NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN
WASHINGTON, D.C.

EXPERIMENTS IN THE PRODUCTION AND PHOTOGRAPHY OF INTERSECTING UNDERWATER SHOCK WAVES

by

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PERSONNEL

The photographs were made by Lieut. D.C. Campbell, USNR, who also wrote the report.

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ABSTRACT

This report describes attempts to produce simultaneous explosions for an investigation of intersecting underwater shock waves. The experiments are explained by sketches and the results are given in the form of photographs. No attempt is made to analyze the results.

INTRODUCTION

As the result of an inquiry (1)* from the Bureau of Ordnance of the Navy Department, which has been conducting an investigation of the Munroe effect, the David Taylor Model Basin was authorized (2) to "conduct a photographic examination of both the interaction of shock waves from explosions under water, and their reflection from an obstacle under water." It was hoped that by a study of the collision of shock waves from underwater explosions the tremendous penetrating effect of a hollow coned charge, thought to be due to collision of the shock waves from the sides of the cone, would be greatly clarified.

This project was undertaken as a continuation of somewhat similar work previously reported (3). An advance letter report (4) was submitted on this subject several months ago, accompanied by a few preliminary photographs of intersecting shock waves under water.

To set up the phenomenon to be studied, it is necessary to produce two simultaneous sources of shock. Several attempts made by the Taylor Model Basin to achieve this result are described in the report, and photographs of various types of phenomena are included. No attempt is made to analyze the results of the experiments.

TESTS WITH TWO SIMULATED SHOCK SOURCES

At first, efforts were made to detonate two closely-spaced Number 8 detonators within 5 microseconds of each other but these tests were unsuccessful, as were similar trials with Mark 1, Modification 1 mine detonators. The pairs of charges were fired by various means, including a setup with 1200 volts on the circuit and 180 microfarads in parallel with each charge. The time between detonations of the two charges of each pair varied from 300 microseconds to 1 or 2 milliseconds. The differences were erratic, and it was found impossible to establish a constant relationship of time and applied voltage in the firing circuit.

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* Numbers in parentheses indicate references on page 10 of this report.

Following this, a sort of double-ended cannon was built, having the form of a hollow tube in which a length of Primacord extending from one opening to the other was used as the explosive, and in which a detonator at midlength of the cannon served to set off both ends of the Primacord simultaneously.

The first cannon was a piece of extra heavy seamless steel tubing, 1 1/4 inches in outside diameter, fitted with two U-shaped rods welded on for the suspension lines. A 1/2-inch hole drilled at midlength permitted insertion of a Number 8 detonator, which was firmly attached to a piece of Primacord 12 inches long, folded up and inserted in the tube.

The second cannon, as shown in Figure 1, was machined from a rod of medium steel, with chambers in each end in which Primacord was wound.

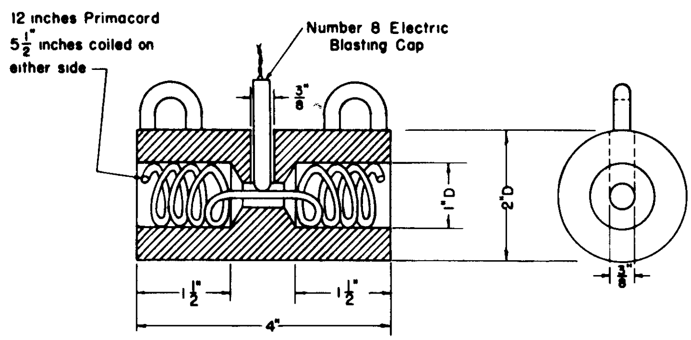

Figure 1 - Sectional Diagram of Bar Cannon used with Setup shown in Figure 2 to obtain Photographs in Figures 4a and 4b

The end chambers were connected by a 3/8-inch hole drilled through the intervening metal, and another 3/8-inch hole was drilled through one side of the cannon at midlength to admit a Number 8 blasting cap. A 12-inch length of Primacord was inserted into the container so that each chamber contained a coil of 5 1/2 inches.

A Number 8 blasting cap was placed in the center to set off both Primacord charges simultaneously.

To take the photographs, the cannons were suspended in succession in the small model basin between the camera and the source of light, as shown in Figure 2. The micro-flash unit was set to operate at selected intervals of time after the charge was fired.

A pair of photographs taken with the tubing cannon are shown in Figures 3a and 3b. There are multiple shock waves here but the intersections are not definite.

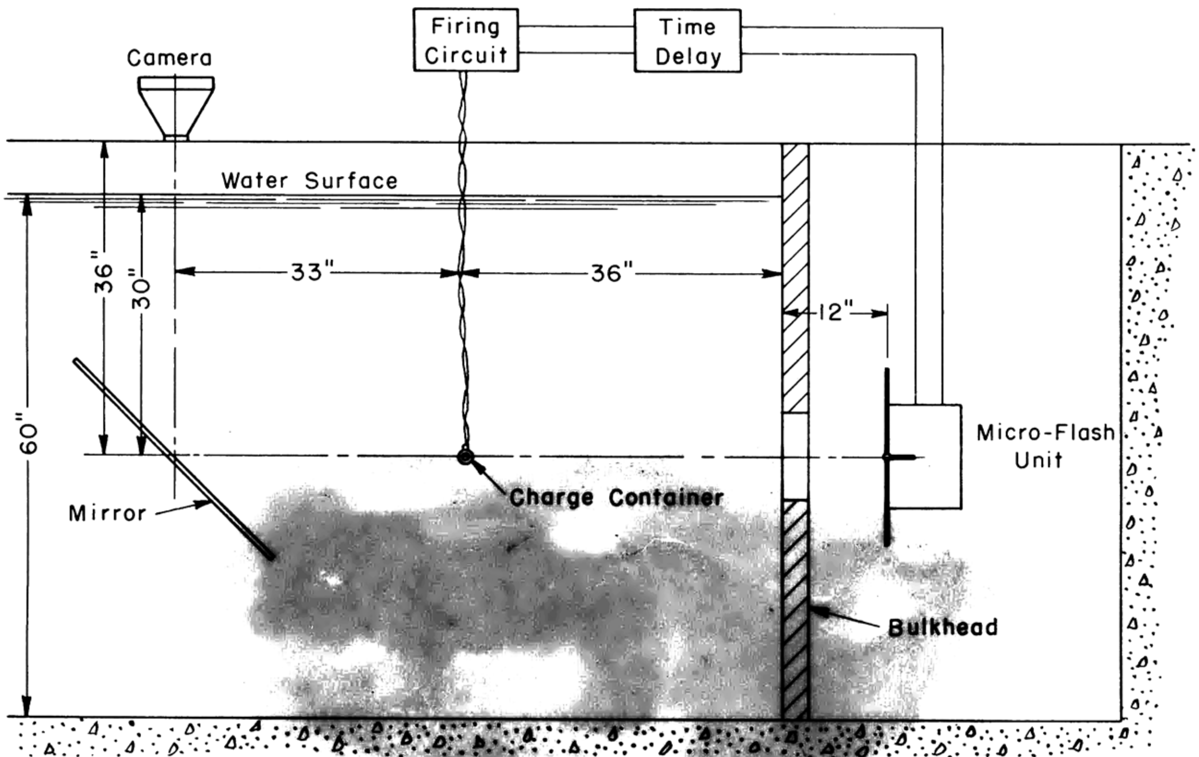

Figure 2 - Schematic Diagram of Setup used to obtain Cannon Photographs shown in Figures 3a, 3b, 4a, 4b, 5a, and 5b

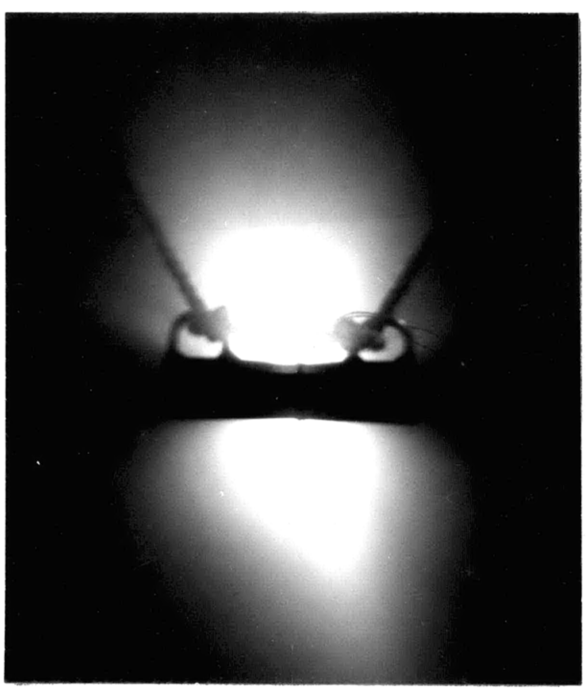

Figure 3a - Photograph of Seamless Tubing Cannon containing Primacord, before Explosion.

Shot 1, 17 July 1943.

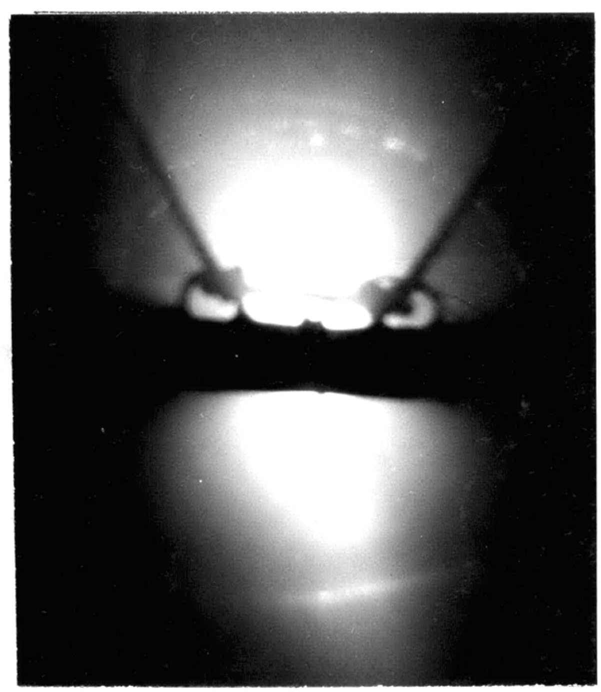

Figure 3b - 70 microseconds After Detonation. Note the faint shock wave surrounding the cannon.

Shot 2, 17 July 1943.

Figures 4a and 4b show shock waves produced by the charge in the bar cannon. There are intersections between these waves but these points appear to have no special significance.

Although shock-wave photographs of this kind had been made before at the Taylor Model Basin, on which the bright streaks or "corona" effect had been observed, it was not until Figures 4b and 5a were examined that these corona effects were considered as anything more than incidental aspects of the general phenomenon. This feature will be discussed further in a subsequent section of the report.

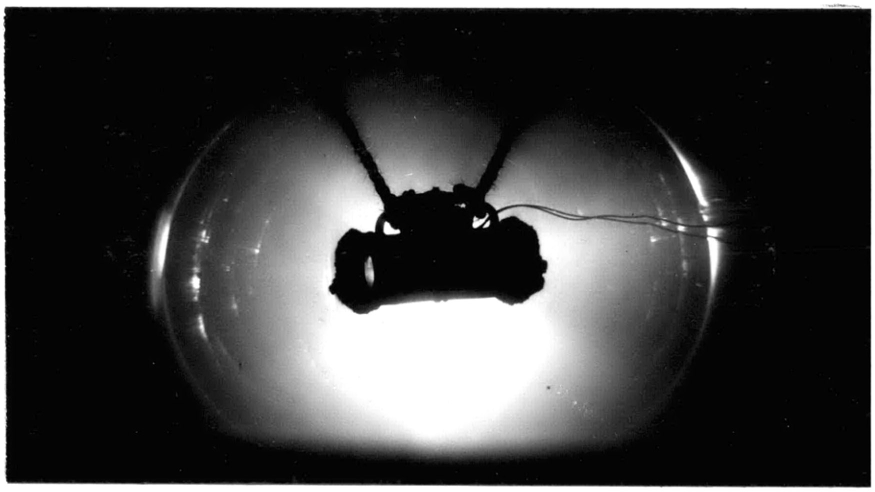

Figure 4a - Shot 1, 21 July 1943, 70 microseconds After Detonation.

The multiplicity of shock waves in this and other photographs is due to the transmission of shock through the metal of the cannon and to the fact that the two mouths of the cannon do not act as point sources.

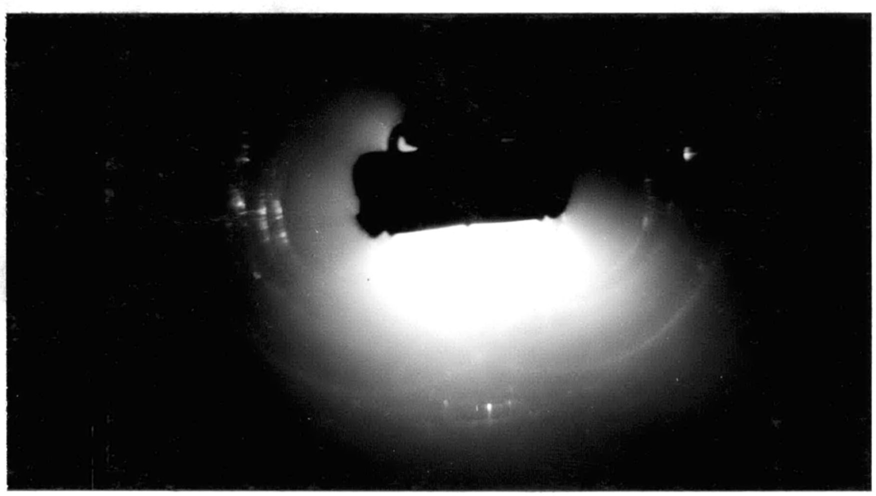

Figure 4b - Shot 2, 21 July 1943, 70 microseconds After Detonation.

The so-called "corona" effects show up rather more clearly here than on previous photographs of this kind, especially on the two inside intersecting waves directly under the cannon.

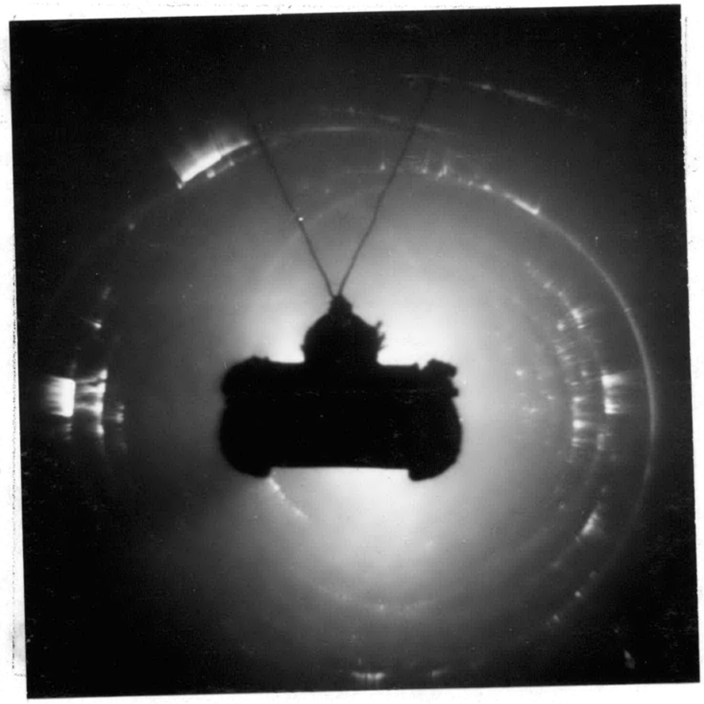

Figure 5a - Shot 2, 27 July 1943, 60 microseconds After Detonation.

The container used in this and the succeeding shot, shown in Figure 5b, was 3 inches long, but was otherwise the same as that illustrated in Figure 1.

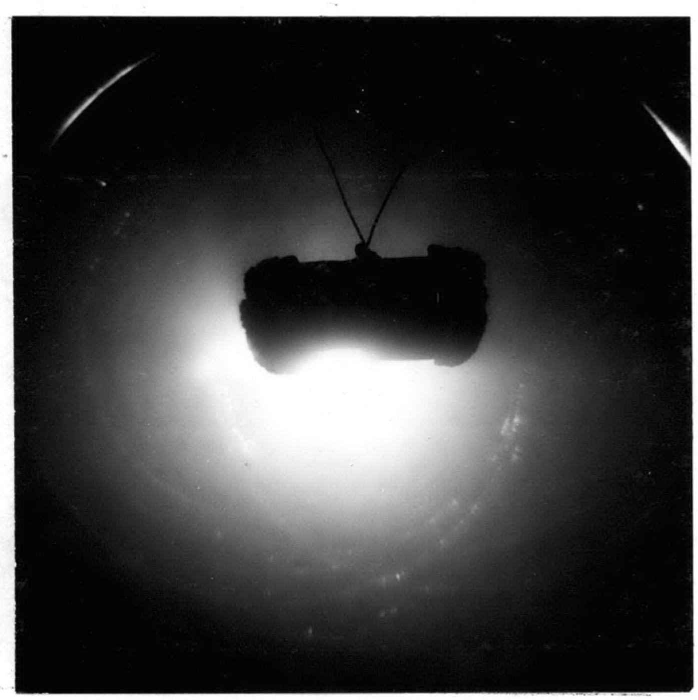

Figure 5b - Shot 3, 27 July 1943, 80 microseconds After Detonation.

TEST OF MULTIPLE REFLECTION OF A SINGLE SHOCK WAVE

When it became obvious that the cannon method would not serve as point sources for pairs of single simultaneous shock waves, and when, incidentally, both cannons had been split open by the explosions, a new arrangement was adopted, as shown in Figure 6, in which a charge was suspended between the surfaces of two masses lying at an angle to each other. It was expected that the reflected waves from the single source and the two surfaces would intersect in the area of vision. This was found to be the case, and intersections showing some sort of unusual phenomenon were observed when the adjacent surfaces lay at an angle of 150 degrees with each other; see Figures 7a to 7d inclusive.

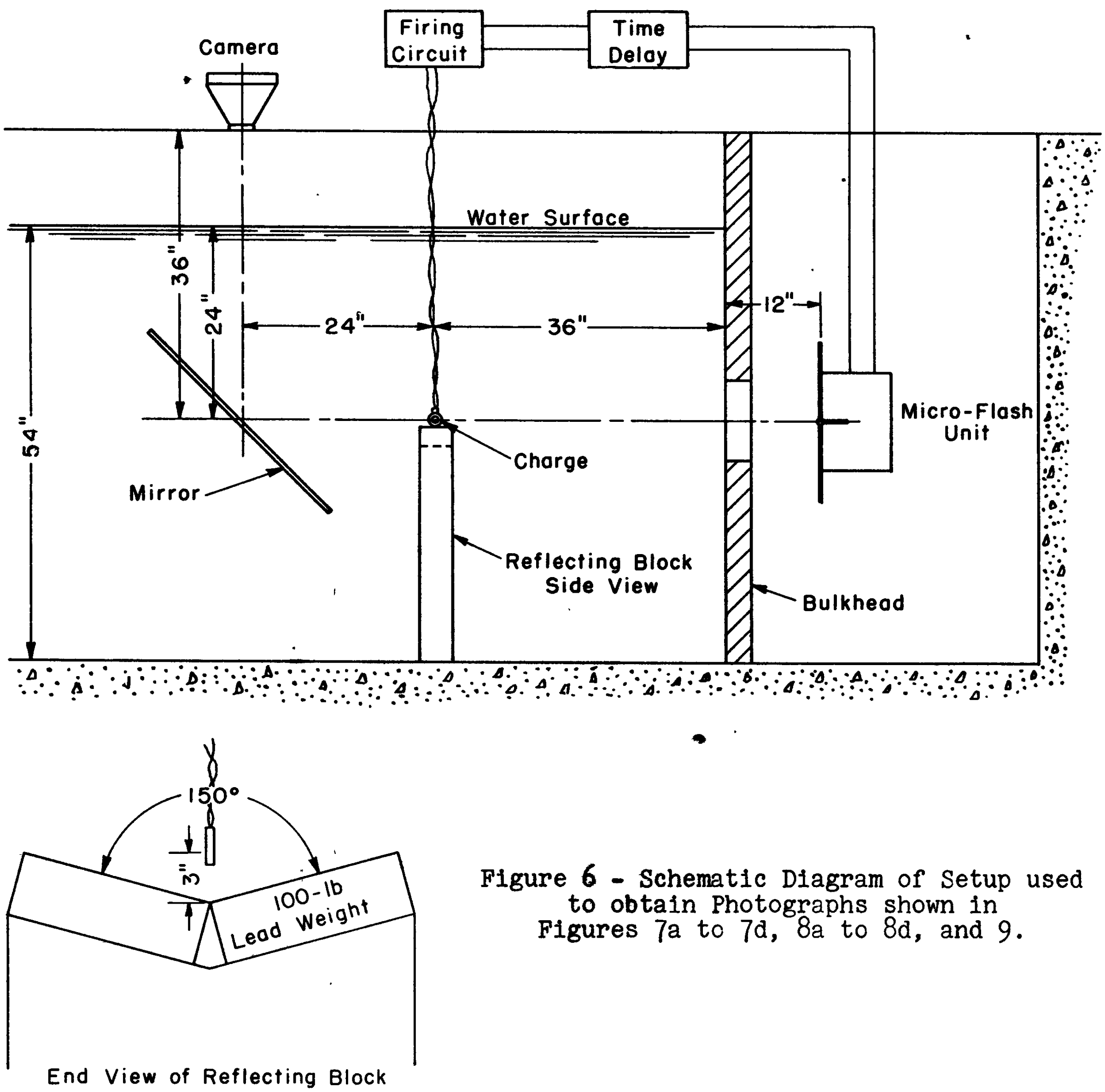

Figure 6 - Schematic Diagram of Setup used to obtain Photographs shown in Figures 7a to 7d, 8a to 8d, and 9.

At the extreme top of Figures 7b, 7c, and 7d, it will be noted that the corona previously observed appears at the intersecting point of the two reflected waves, and at this point only.

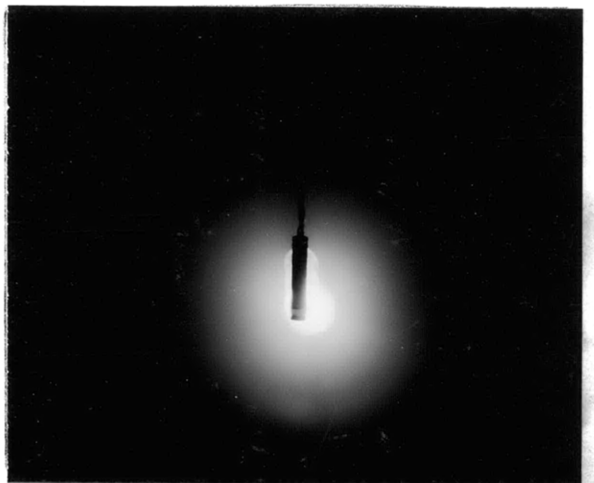

Figure 7a - Calibration Shot C-1, 10 August 1943.

Figure 7b - Shot 1, 10 August 1943, 170 microseconds After Detonation.

Figure 7c - Shot 2, 10 August 1943, 190 microseconds After Detonation.

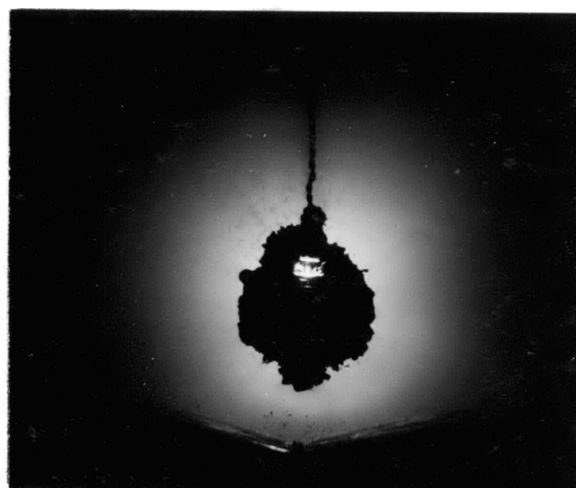

Figure 7d - Shot 3, 10 August 1943, 210 microseconds After Detonation.

Figures 7a to 7d - In each of these shots a Mark 1, Modification 1 mine detonator was fired directly above the apex of the 150-degree angle shown in Figure 6, at a distance of 3 inches.

Note the presence of cavitation bubbles in the angle of the weights. This is the first time that such bubbles have been noted at so early a stage in the explosion. This may be evidence of a Mach region.

In Figures 8a to 8d inclusive there are shown the results of offsetting the detonator from the apex formed by the two reflecting planes. In Figure 9 the detonator is in contact with one of the masses. All these results are rather negative so far as shock wave intersections are concerned.

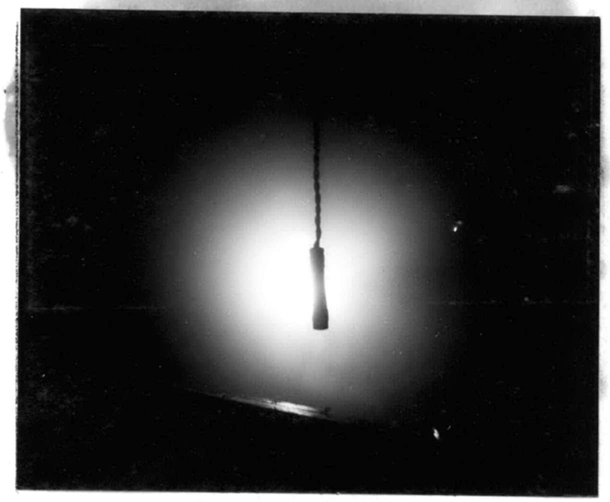

Figure 8a - Calibration Shot C-2, 10 August 1943.

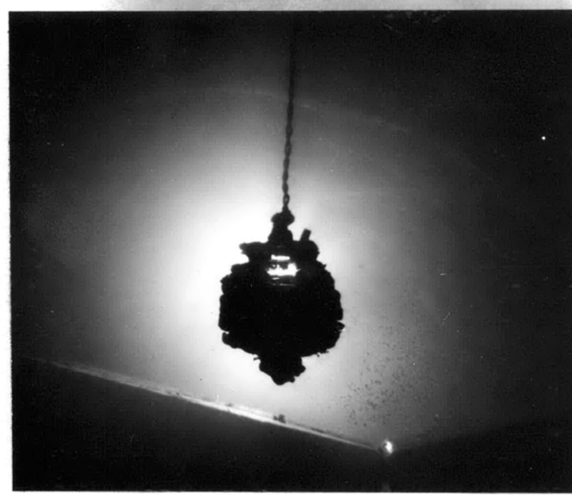

Figure 8b - Shot 4, 10 August 1943, 170 microseconds After Detonation.

Figure 8c - Shot 5, 13 August 1943, 190 microseconds After Detonation.

Figure 8d - Shot 6, 13 August 1943, 210 microseconds After Detonation.

Figures 8a to 8d - The setup used to obtain these photographs was the same as that for Figures 7a to 7d, except that for Shots 4, 5, and 6 the detonator was moved 2 inches horizontally from the apex of the angle, and was placed 3 inches above it.

DISCUSSION OF RESULTS

Further study of Figure 7b led to the conclusion that the corona outside of the shock waves was quite definitely associated with the intersection, even though other photographs showed definite corona effects where no intersections were discernible.

The fact that the corona appeared outside the shock wave trace led to a questioning of the validity of the optical diagram previously drawn to account for these phenomena, and to a decision to get at the fundamentals of the reflection and refraction effects before making any more shock wave photographs.

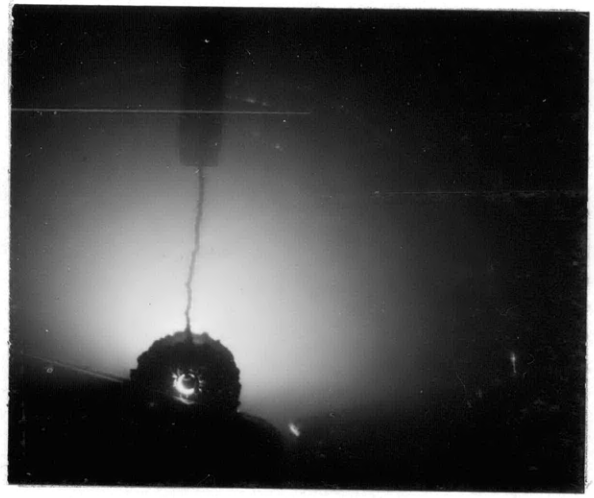

Figure 9 - Shot 6b, 13 August 1943,
120 microseconds After Detonation.

For this shot the detonator was in contact with the lead reflecting block at the same horizontal distance from the apex.

As a result of conferences with Dr. I.C. Gardner of the National Bureau of Standards and with Professor P.W. Bridgman of Harvard University, a new set of experiments are to be made in an effort to arrive at a clear understanding of the physical phenomena associated with these underwater shock photographs.

Figure 7b - Shot 1, 10 August 1943,
170 microseconds After Detonation.

Several photographs were made by a shadow method similar to that employed in England by Colonel P. Liebesart of the French Army. In this method photosensitive materials are suspended in water on the side of a charge opposite the light source. However, since the details of correct spacing, emulsion speed, and light intensity have not yet been worked out these photographs were not satisfactory and they are not included in this report.

REFERENCES

(1) BuOrd CONFIDENTIAL letter S68(Re6) of 6 March 1943 to BuShips.

(2) BuShips CONFIDENTIAL letter C-S81-3(374a) of 17 March 1943 to David Taylor Model Basin.

(3) "Photographic Studies of Shock Waves in Water," by Lieut. D.C. Campbell, USNR, TMB CONFIDENTIAL Report R-77, November 1942.

(4) TMB CONFIDENTIAL letter C-S81-3, C-S85-2 of 3 July 1943 to BuOrd, copy to BuShips.