NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-448

Mariner Mars 1971 Spacecraft Destruct Unit

D. P. Davis

F. L. Sola

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

November 15, 1969

31

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-448

Mariner Mars 1971 Spacecraft Destruct Unit

D. P. Davis
F. L. Sola

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

November 15, 1969

Prepared Under Contract No. NAS 7-100
National Aeronautics and Space Administration

Preface

The work described in this report was performed by the Propulsion Division of the Jet Propulsion Laboratory.

[redacted]

Contents

I. Introduction 1

II. Destruct Unit Design and Performance Requirements 1

III. Test Plan 2

A. Flat-Plate Tests 2

B. Pressurized-Tank Test 2

IV. Test Results 2

A. Results of Flat-Plate Tests 2

B. Results of Pressurized-Tank Test 3

V. Conclusions 3

References 3

Figures

1. *Mariner* Mars 1971 spacecraft launch configuration 4
2. Surveyor conical-shaped charge 4
3. Proposed location of destruct unit for *Mariner* Mars 1971 spacecraft 5
4. Flat-plate destruct test configuration 5
5. Flat-plate test setup before shaped-charge initiation 6
6. Condition of plates after shaped-charge detonation 6
7. Diagram of *Gemini* tank destruct test configuration 7
8. Prefiring setup for pressurized-tank test 7
9. Postfiring condition of tank and bulkhead 8
10. Interaction of a shaped charge with a pressurized, water-filled *Gemini* tank 9

Mariner Mars 1971 Spacecraft Destruct Unit

I. Introduction

The national range safety policies require that space vehicles containing propulsion systems provide for both a zero-thrust condition and propellant dispersion should flight termination become necessary (Ref. 1). *Mariner*-class space vehicles flown in previous missions contained propulsion systems of a size and propellant quantity that allowed the above requirement to be waived.

A space vehicle is presently being designed and fabricated for launching in 1971 to place a scientific payload in orbit about the planet Mars. In order to perform this mission, a significant fraction of the vehicle is propellant (approximately 50% of 2100 lb). In anticipation of the requirement for a vehicle destruct capability, an effort was initiated in the spring of 1968 and successfully completed in the summer of the same year to evaluate the existing *Surveyor* flight-qualified destruct unit for use in the *Mariner* Mars 1971 mission.

II. Destruct Unit Design and Performance Requirements

The *Mariner* Mars 1971 spacecraft propulsion subsystem consists basically of two spherical titanium 6Al-4V alloy propellant tanks that contain nitrogen tetroxide and monomethylhydrazine, two high-pressure nitrogen storage tanks, and a 300-lb-thrust rocket engine. The spacecraft is launched in the configuration shown in Fig. 1 with the propellant tanks pressurized at 100 psia.

A destruct unit originally developed for the *Surveyor* spacecraft and flown on seven flights was the basis for the design of the *Mariner* Mars 1971 destruct system. Its function in the *Surveyor* was to terminate thrust and disperse the solid propellant in a spherical rocket motor weighing approximately 1200 lb. The standoff distance for the conical-shaped charge is about 8 in. A cross-section of the *Surveyor* conical-shaped charge is shown in Fig. 2. The charge contains approximately 410 g of RDX explosive, which is initiated by means of a redundant mild detonating fuse (MDF). The MDF lines are interrupted by a mechanical safety and arming mechanism in the *Centaur* command destruct subsystem, which is armed just before launch.

In the *Mariner* Mars 1971 basic design the destruct unit is located on the *Centaur* forward equipment shelf with a view of the outer edge of a propellant tank (Fig. 3). This design has two advantages in that (1) there is no crossing of electrical or explosive wires from launch vehicle to spacecraft interface, and (2) no destruct equipment is carried on the spacecraft for the mission duration.

A test program was formulated to verify that the shaped charge already developed and qualified for the *Surveyor* (Ref. 2) could adequately meet the *Mariner* Mars 1971 requirements of a much greater standoff distance (approximately 70 in.) and penetration of the *Centaur* thermal bulkhead (epoxy–fiberglass honeycomb structure, 1 in. thick) before striking the tank (see Fig. 1). It is well known (Refs. 3 and 4) that the performance of a shaped charge is strongly dependent on the standoff distance, i.e., the distance between the lined cavity and the target, at initiation of the explosive. In this application, because there is almost an order-of-magnitude difference between the *Surveyor* standoff and the distance between the shaped charge and the target for the *Mariner* Mars 1971, it was imperative to perform early tests.

III. Test Plan

The shaped-charge test plan incorporated two sets of tests: (1) flat-plate tests to assess the distance performance of the shaped charge, and (2) a pressurized-tank test to simulate the actual destruction of a flight propellant tank. The tests were performed at a remote site of the JPL Edwards Test Station.

A. Flat-Plate Tests

The test configuration is shown schematically in Fig. 4. Three aluminum plates, 16 in. square by 1/16 in. thick. were arranged parallel to and in line with each other, 1 ft apart. The shaped charge was placed to face the center of the squares. Two tests were performed in this configuration to evaluate distances of 4 ft and 6 ft between the shaped charge and the initial plate. Figure 5 shows the test fixture with the aluminum plates attached and the shaped charge set at a distance of 4 ft from the nearest plate. The shaped charge in this test, as in all others, was initiated by a number 6 blasting cap fired from a portable firing unit. Figure 6 shows the results of detonation. A second test, similar in all respects to the first, but with the charge set at a distance of 6 ft, was next made. The results were identical to the first.

A third test was then performed in the same test configuration as tests 1 and 2, with the exception that a 1-in.-thick epoxy–fiberglass honeycomb section was mounted between the first aluminum target and the shaped charge, 20 in. in front of the shaped charge. Postfiring examination of the plates indicated that no discernible reduction in the destructive capability of the shaped charge was caused by interposing the honeycomb panel.

B. Pressurized-Tank Test

After the successful completion of the flat-plate tests, it was decided to perform a test under conditions that would simulate flight conditions to the maximum extent possible. Because manufacture of *Mariner* Mars 1971 propellant tanks had not begun, a surplus *Gemini* tank fabricated of titanium 6Al-4V alloy (the same material as used for the *Mariner* tanks) was selected as a suitable substitute. A *Centaur* thermal bulkhead was made available by General Dynamics/Astronautics. Figure 7 is a schematic of the test setup in which the geometric relationship of the tank, honeycomb thermal bulkhead, and shaped charge was the same as that predicted for the actual flight. An additional aluminum plate was located adjacent to the tank as shown. Its purpose was to act as a target for any secondary missiles created by the interaction of the shaped-charge jet and the tank. The prefiring test setup is shown in Fig. 8.

The tank was filled with 172 lb of water, with an ullage of 15%, the same as for *Mariner* Mars 1971. Nitrogen was used to pressurize the tank to 100 psig, which produced a tank-wall stress level equivalent to that of the *Mariner* Mars 1971 tank in the launch configuration. A Fastax high-speed camera was used to document the test firing. The camera was sequenced to provide as high a frame speed as possible during the firing of the shaped charge. Initiation of the shaped charge resulted in complete destruction of the pressurized water-filled tank.

IV. Test Results

A. Results of Flat-Plate Tests

Several significant results were obtained from the performance of the series of flat-plate tests. It was established that the performance of the *Surveyor* conical-shaped charge is not limited to use at short (~8 in.) standoff distances, but has the capability of perforating a series of 1/16-in. aluminum plates at distances of 4 and 6 ft. The attenuating effect of a 1-in.-thick epoxy–fiberglass honeycomb was negligible.

Examination of the aluminum target plates after the tests indicated several important factors of value in applying the shaped charge to the destruction of targets at long distances:

(1) The jet does not develop much spreading; i.e., it is fairly well collimated. At a distance of 6 ft an aluminum target plate had most of the damage

located over an area about 6 in. wide. This corresponds to a jet spread of 5 deg.

(2) The jet impingement on the aluminum target was quite reproducible. Precise measurements could not be made, but observations of the damage sites for the three tests showed the majority to be located at about the center of the target plates.

B. Results of Pressurized-Tank Test

The location and orientation of the principal components of the pressurized-tank test duplicated the predicted flight configuration for the *Mariner* Mars 1971. The test, which resulted in the destruction of the *Gemini* tank, established the capability of the *Surveyor* shaped charge to perform the required destruct function. The aluminum plate set up to serve as a target for secondary missiles from the *Gemini* tank did not provide any useful information. Apparently the plate was displaced by the shock wave before any particles from the tank could reach it. Figure 9 shows the section of the *Centaur* thermal bulkhead after firing and some of the tank fragments that were collected from the vicinity of the test stand. Debris was scattered randomly for a distance up to 100 ft from the initial test position.

A series of photographs taken from frames of the Fastax film is reproduced in Fig. 10. The camera was operating at a speed of 6075 frames/s and the time from the first to the last frame was 1.3 ms. The development of the jet and its angular confinement are apparent from the photographs. The excess energy available from the jet is demonstrated by the jet exit from the rear of the tank.

V. Conclusions

The tests demonstrated that it is feasible to use the conical-shaped charge, which was developed and qualified for application on the *Surveyor* spacecraft, for the *Mariner* Mars 1971 destruct requirements. The increased distance from the shaped charge to the target does not reduce the capability of the destruct unit to perforate and destroy a pressurized *Mariner* Mars 1971 propellant tank. The jet spreading and the reproducibility of impact accuracy permit the location of the shaped-charge destruct unit in a region having a limited view of the intended target.

Without additional tests, no conclusions can be drawn with respect to the production of secondary missiles having destruct capability for an adjacent pressurized propellant tank.

References

1. *Range Safety Manual*, Volume I, AFETRM 127-1. Headquarters Air Force Eastern Test Range, Air Force Systems Command, United States Air Force, Patrick AFB Florida, Jan. 1, 1969.
2. *Flight Termination System for Centaur Vehicle AC-8*, Report GDC-BTD66-025, Contract NAS 3-3232. General Dynamics/Astronautics, San Diego, Calif., Mar. 1, 1966.
3. Birkhoff, G., MacDougall, D. P., Pugh, E. M., and Taylor, G., "Explosives With Lined Cavities," *Journal of Applied Physics*, Vol. 19, p. 563, 1948.
4. Eichelberger, R. J., "Experimental Test of the Theory of Penetration by Metallic Jets," *Journal of Applied Physics*, Vol. 27, p. 63, 1956.

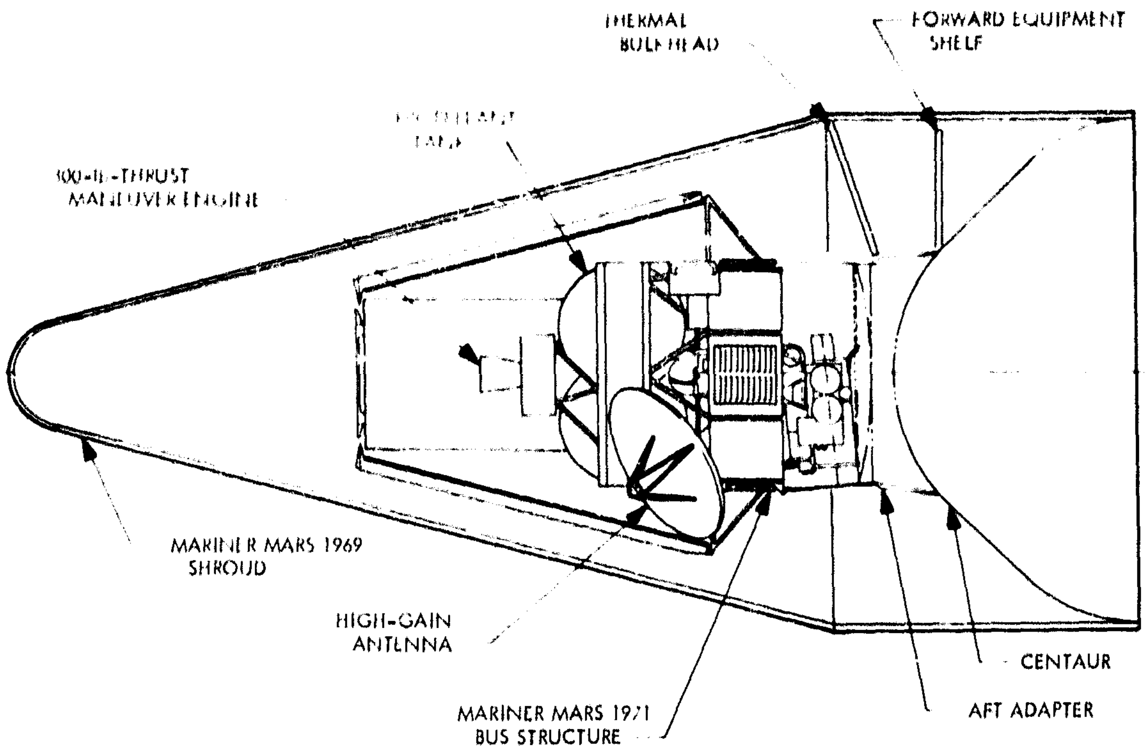

Fig. 1. *Mariner* Mars 1971 spacecraft launch configuration

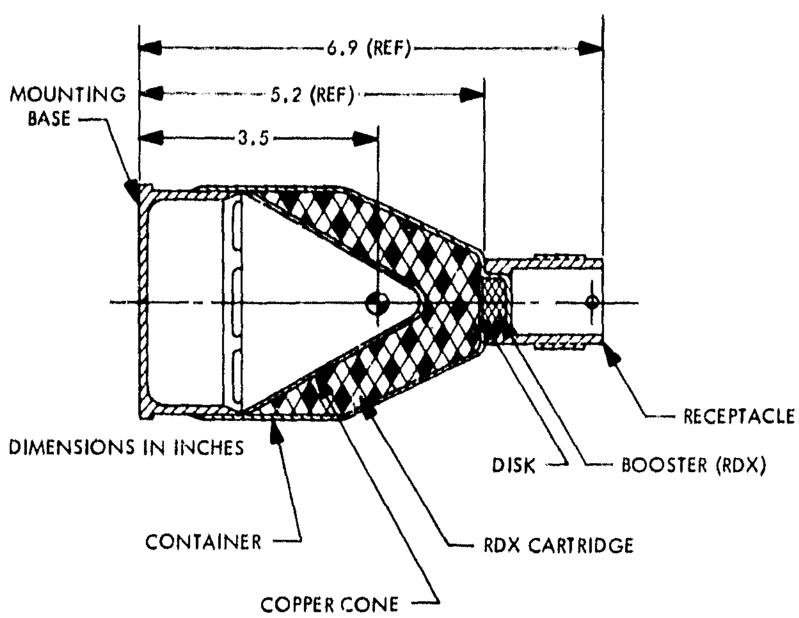

Fig. 2. *Surveyor* conical-shaped charge

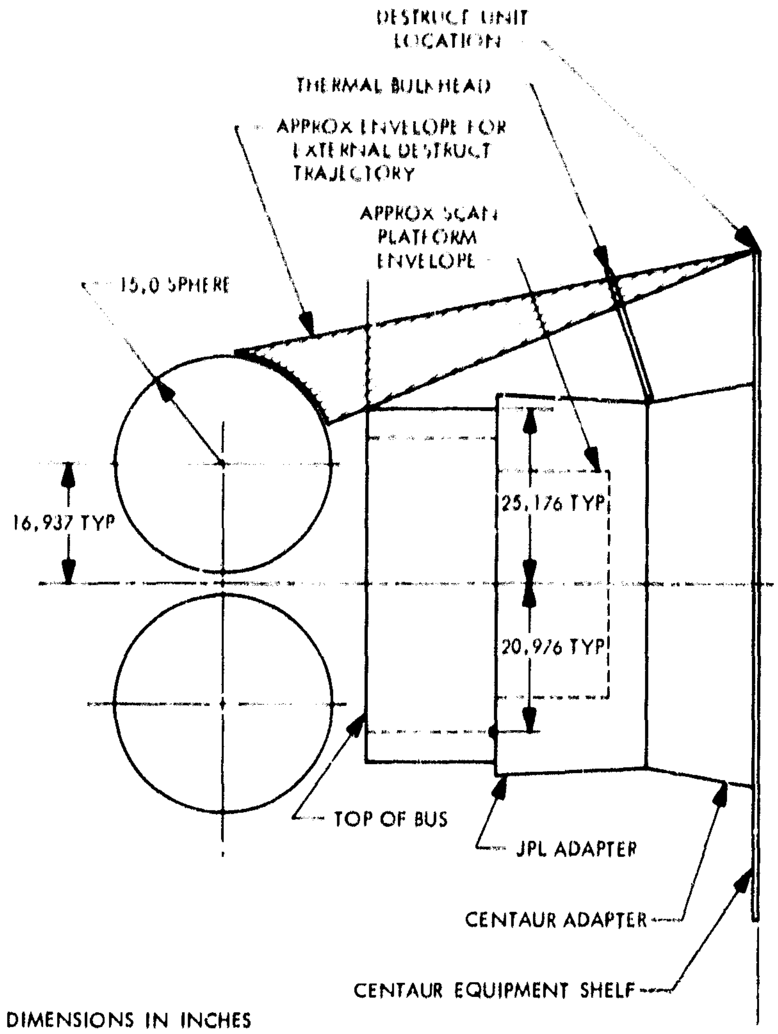

Fig. 3. Proposed location of destruct unit for *Mariner* Mars 1971 spacecraft

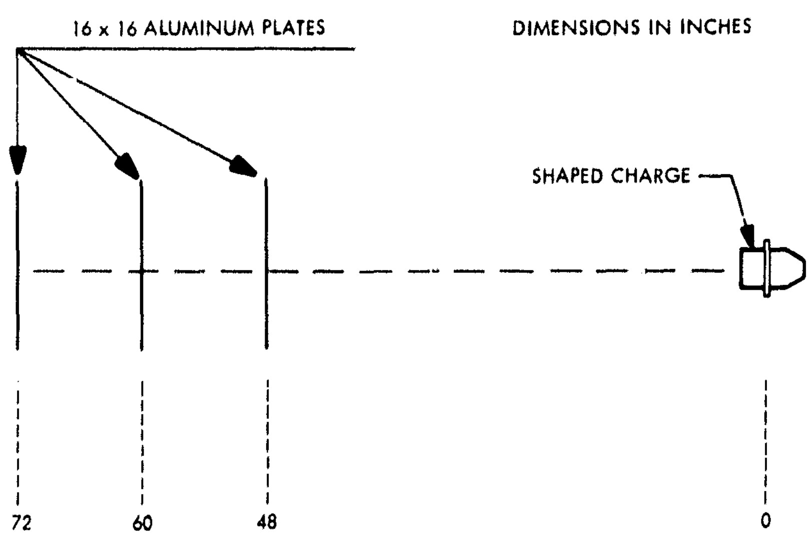

Fig. 4. Flat-plate destruct test configuration

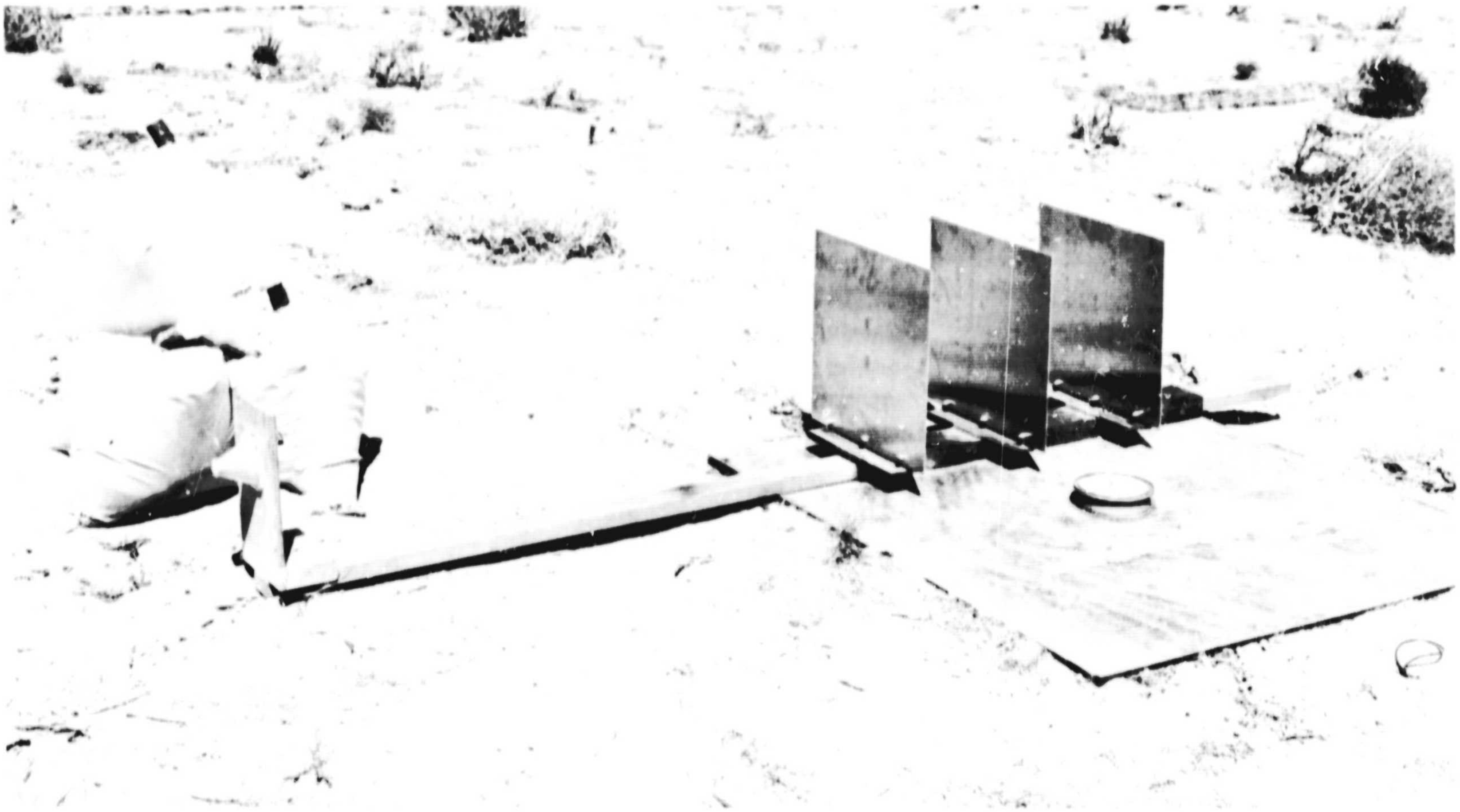

Fig. 5. Flat-plate test setup before shaped-charge initiation

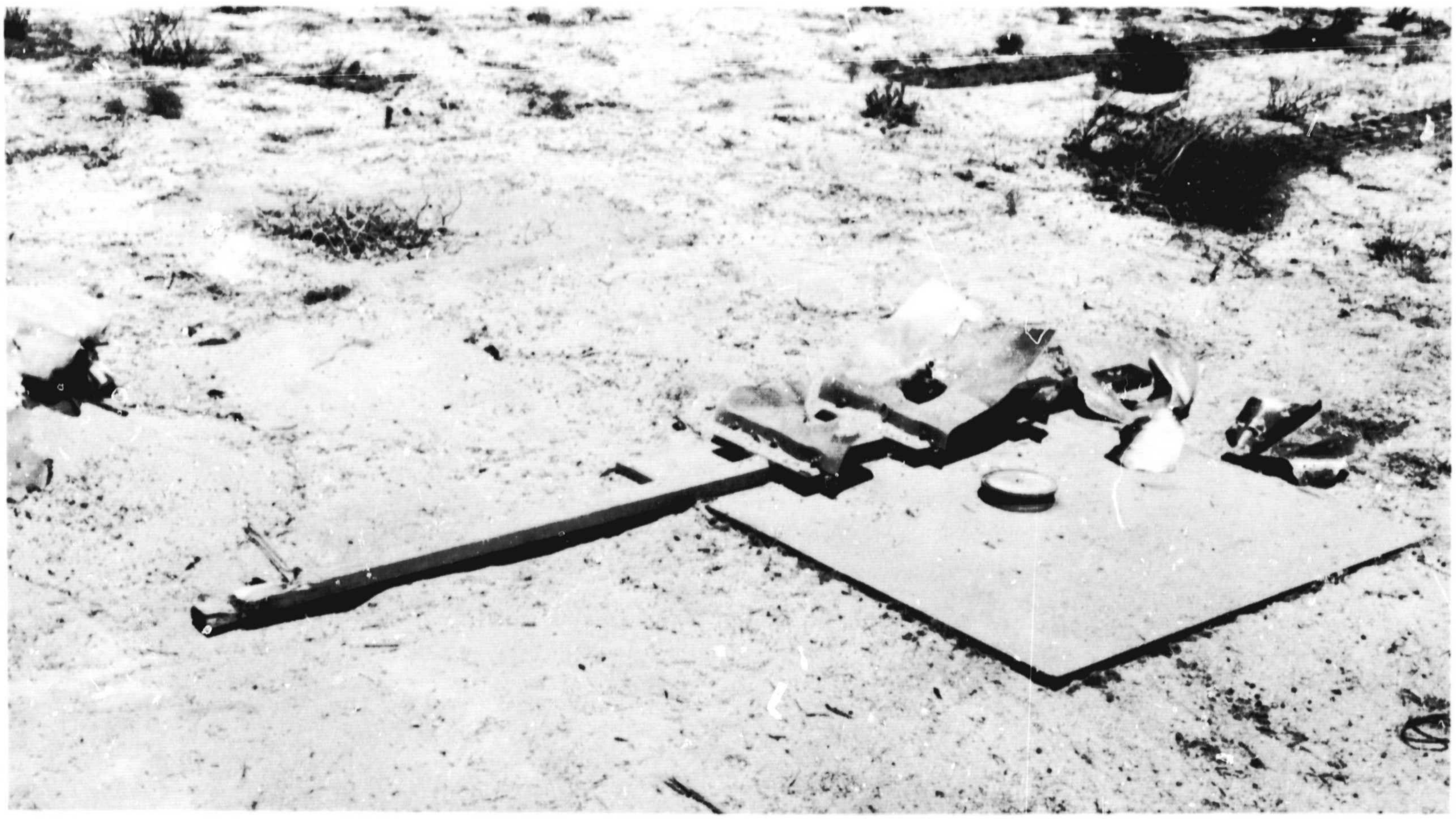

Fig. 6. Condition of plates after shaped-charge detonation

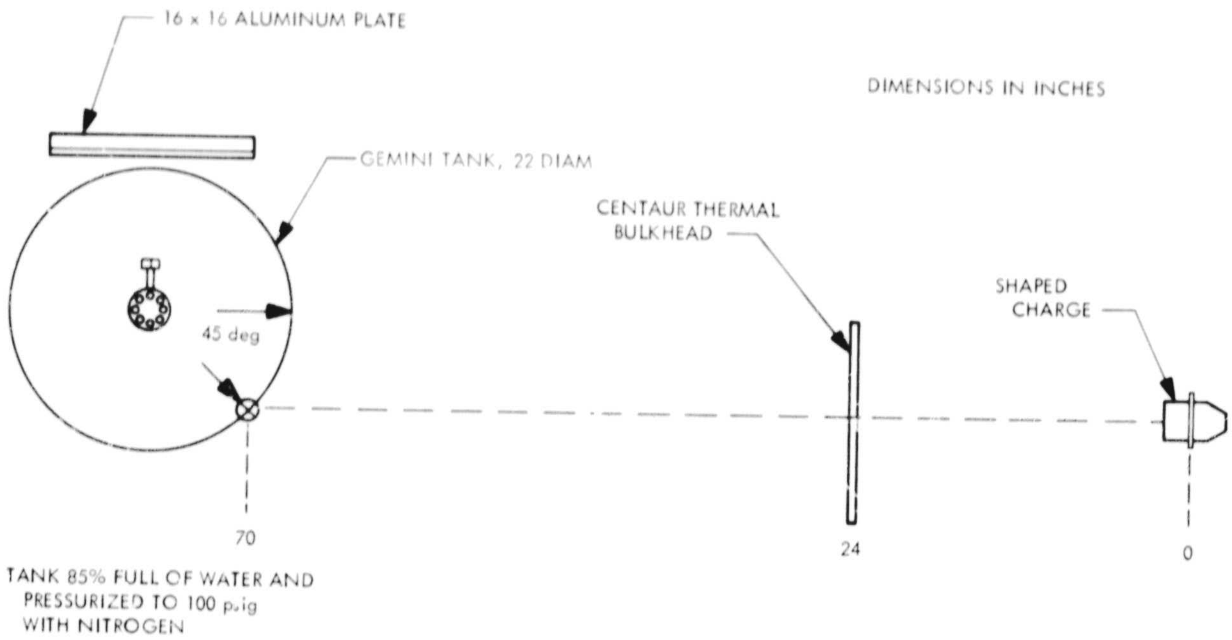

Fig. 7. Diagram of *Gemini* tank destruct test conf‹ ›ation

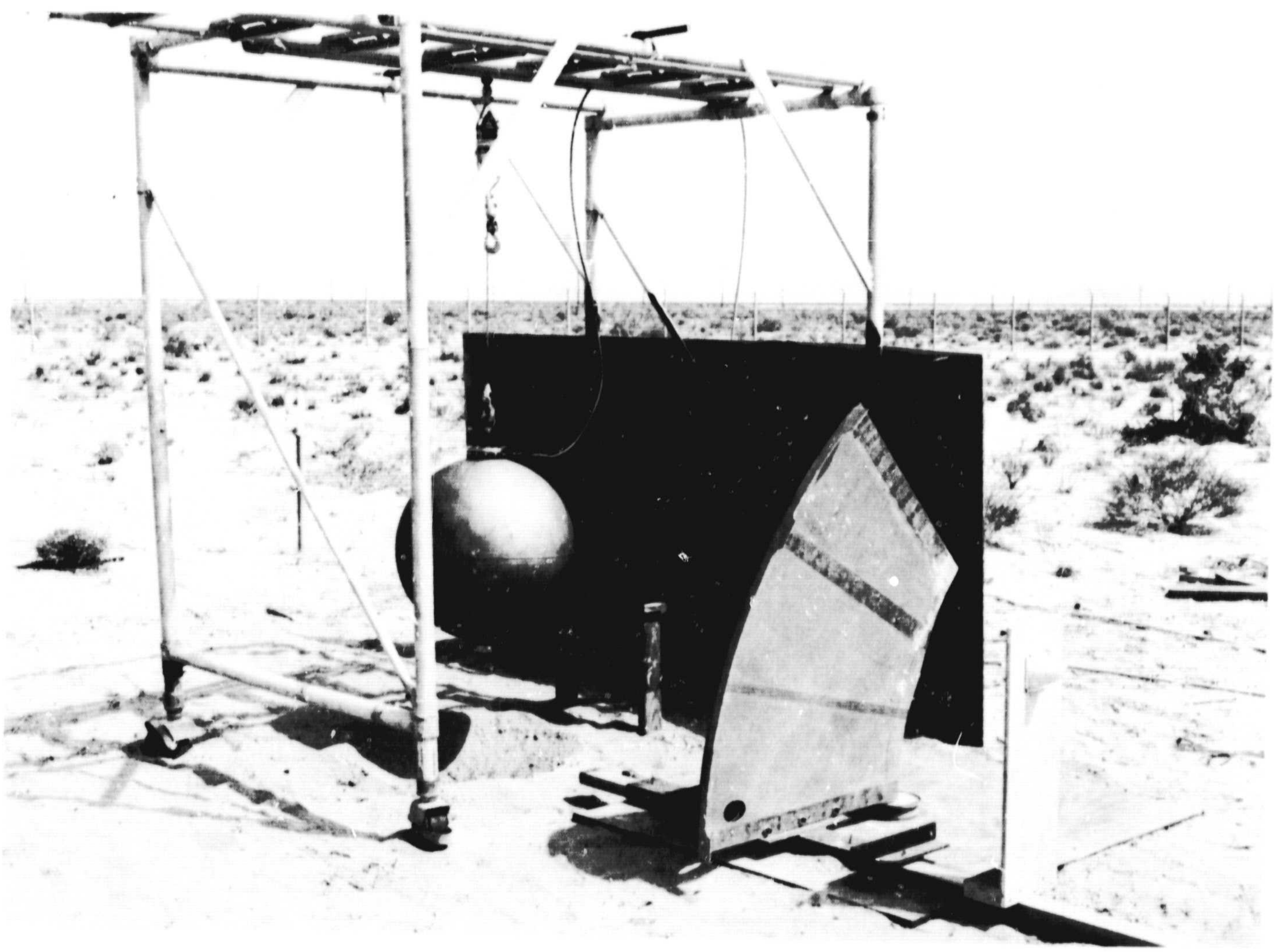

Fig. 8. Prefiring setup for pressurized-tank test

Fig. 9. Postfiring condition of tank and bulkhead

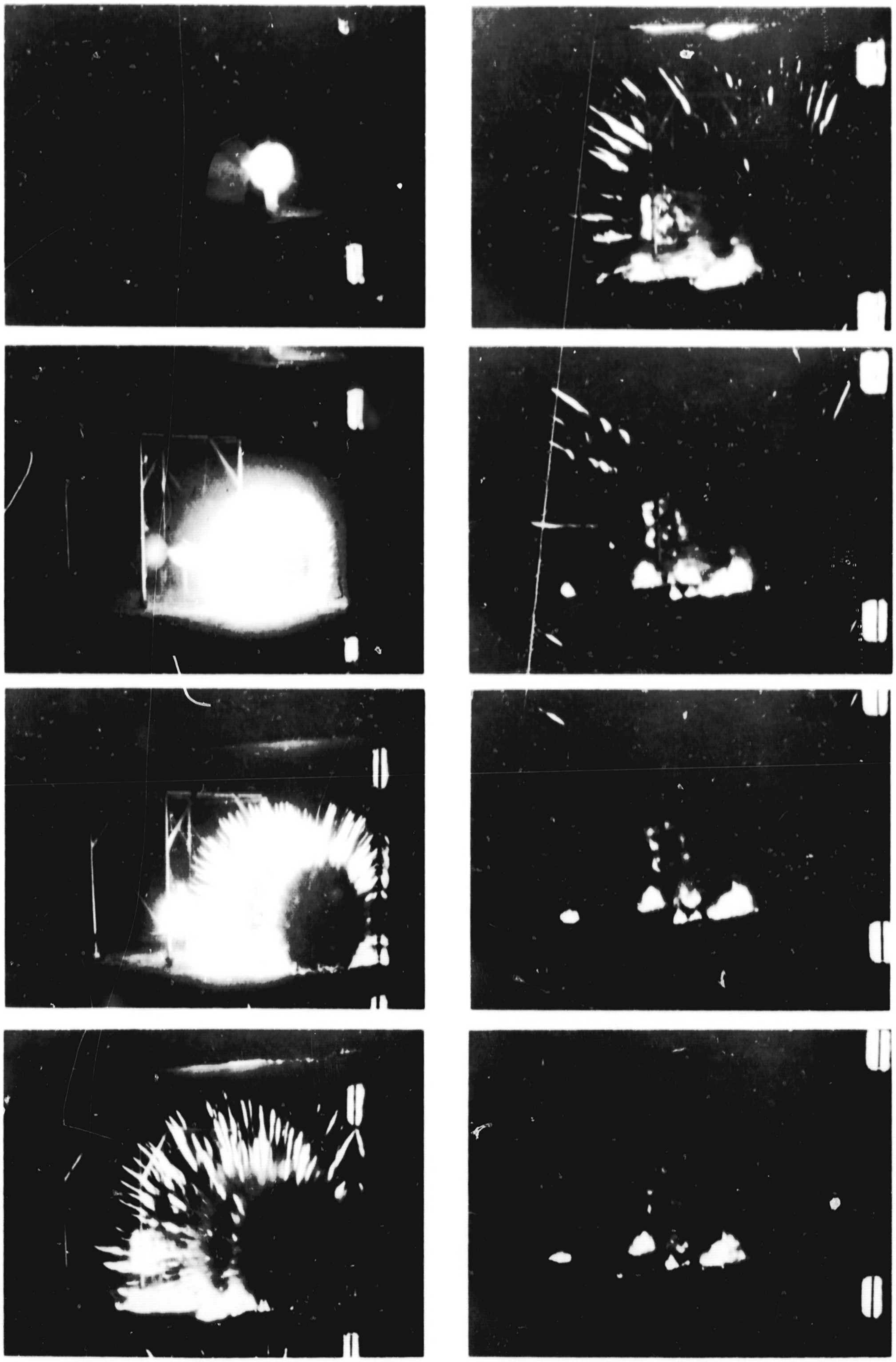

Fig. 10. Interaction of a shaped charge with a pressurized, water-filled *Gemini* tank

NASA — JPL — Coml., L.A., Calif.

HOW TO FILL OUT THE TECHNICAL REPORT STANDARD TITLE PAGE

Make items 1, 4, 5, 9, 12, and 13 agree with the corresponding information on the report cover. Use all capital letters for title (item 4). Leave items 2, 6, and 14 blank. Complete the remaining items as follows:

3. Recipient's Catalog No. Reserved for use by report recipients.

7. Author(s). Include corresponding information from the report cover. In addition, list the affiliation of an author if it differs from that of the performing organization.

8. Performing Organization Report No. Insert if performing organization wishes to assign this number.

10. Work Unit No. Use the agency-wide code (for example, 923-50-10-06-72), which uniquely identifies the work unit under which the work was authorized. Non-NASA performing organizations will leave this blank.

11. Insert the number of the contract or grant under which the report was prepared.

15. Supplementary Notes. Enter information not included elsewhere but useful, such as: Prepared in cooperation with... Translation of (or by)... Presented at conference of... To be published in...

16. Abstract. Include a brief (not to exceed 200 words) factual summary of the most significant information contained in the report. If possible, the abstract of a classified report should be unclassified. If the report contains a significant bibliography or literature survey, mention it here.

17. Key Words. Insert terms or short phrases selected by the author that identify the principal subjects covered in the report, and that are sufficiently specific and precise to be used for cataloging.

18. Distribution Statement. Enter one of the authorized statements used to denote releasability to the public or a limitation on dissemination for reasons other than security of defense information. Authorized statements are "Unclassified—Unlimited," "U.S. Government and Contractors only," "U.S. Government Agencies only," and "NASA and NASA Contractors only."

19. Security Classification (of report). NOTE: Reports carrying a security classification will require additional markings giving security and downgrading information as specified by the Security Requirements Checklist and the DoD Industrial Security Manual (DoD 5220.22-M).

20. Security Classification (of this page). NOTE: Because this page may be used in preparing announcements, bibliographies, and data banks, it should be unclassified if possible. If a classification is required, indicate separately the classification of the title and the abstract by following these items with either "(U)" for unclassified, or "(C)" or "(S)" as applicable for classified items.

21. No. of Pages. Insert the number of pages.

22. Price. Insert the price set by the Clearinghouse for Federal Scientific and Technical Information or the Government Printing Office, if known.

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. 33-448	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle MARINER MARS 1971 SPACECRAFT DESTRUCT UNIT		5. Report Date November 15, 1969 6. Performing Organization Code
7. Author(s) D. P. Davis, F. L. Sola		8. Performing Organization Report No.
9. Performing Organization Name and Address JET PROPULSION LABORATORY California Institute of Technology 4800 Oak Grove Drive Pasadena, California 91103		10. Work Unit No. 11. Contract or Grant No. NAS 7-100 13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

To conform to national range safety policies, the Mariner Mars 1971 spacecraft must have a vehicle destruct capability. This report describes a test program to evaluate the use of the Surveyor flight-qualified destruct unit as the basis for the Mariner Mars 1971 design. The critical performance factors are the conical-shaped-charge standoff distance, which is 8 in. for the Surveyor vs approximately 70 in. for the Mariner, and the additional requirement of penetration of the Centaur thermal bulkhead in the Mariner configuration. After a series of flat-plate tests to assess the distance performance of the shaped charge and the attenuating effect of a honeycomb panel mounted between the target plate and the shaped charge, a pressurized-tank test was conducted to simulate the actual destruction of a flight propellant tank. The tests demonstrated that the increased distance from the conical-shaped charge to the target does not reduce its destruct capability, and that it is feasible to use the Surveyor design for the Mariner Mars 1971 destruct requirements.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Mariner Mars 1971 Project Pyrotechnics	Unclassified -- Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	9	