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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-448

*Mariner Mars 1971 Spacecraft
Destruct Unit*

D. P. Davis

F. L. Sola

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PASADENA, CALIFORNIA

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31

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Preface

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



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 pre-firing 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 *Surrey* 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 Eastax 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 *Surrey* 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.

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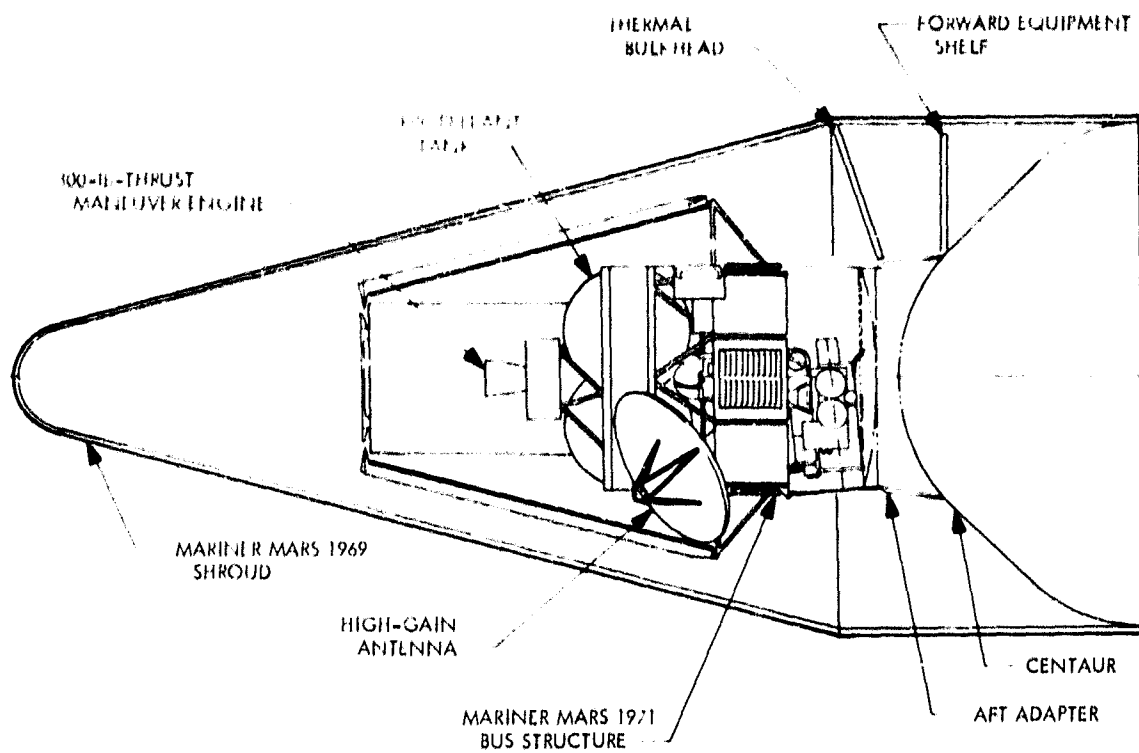


Fig. 1. Mariner Mars 1971 spacecraft launch configuration

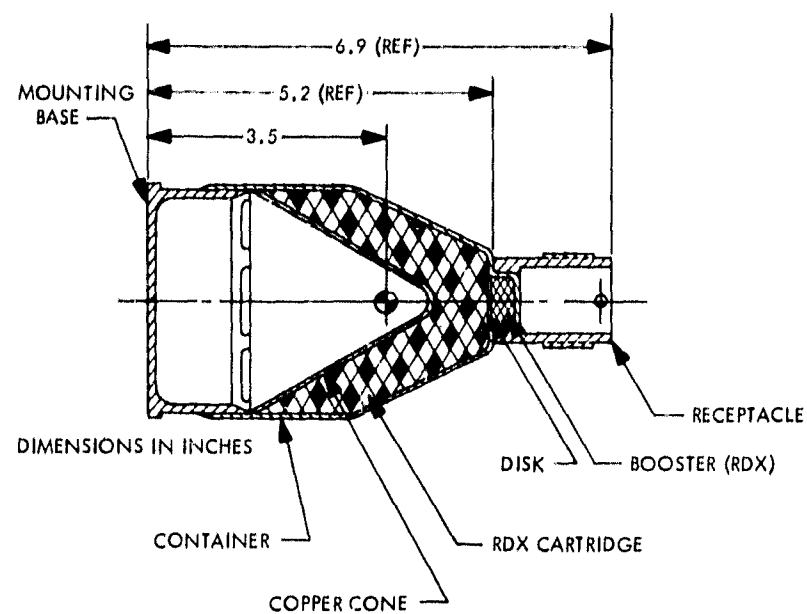


Fig. 2. Surveyor conical-shaped charge

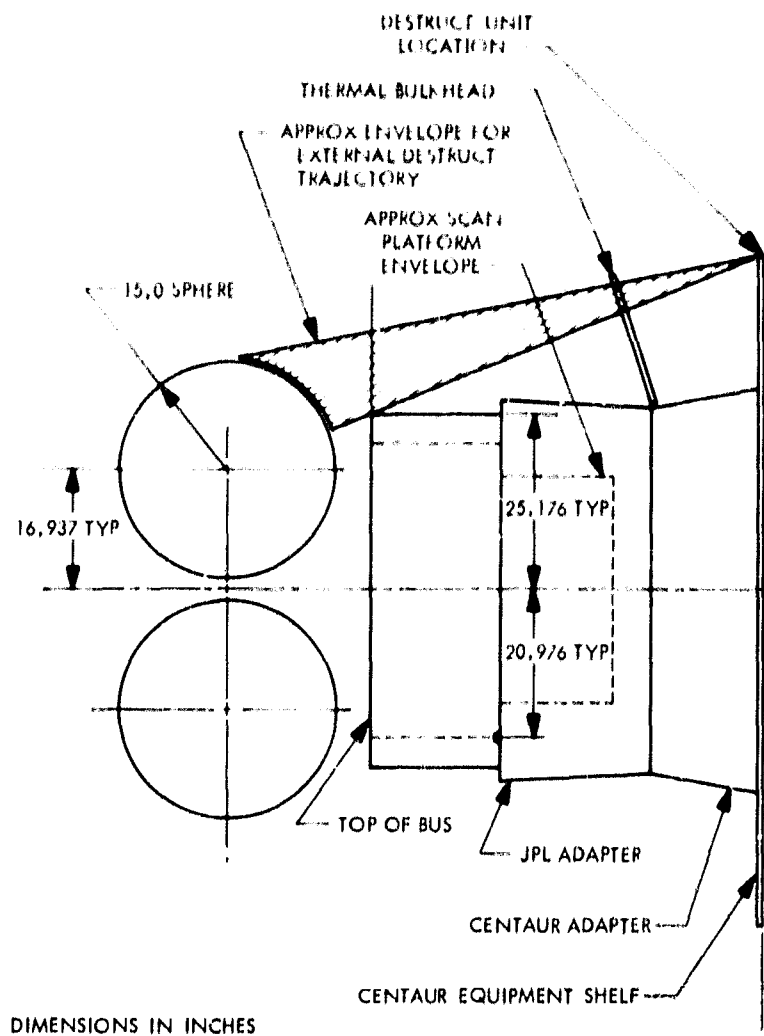


Fig. 3. Proposed location of destruct unit for *Mariner Mars 1971* spacecraft

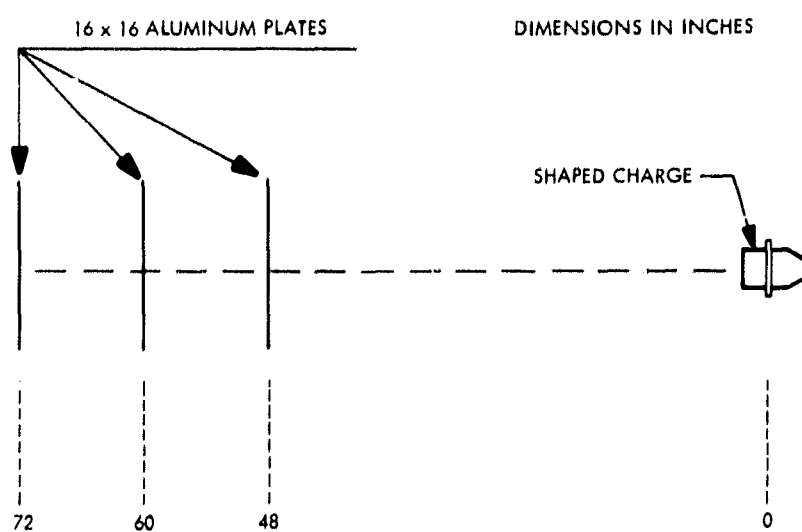


Fig. 4. Flat-plate destruct test configuration

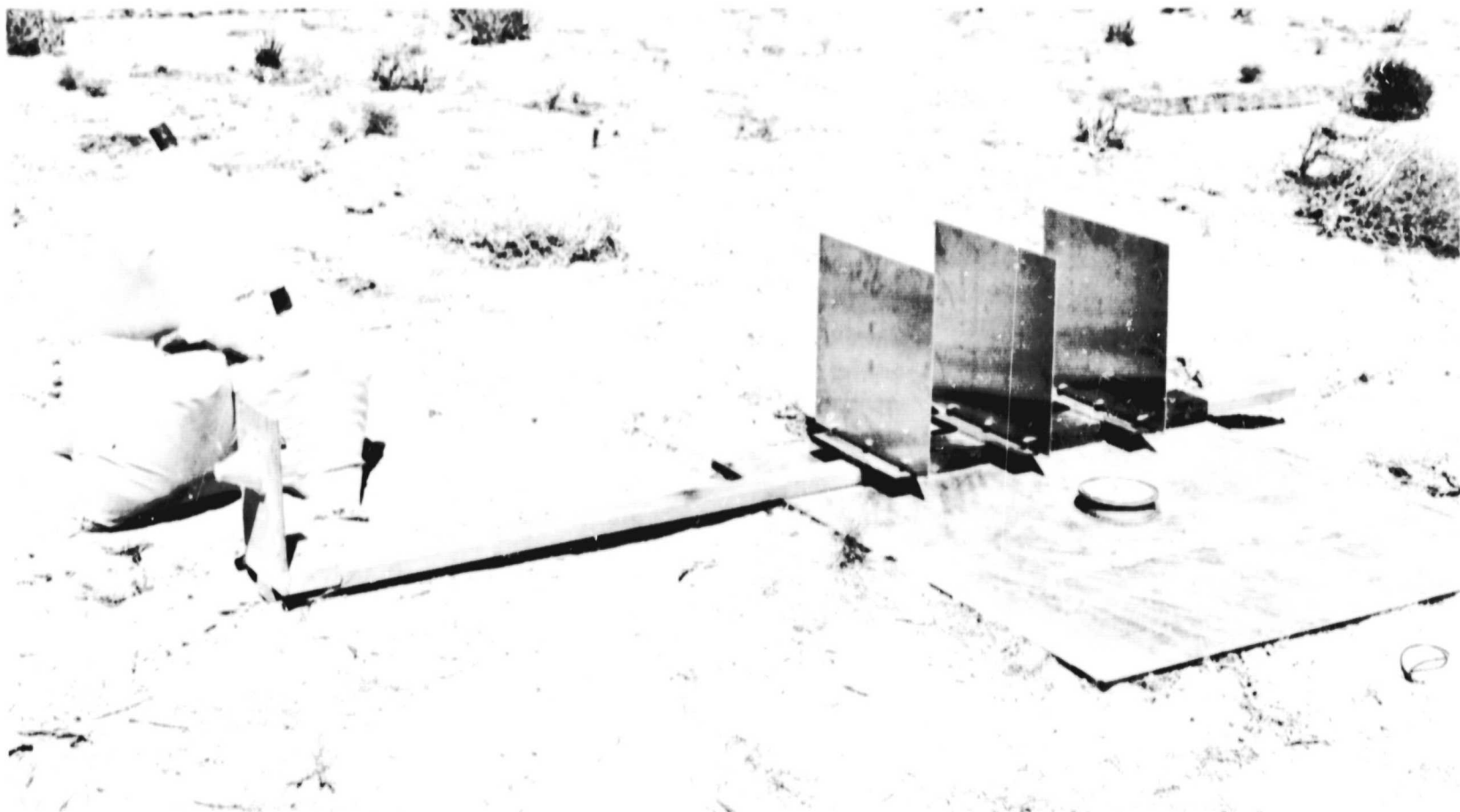


Fig. 5. Flat-plate test setup before shaped-charge initiation



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

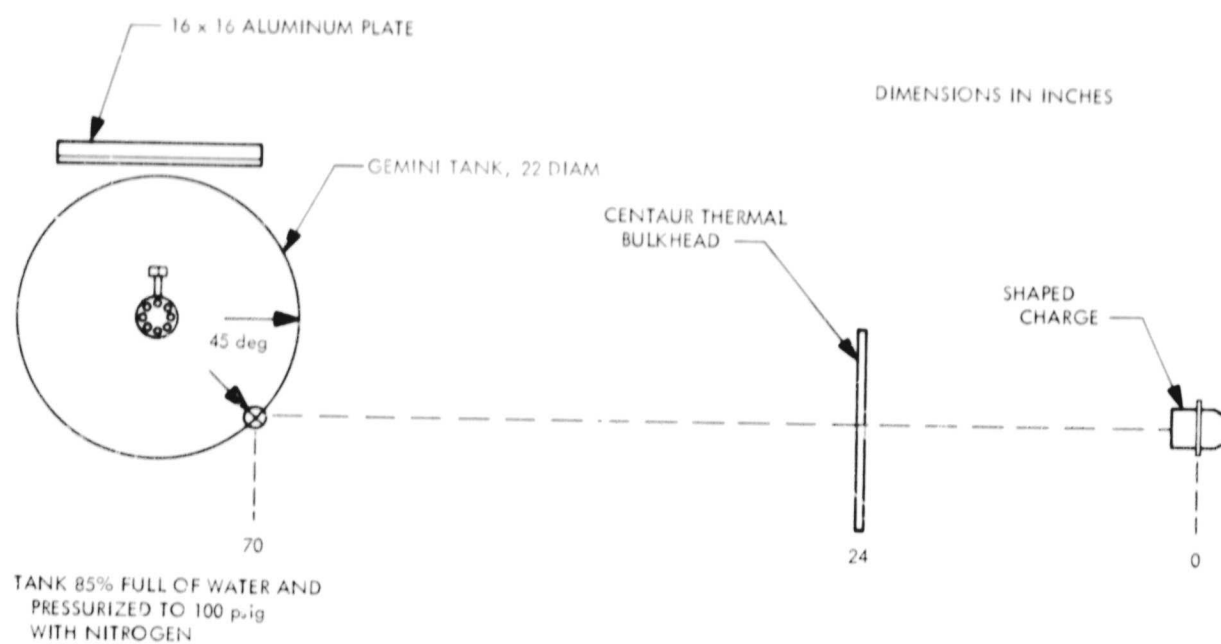


Fig. 7. Diagram of Gemini tank destruct test configuration

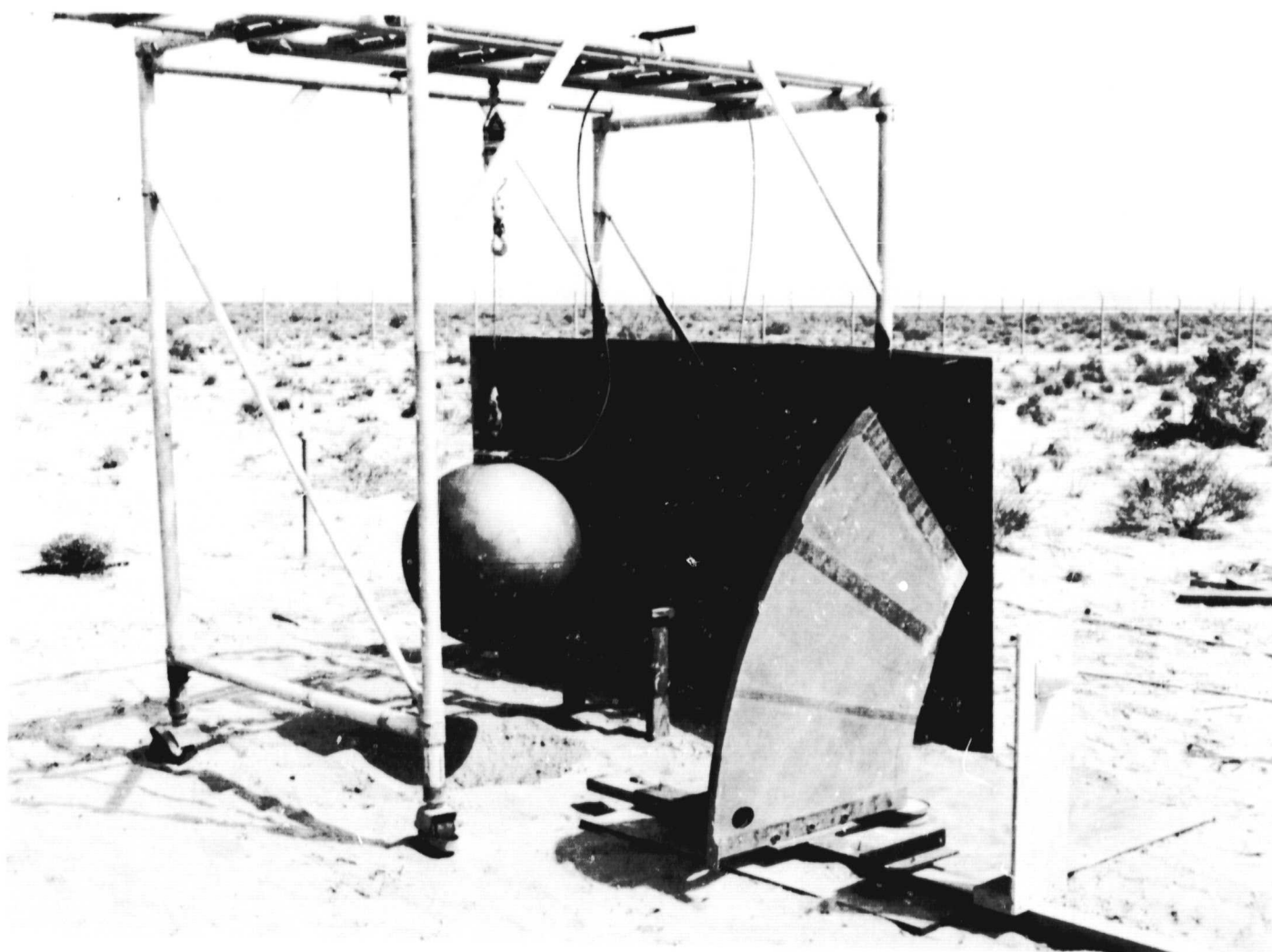


Fig. 8. Prefiring setup for pressurized-tank test



Fig. 9. Postfiring condition of tank and bulkhead

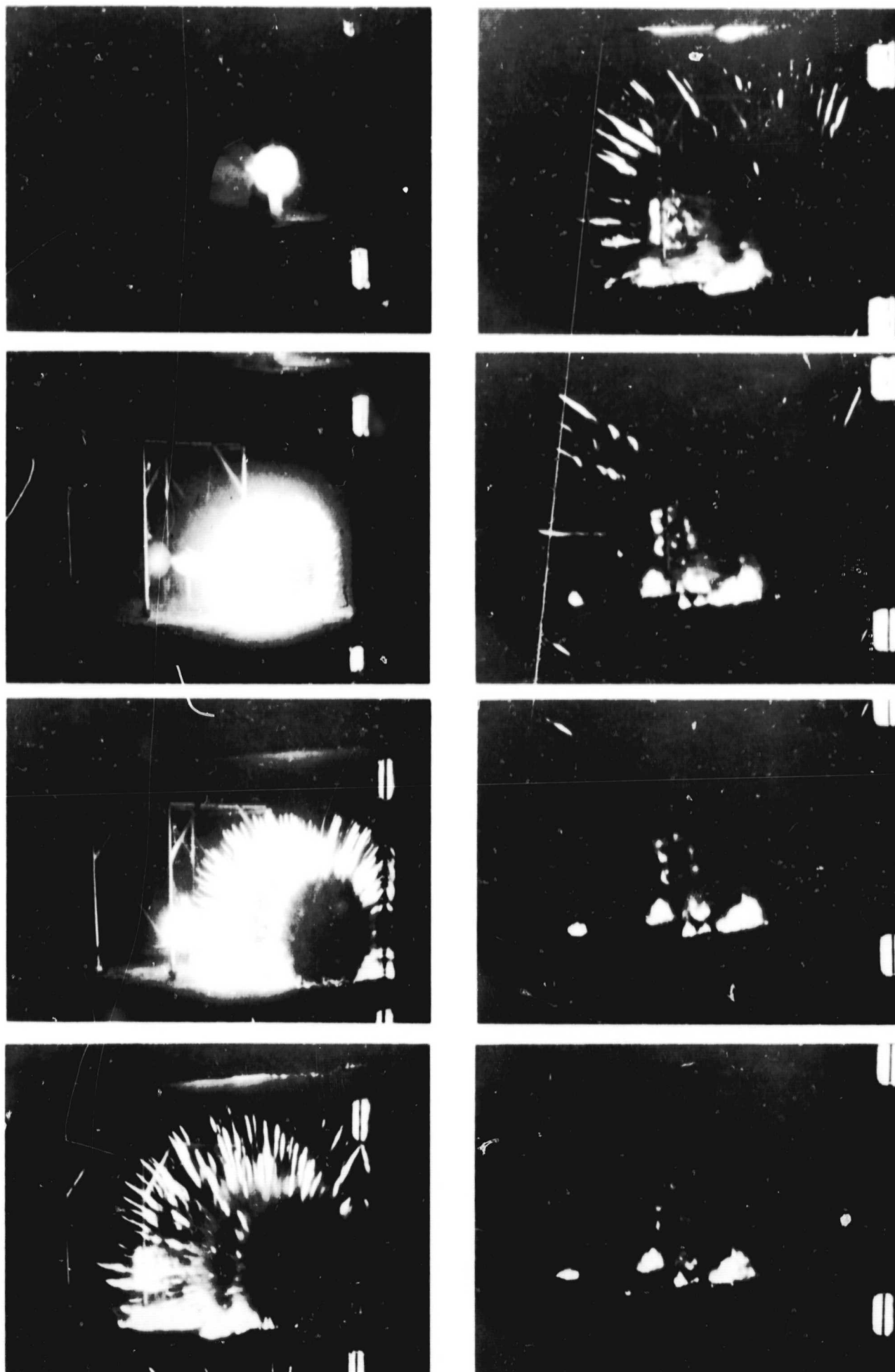


Fig. 10. Interaction of a shaped charge with a pressurized, water-filled Gemini tank

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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.					
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