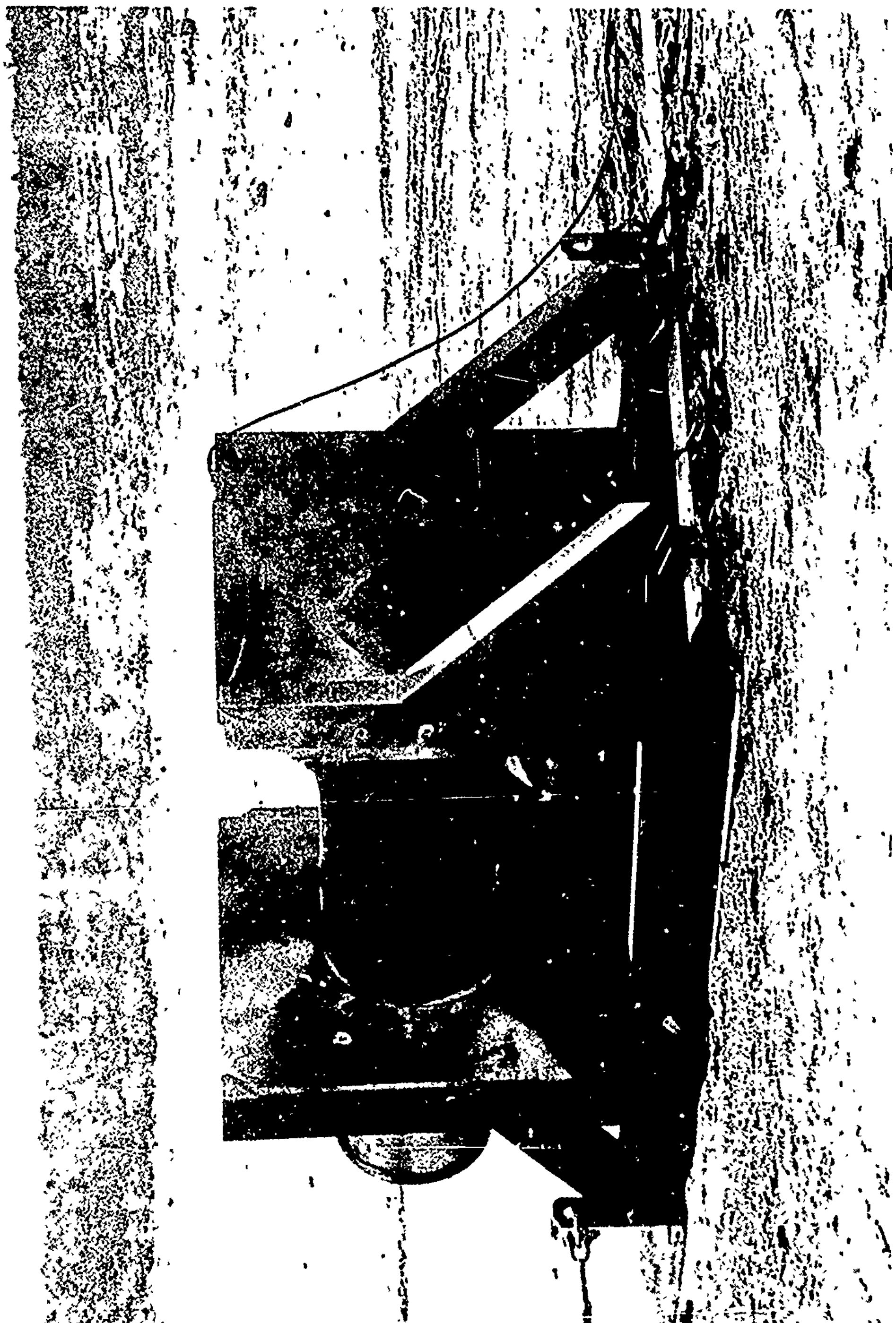

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Figure 1. Post-test View of Stand

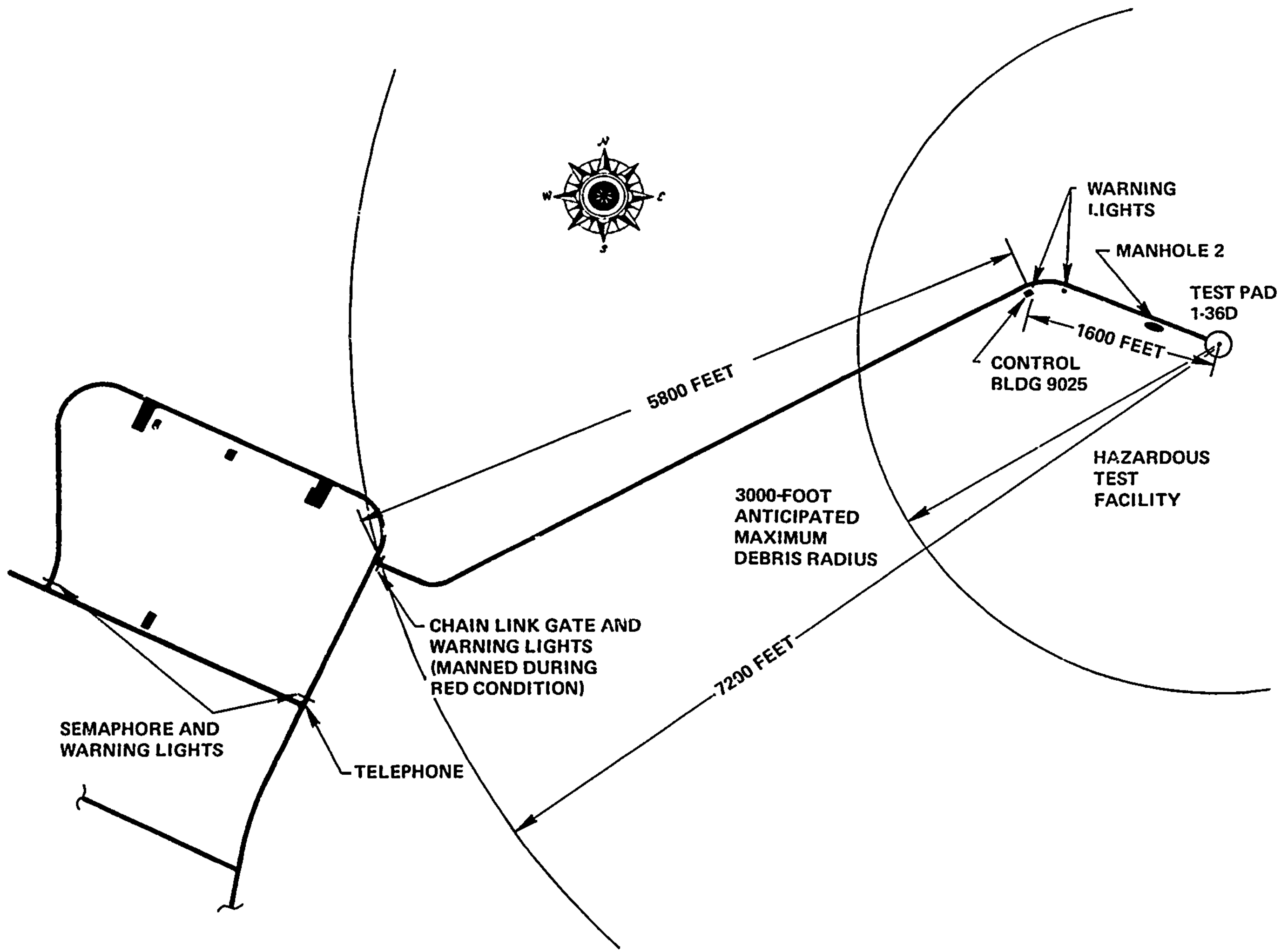

Figure 2. Layout Schematic of Test Area

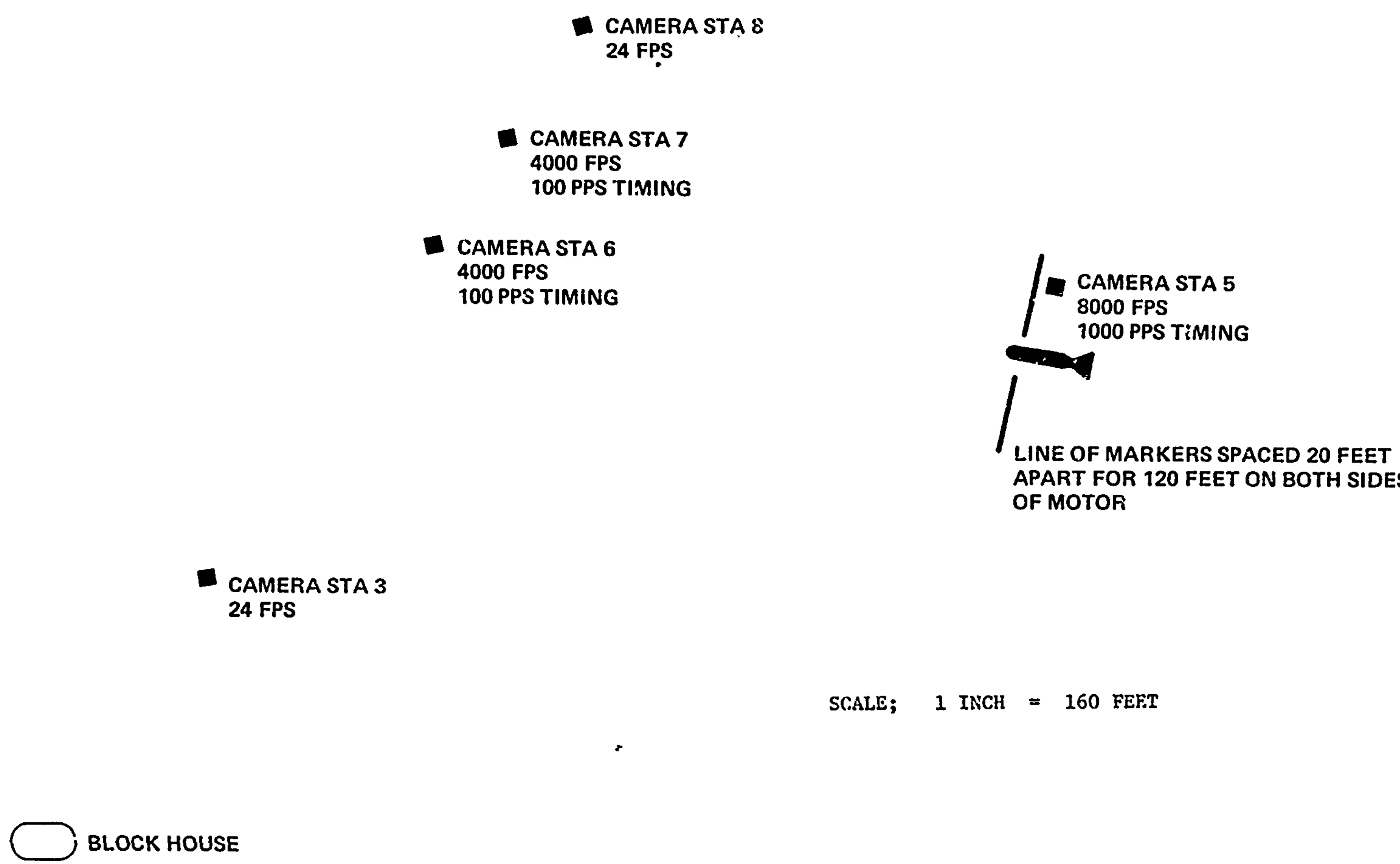

Figure 3. Camera Layout

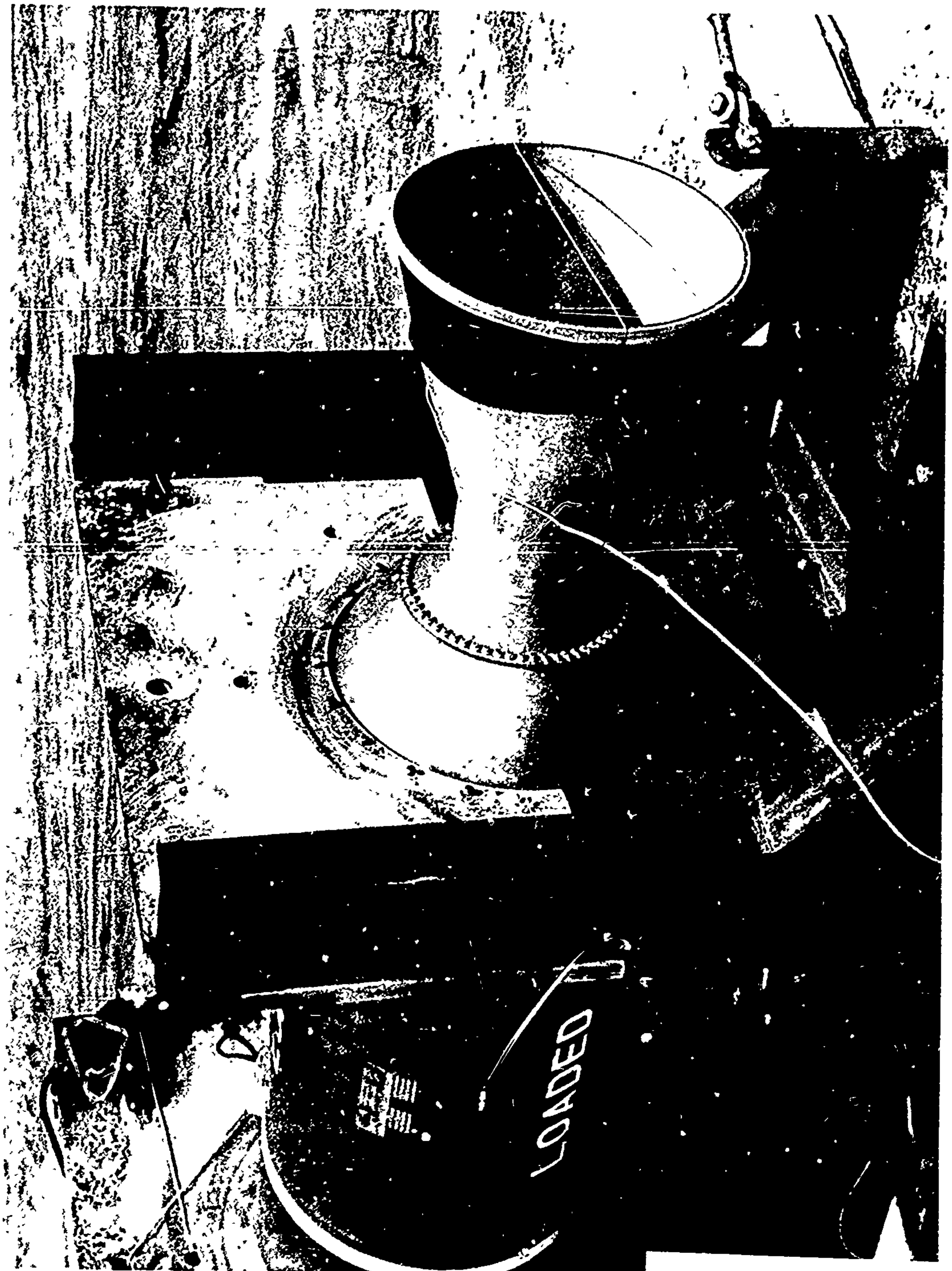

Figure 4. Pre-test View of Nozzle

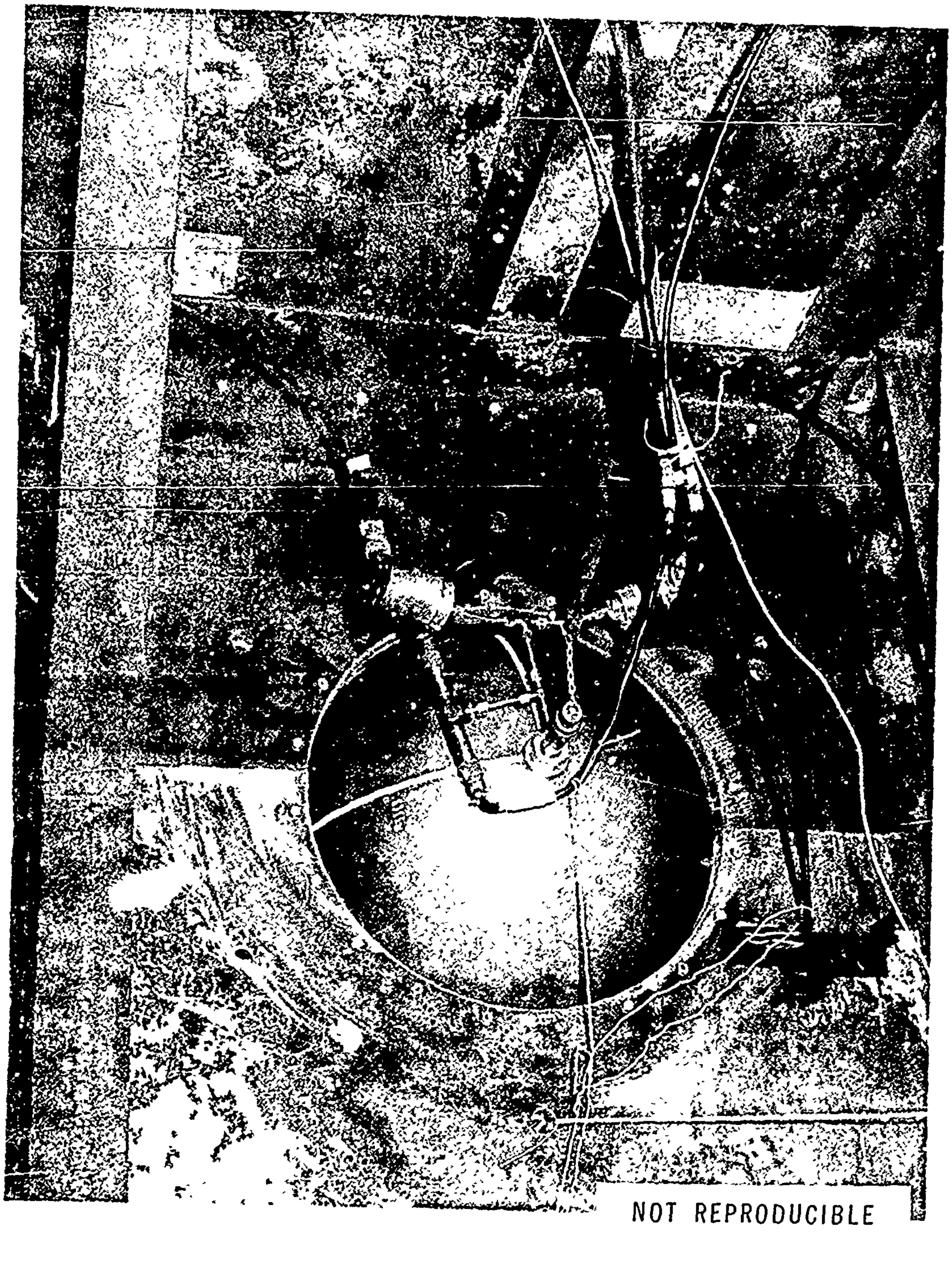

Figure 5. Pressure Switches

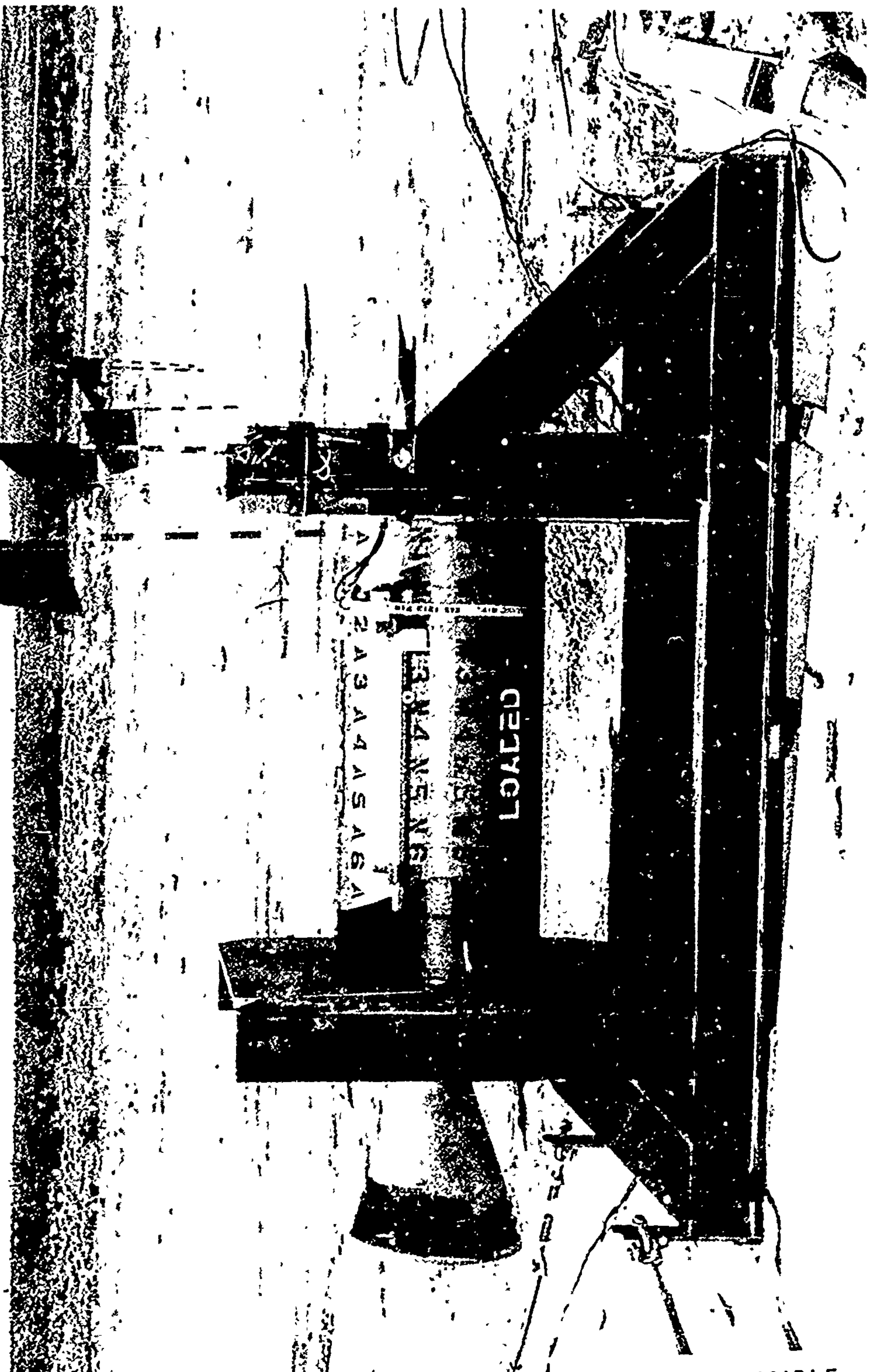

Figure 6. Pre-test Motor View

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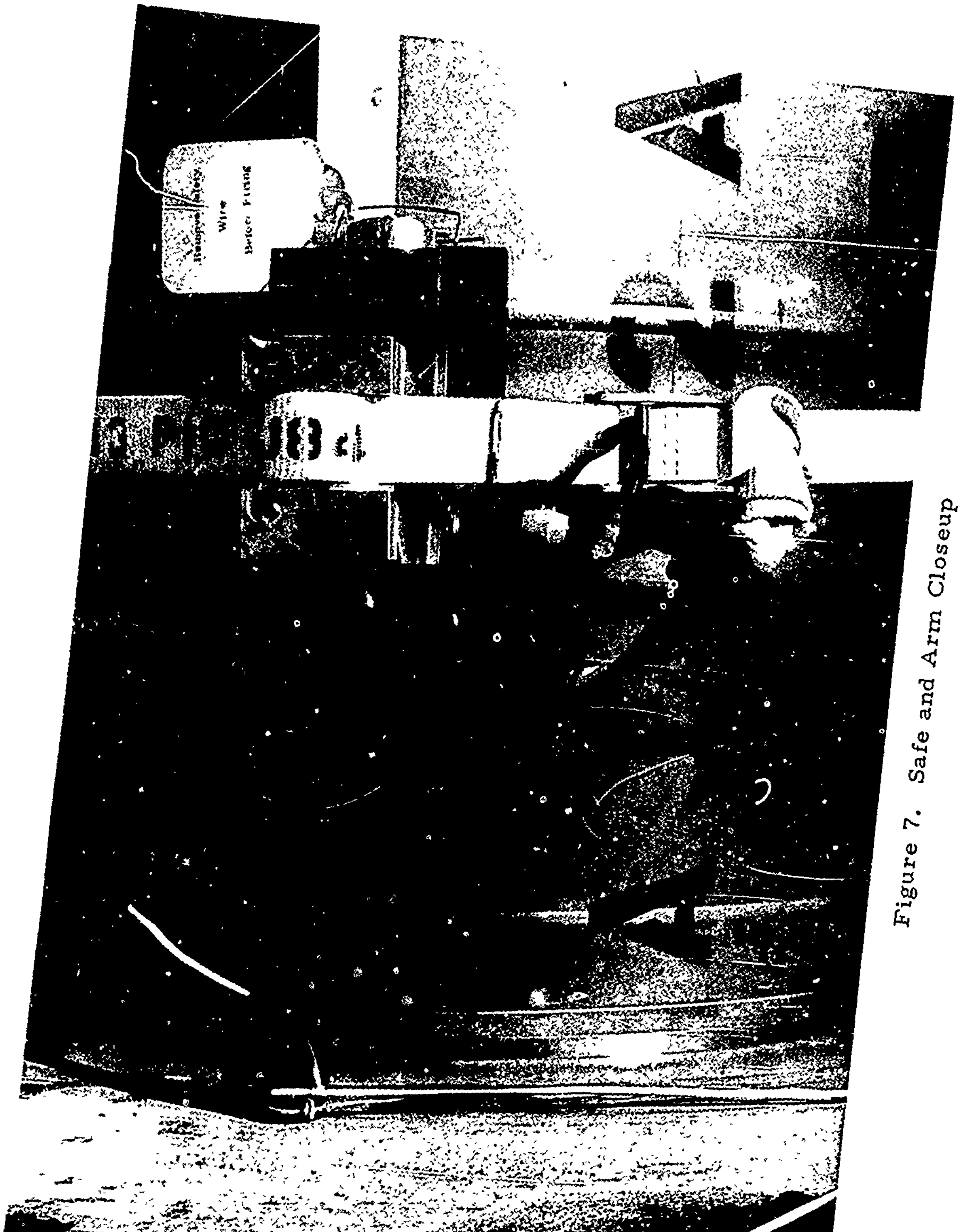

Figure 7. Safe and Arm Closeup

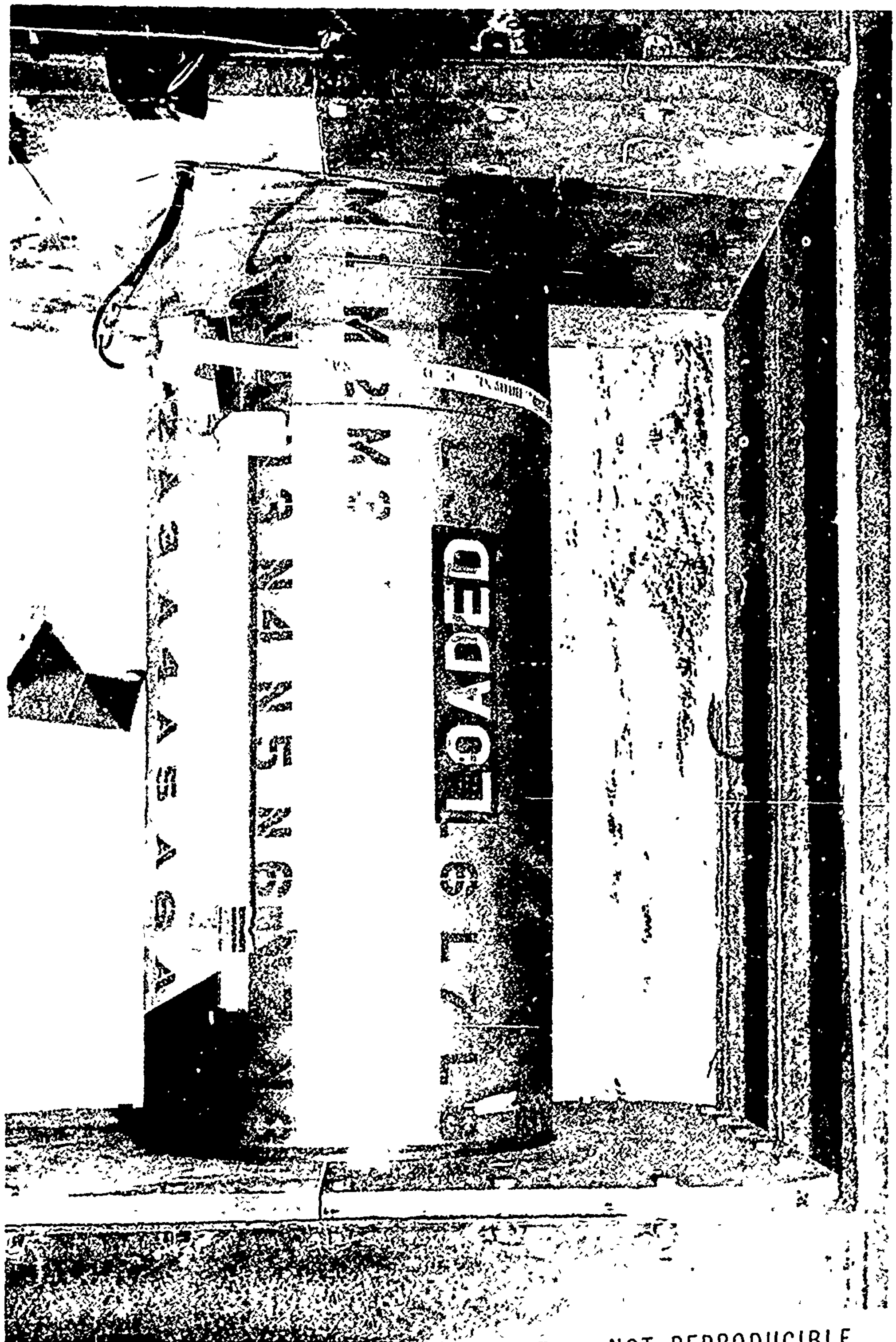

Figure 8. LSC Installation

Figure 9. Post-Test View of Dome

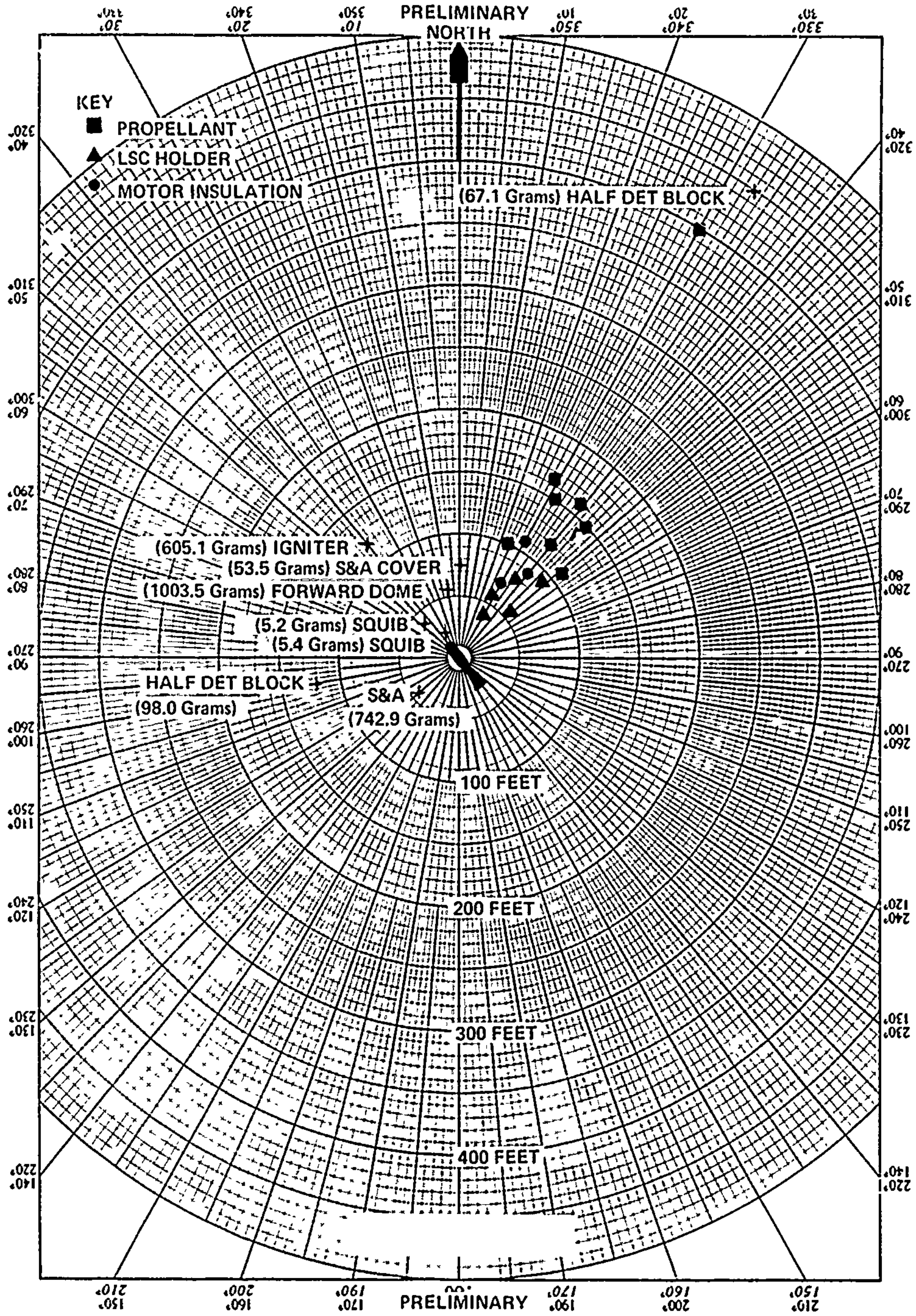

Figure 10. Debris Map

TABLE I. FM TAPE REVIEW

Time (seconds)	Event
0.0	Fire current on (magnitude = 5.6 amperes)
0.021	Breakwire off
0.030	Pressure switches on
0.065	Chamber pressure peaks (magnitude = 330 psi)
5.258	4000 frames/sec camera on
5.782	8000 frames/sec camera on
7.248	Destruct current on (magnitude = 4.35 amperes)
7.263	Chamber pressure stabilizes at zero

TABLE II. CAMERA STATION 5 REVIEW

Frames	Camera Speed (frames/sec)	Event
1	5300	Faint indication of flash bulb. Linear shaped charge (LSC) detonates
2	5300	Smoke down length of LSC; LSC holder comes off
21	5300	Fire between T plate and stand
22	5300	Fire coming out dome
46	5300	Definite reduction in plume (approximately 10 milliseconds after T_o)
400	5300	Fire subsides
5400	7000	Fire flares up
5640	7000	Fire subsides
5840	7000	Fire flares up
6030	7000	Fire subsides
6240	7000	Fire flares up
6430	7000	Fire subsides
6620	7000	Fire flares up
6830	7000	Fire subsides
7040	7000	Fire flares up
7250	7000	Fire subsides
7460	7000	Fire flares up

AUTHORS' BIOGRAPHIES

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Capt Seibel is a 1968 graduate of Princeton University where he earned a bachelor's degree in Aeronautical Engineering. He is presently attending Oklahoma State University in order to obtain a master's degree in General Engineering.

His first assignment was at the Air Force Rocket Propulsion Laboratory. He spent 3 years in the Solid Rocket Division at the AFRPL as a Systems Support Engineer.

CHARLES P. PRICE, III, CAPT, USAF

Capt Price is a 1968 graduate of the United States Air Force Academy. He received a bachelor's degree in Engineering Sciences.

He has been assigned at the AFRPL as an Engineer in the Solid Rocket Division where he has obtained experience in both the design and analysis and systems support areas.