THE DAVID TAYLOR MODEL BASIN
BUREAU OF SHIPS
NAVY DEPARTMENT
WASHINGTON, D. C.

PHOTOGRAPHIC STUDIES OF SHOCK WAVES IN WATER

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PERSONNEL

The tests were carried out by Dr. H.E. Edgerton, Dr. C.W. Wyckoff, and Lt. (jg) D.C. Campbell, USNR. The report is the work of Lieutenant Campbell.

PHOTOGRAPHIC STUDIES OF SHOCK WAVES IN WATER

INTRODUCTION

Several photographs of shock waves in water have been obtained during investigation of underwater explosions at the David W. Taylor Model Basin.

No definite program of research has been followed and the pictures included herewith are preliminary to any set course of investigation. No conclusions will be drawn as the pictures for the most part speak for themselves.

PROCEDURE

The experiments were carried out with very small charges. Mark 1 mine detonators containing 4 1/4 grams of fulminate of mercury were used. This is equivalent roughly to 1/200 pound of TNT.

The light source used in these experiments is the micro-flash device developed by Edgerton. The flash is very intense and has a duration of 1 to 3 microseconds. The use of this equipment in photographing the gas globe produced by underwater explosions is described in Reference (1).* The equipment has been described in some detail in Reference (2).

A TMB electronic switch (3) was employed to produce a time delay between the firing of the detonator and the lamp flash. The exact time that elapsed between the closing of the electronic switch and the flash of the lamp is uncertain. All the intervals given in this report are therefore approximate.

The lamp is arranged so that the beam enters the water vertically through a waterscope, with a light shield and aperture inserted to give better definition to the shock wave shadows. A polished plate glass mirror placed under the waterscope is used to direct the light beam toward the charge. The shadow of the charge and of any disturbance which is produced on firing is projected onto a vertical backboard painted white.

A standard 4- by 5-inch camera using Super-XX film was used to take the pictures; these were all separate single exposures.

The experiments were performed in 5 feet 8 inches of water in the west end of the Small Model Basin. This section of the basin has been specially cleaned and prepared for underwater photography. Clean water is always available, which eliminates one of the greatest difficulties in underwater photography. The space may be darkened at will without any inconvenience to other projects.

By setting up the relation between the intervals after the instant of detonation and the observed diameters of the shock waves in the various photographs, it is possible to obtain an estimate of the rate of propagation of the wave. These figures are set down in Table 1. (Text continued on page 14.)

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* Numbers in parentheses indicate references on page 15 of this report.

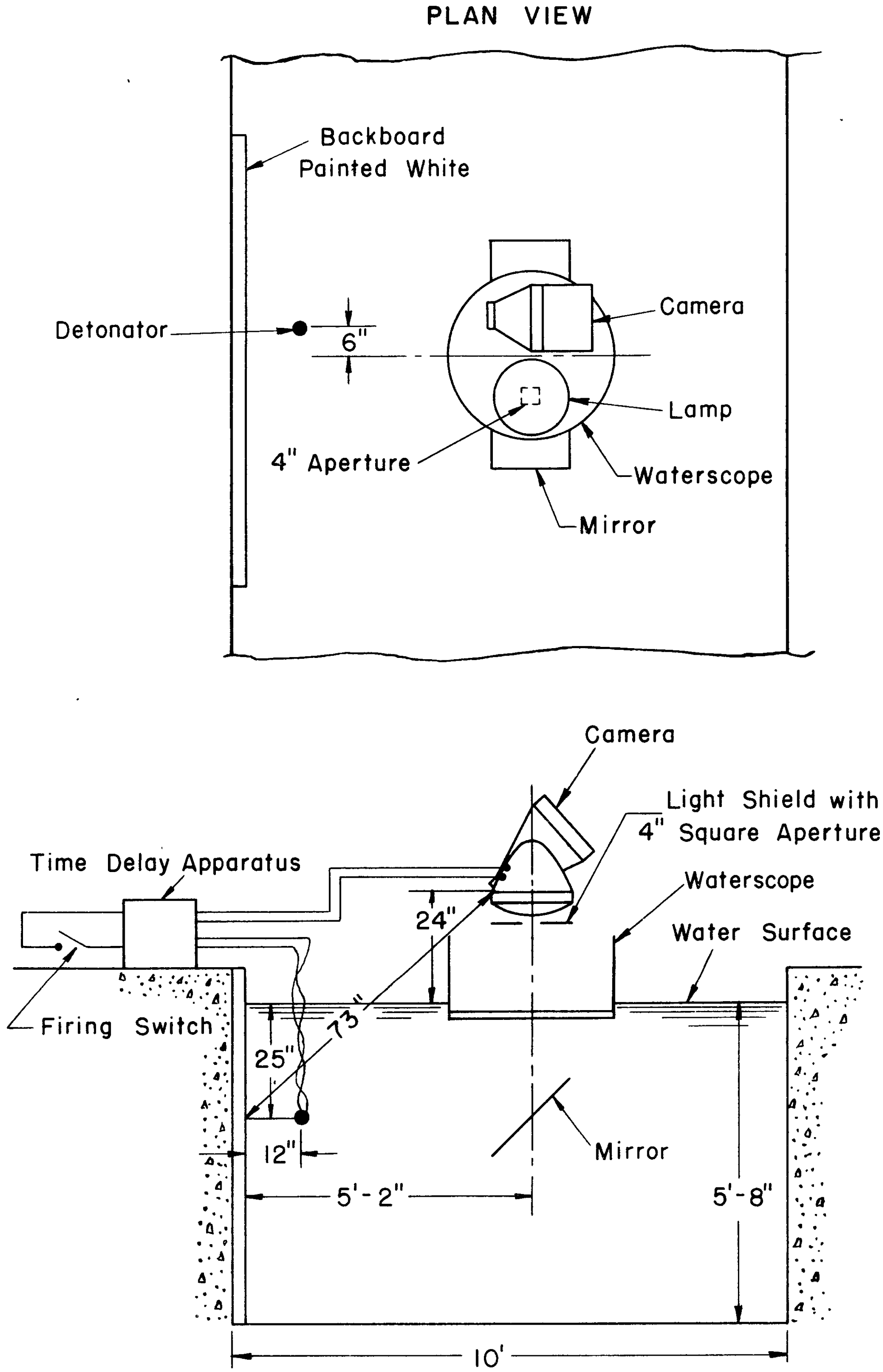

Figure 1 - Arrangement of Equipment used to obtain the Photographs, Figures 2 and 3

Here the light is projected through the waterscope and reflected by the mirror, but the photograph is taken diagonally through the air-water surface.

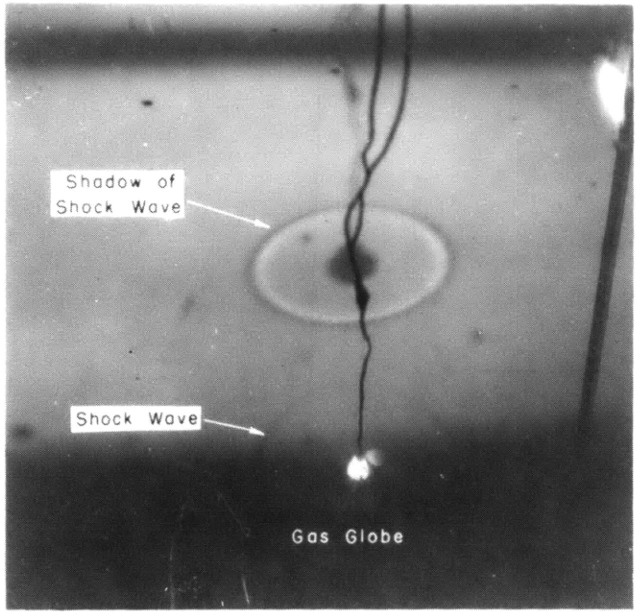

Figure 2 - Depth of charge - 25 inches. Time after start of explosion - 176 microseconds.

This photograph taken diagonally through the water surface toward the white backboard shows a comparatively early stage in the explosion. The explosion globe may just be seen in the foreground; the white spot at the top of the globe indicates the point at which detonation occurred. This is recorded on the film because the camera shutter was open at the time the charge was fired. The shock wave, moving spherically outward, has reached a diameter of approximately five times that of the globe. The shadow of the globe and the shock wave are seen on the backboard 12 inches to the rear of the explosion.

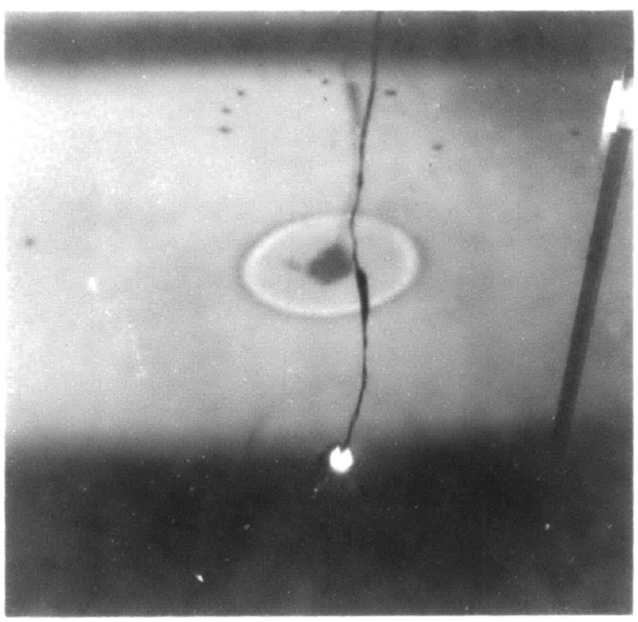

Figure 3 - Depth of charge - 25 inches. Time after start of explosion - 126 microseconds.

This view was also obtained with the setup shown in Figure 1. Both the explosion globe and shock wave and their shadows are to be seen. The shadow is elliptical because the optical axis of the camera is at an angle with the light beam.

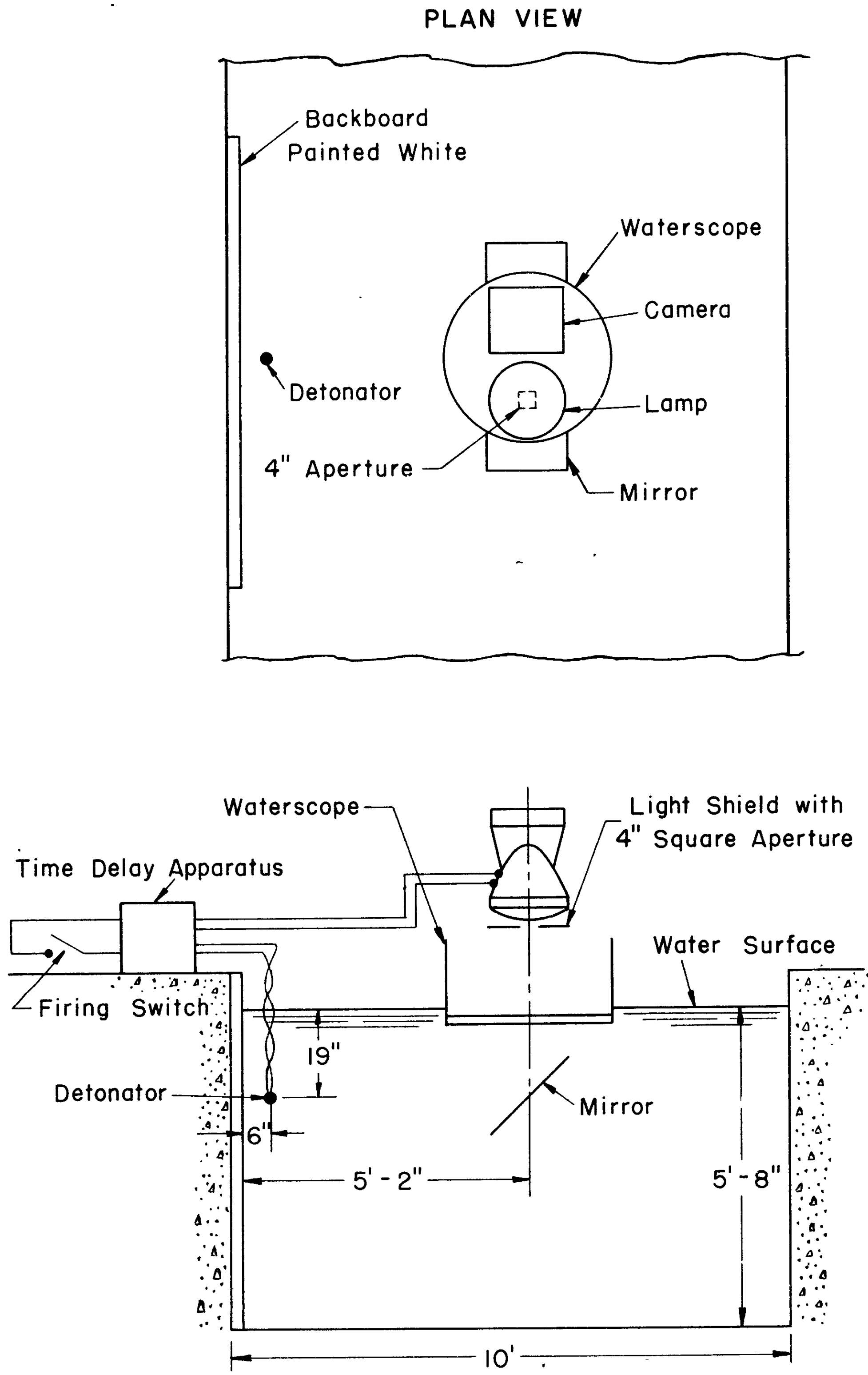

Figure 4 - Arrangement of Equipment used to obtain the Photographs, Figures 5, 6, 7, and 8

Here both the camera and the lamp work through the waterscope and the mirror.

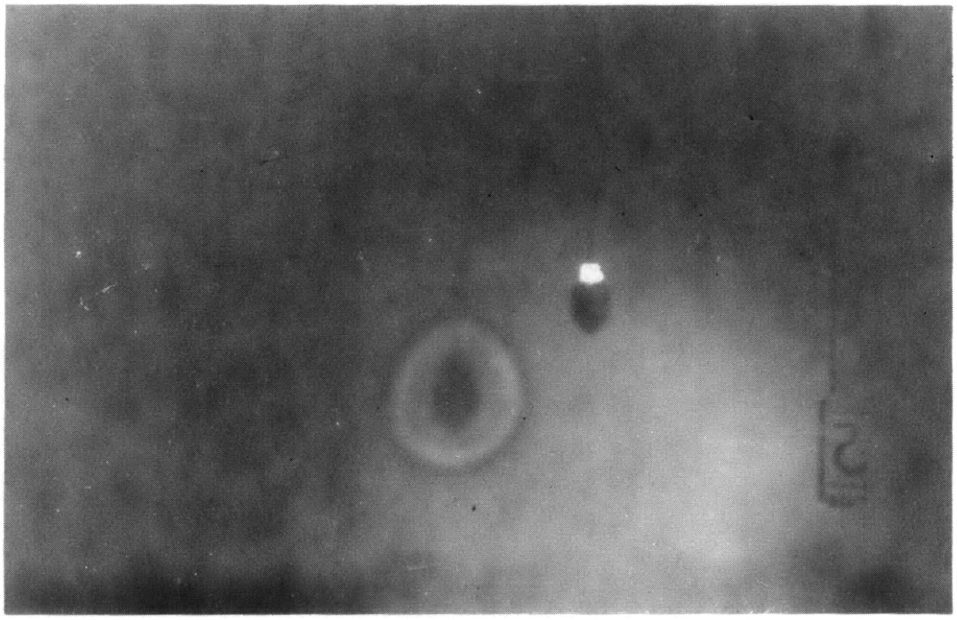

Figure 5 - Depth of charge - 19 inches. Time after start of explosion - less than 65 microseconds. Diameter of shock-wave shadow - 5 1/4 inches.

The actual shock wave around the gas globe appears not to be visible in these photographs.

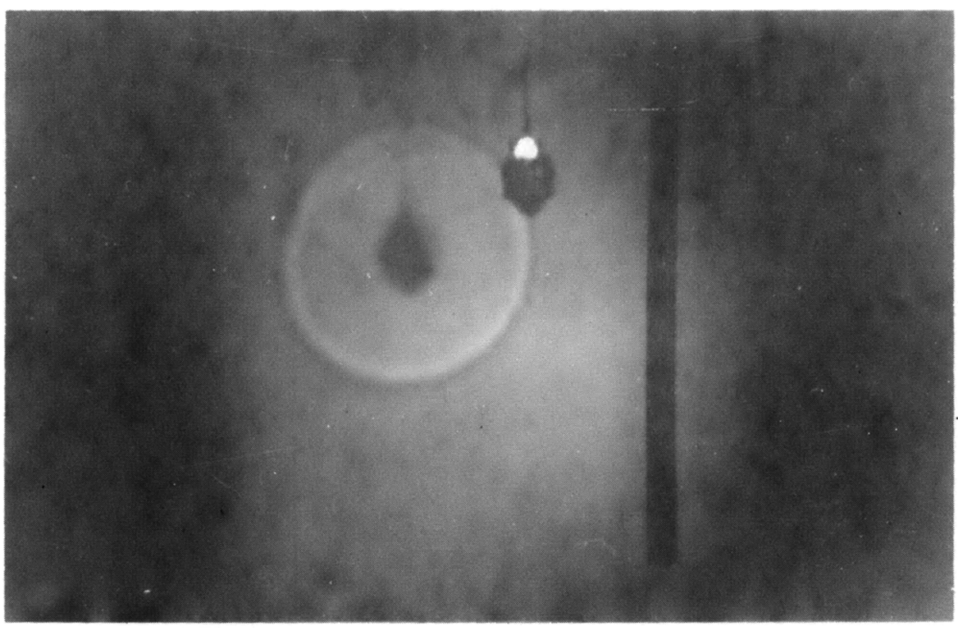

Figure 6 - Depth of charge - 19 inches. Time after start of explosion - 65 microseconds. Diameter of shock-wave shadow - 9.6 inches.

Figure 7 - Depth of charge - 19 inches. Time after start of explosion - 126 microseconds. Diameter of shock-wave shadow - 13.2 inches.

All photographs are separate single exposures.

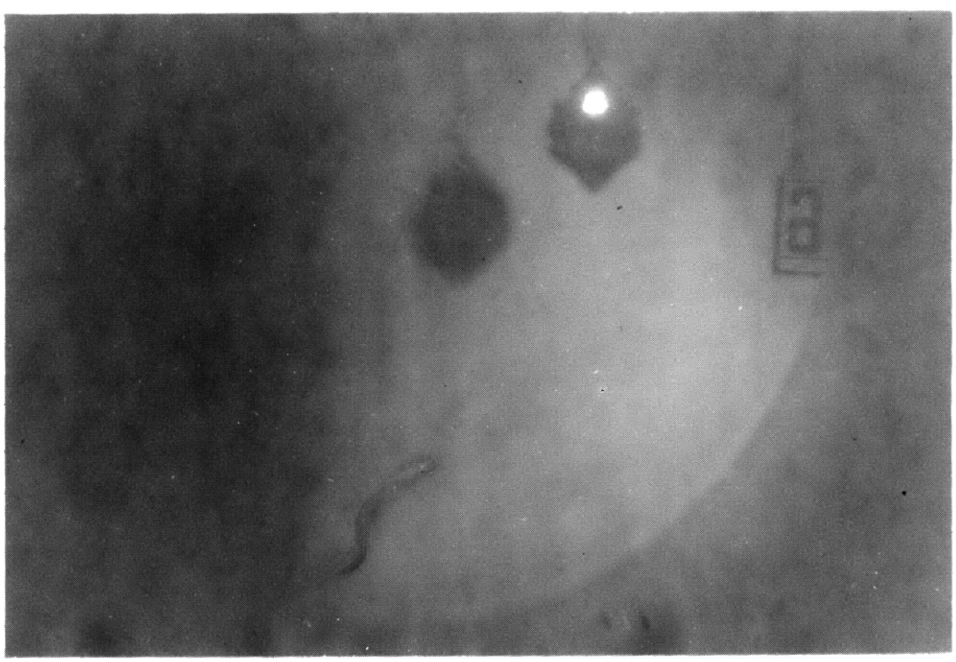

Figure 8 - Depth of charge - 19 inches. Time after start of explosion - 272 microseconds. Diameter of shock-wave shadow - 33.2 inches.

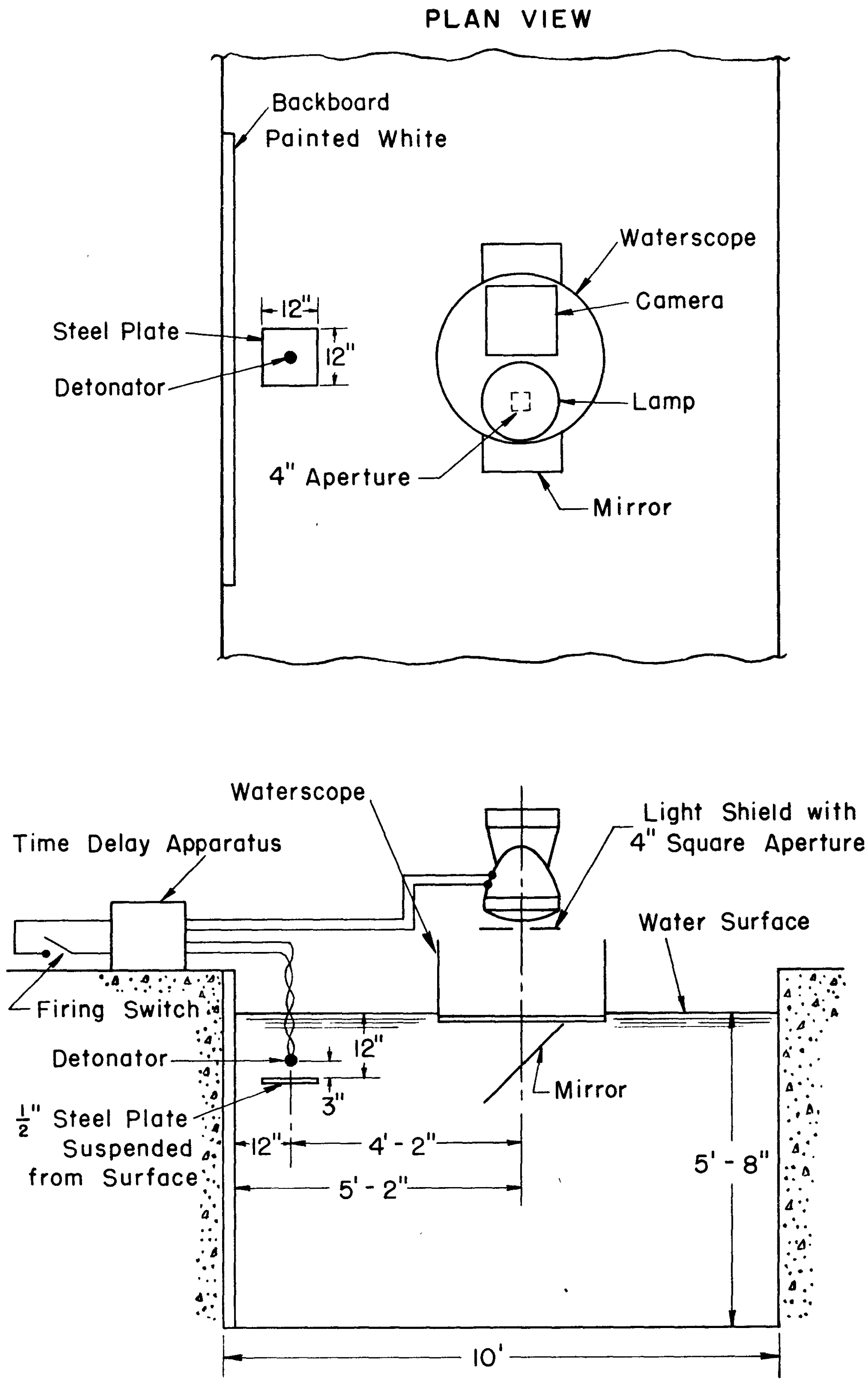

Figure 9 - Arrangement of Equipment used to obtain the Photographs, Figures 10, 11, and 12

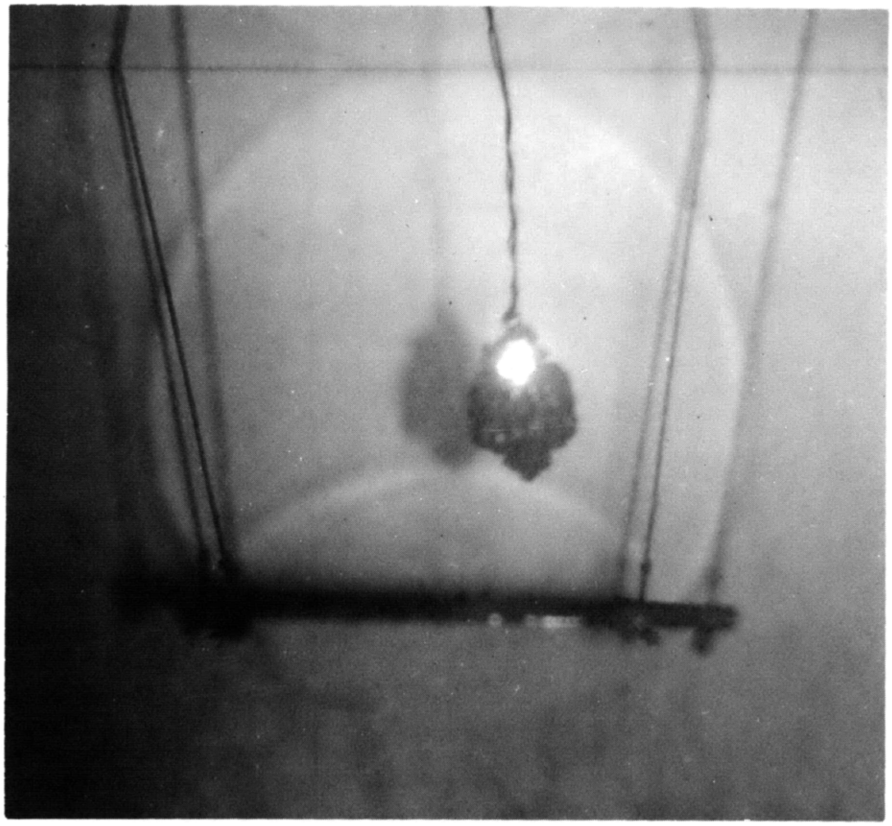

Figure 10 - Depth of charge - 9 inches. Time after start of explosion - 126 microseconds. Diameter of shock-wave shadow - 13.8 inches.

The black object 3 inches below the explosion is a 12 x 12 x 1/2 inch steel plate, suspended from the surface. The shadows of both the reflected and the transmitted shock waves may be seen. The transmitted wave is larger than the reflected wave because of its more rapid transmission through the steel plate. A second smaller wave shadow appears inside the first shadow. It is possible that this is the shadow of a wave reflected from the backboard, or it may result from reflections in the gas globe.

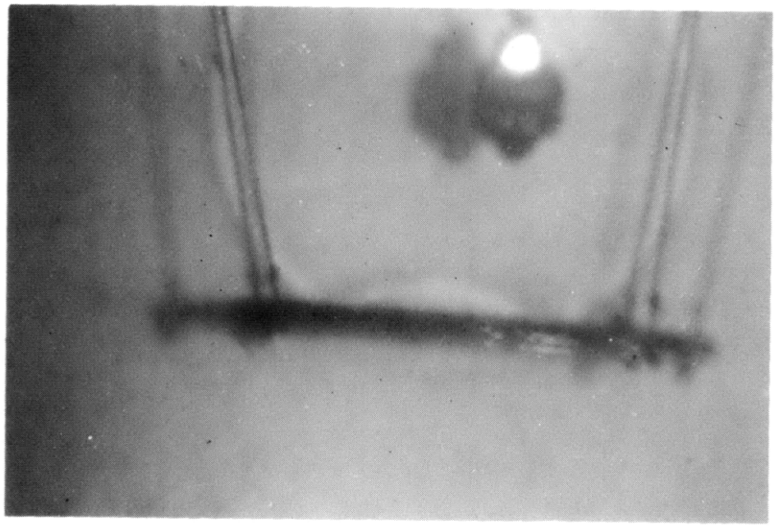

Figure 11 - Depth of charge - 8 inches. Time after start of explosion - 126 microseconds. Diameter of shock-wave shadow - 13.8 inches.

In this photograph the steel plate was placed 4 inches below the charge. A reflected wave and a faint transmitted wave may be seen.

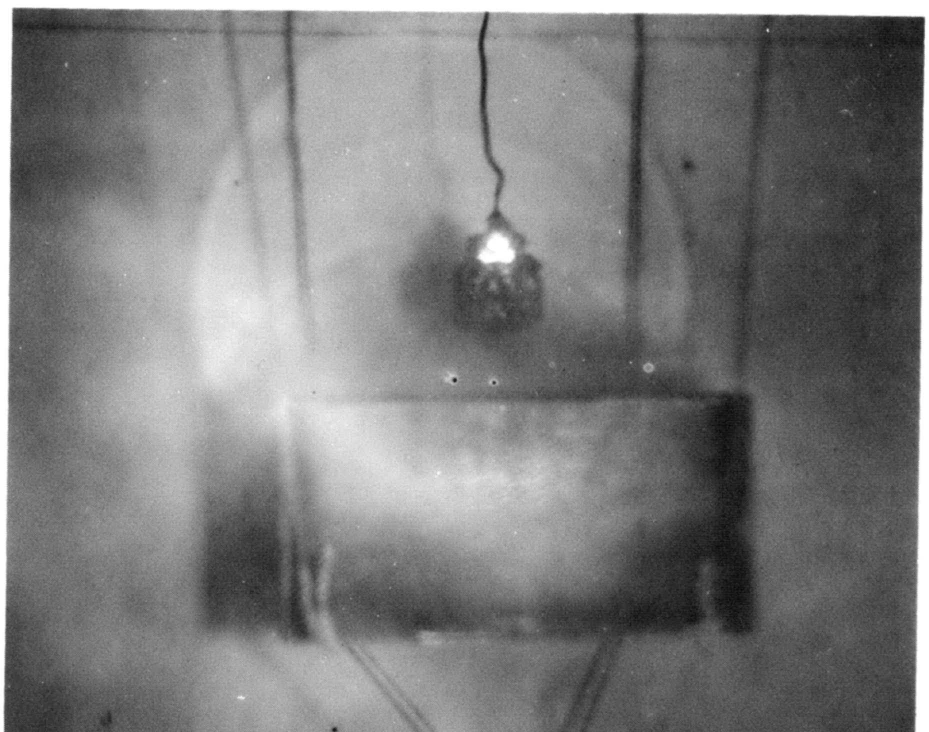

Figure 12 - Depth of charge - 9 inches. Time after start of explosion - 126 microseconds. Diameter of shock-wave shadow - 12.4 inches.

This is the same setup as in Figure 10 except that the steel plate is replaced by a 12 x 12 x 6 inch air-filled box of 0.057 inch steel open to the water on the under side. It is possible that cavitation may be responsible for the haze seen on the near surface of the container. Damage to the box is not apparent at this stage.

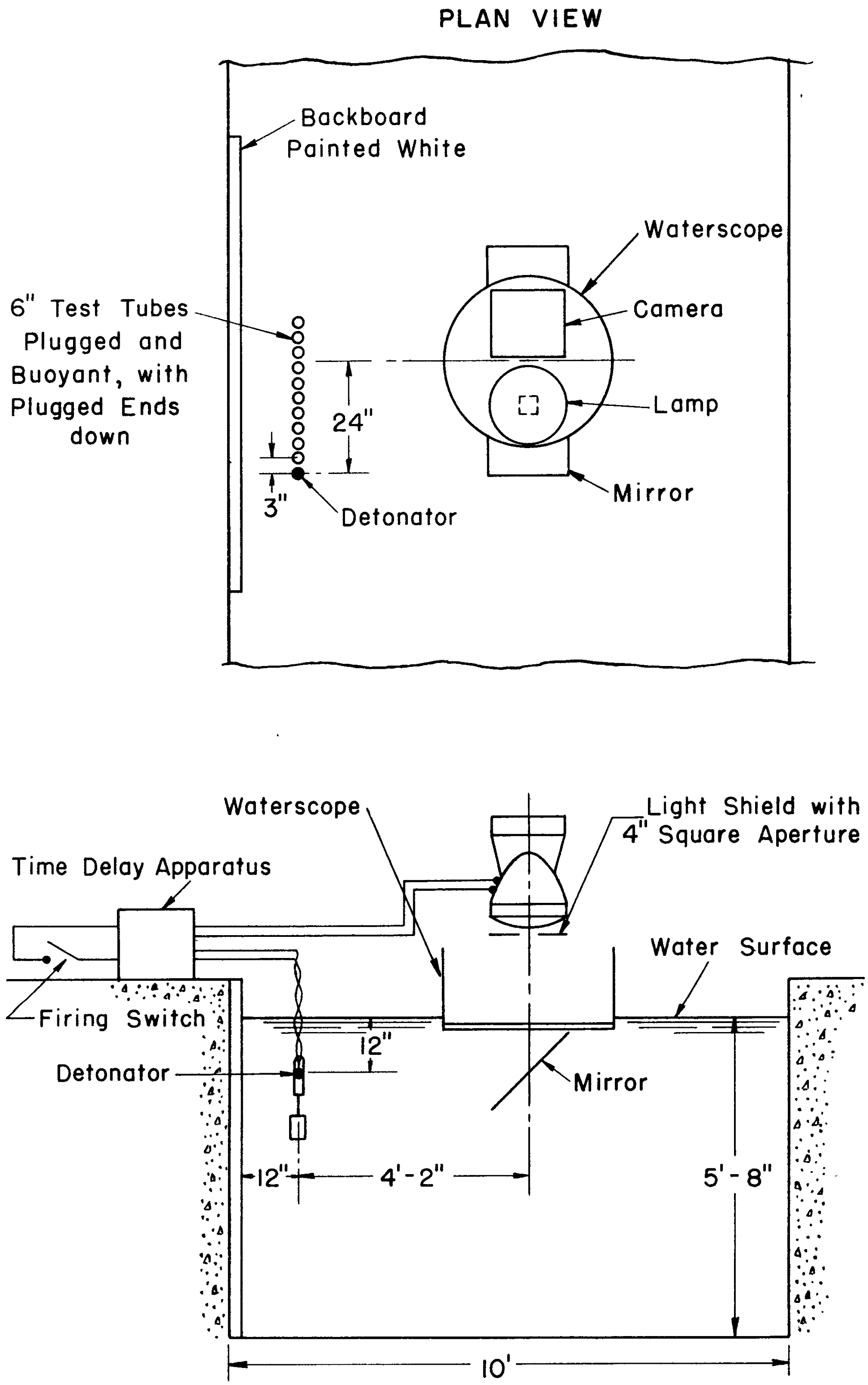

Figure 13 - Arrangement of Equipment used to obtain the Photographs, Figures 14, 15, 16, 17, and 18

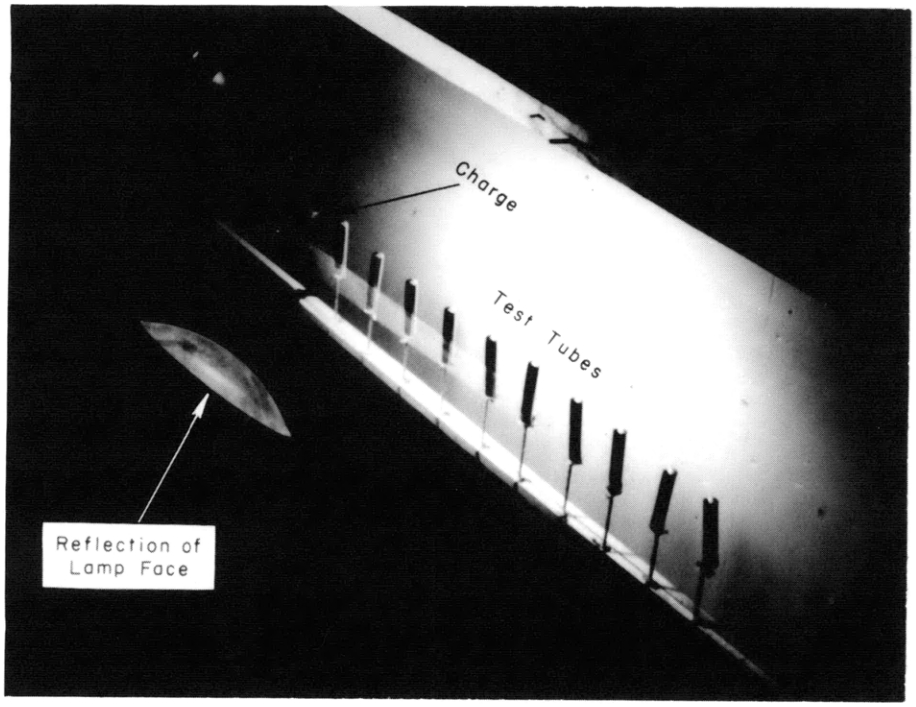

Figure 14 - Above-Water View of Air-Filled Test Tubes and Charge Prior to the Explosion

The row of tubes was illuminated as shown only for this photograph.

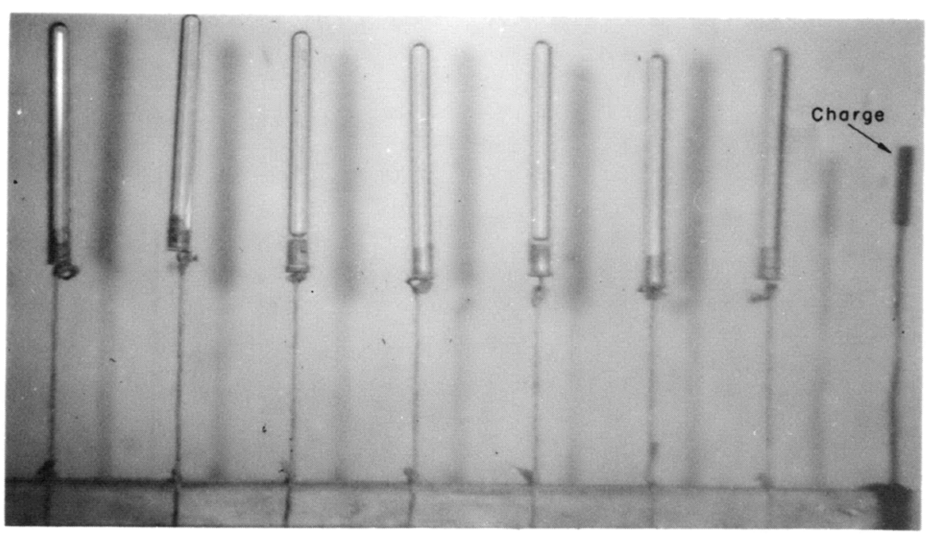

Figure 15 - Underwater View of Test Tubes and Charge

This picture is the reverse of Figure 14 because it was taken through a mirror. The tubes are 6 inches long and are 3 inches apart.

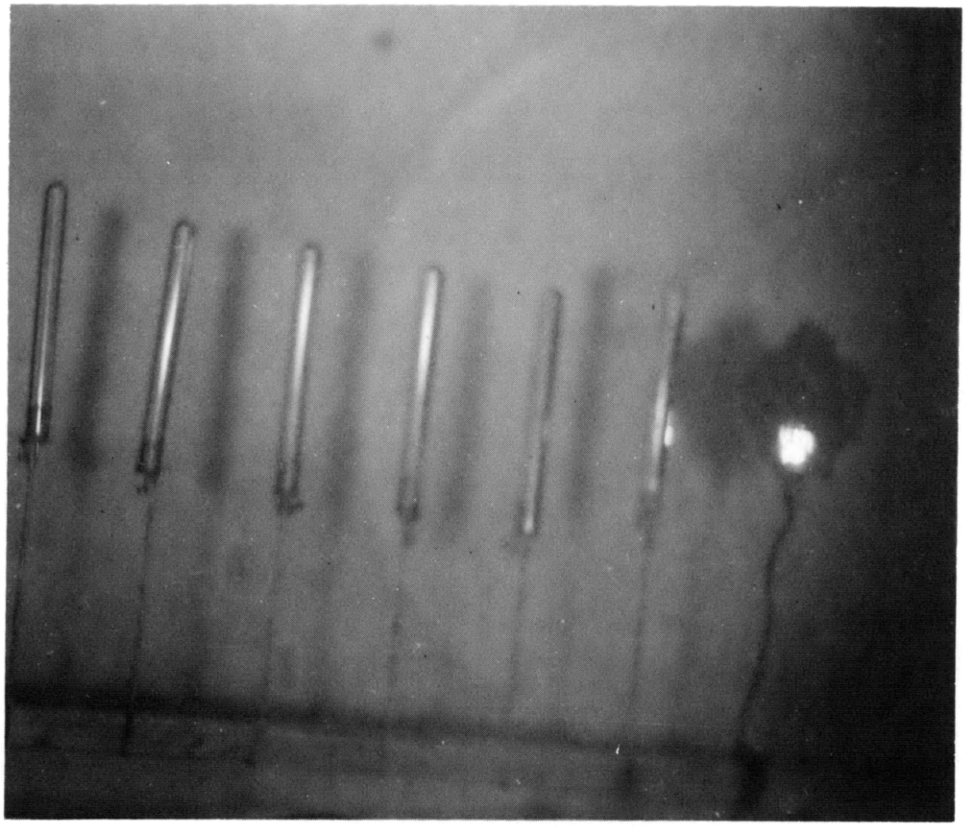

Figure 16 - Depth of charge - 12 inches. Time after start of explosion - 159 microseconds. Diameter of shock-wave shadow - 18 inches.

The light spot on the right-hand tube is apparently only the reflection from the combustion of the charge.

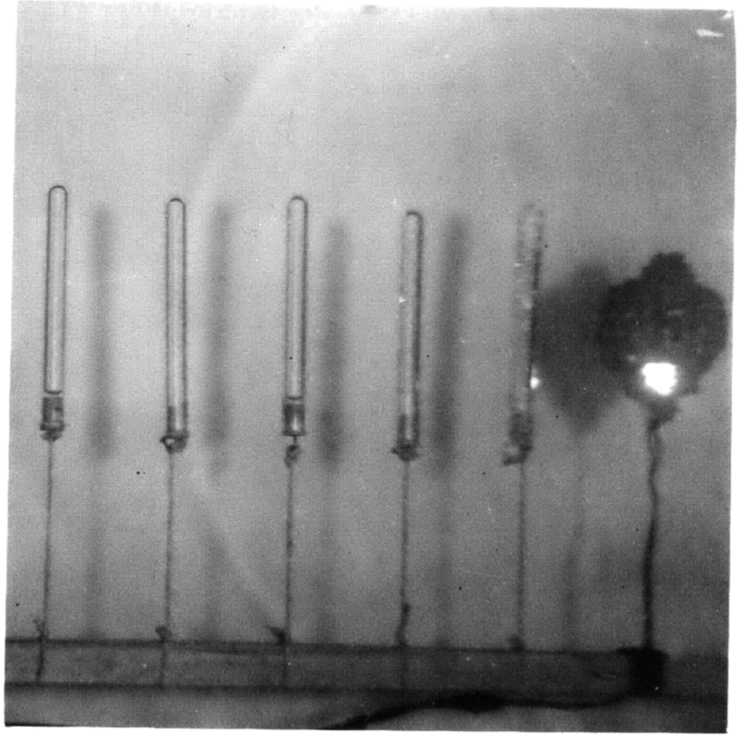

Figure 17 - Depth of charge - 12 inches. Time after start of explosion - 176 microseconds. Diameter of shock-wave shadow - 20.6 inches.

The right-hand tube is still in position but the glass structure appears to be completely fractured.

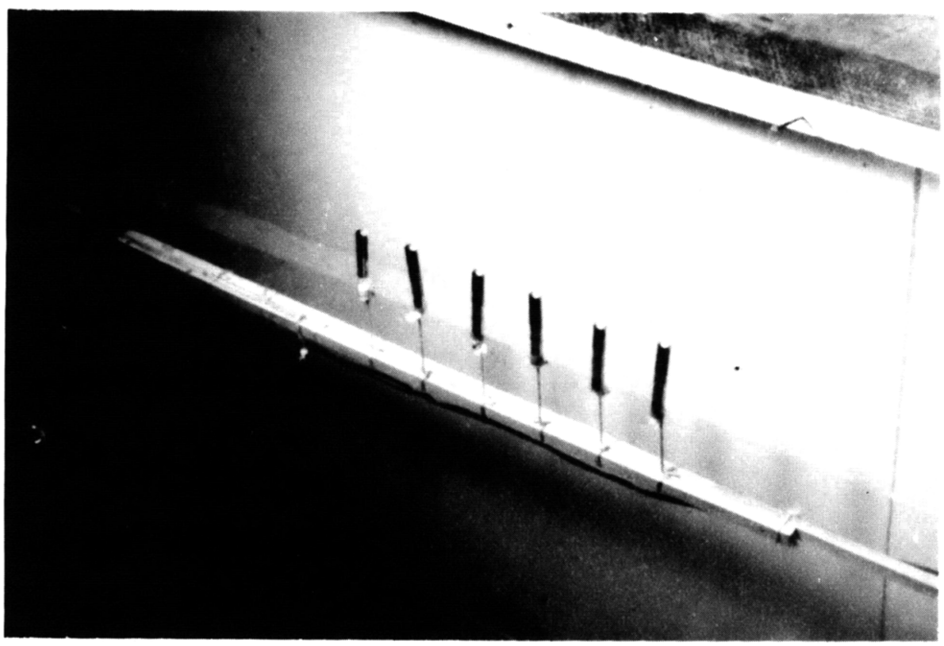

Figure 18 - Remains of Test Tubes after the Explosion

The four test tubes nearest the charge have disappeared.

Although it is known that the shadow of the shock wave is larger than the wave by some 10 per cent, because of the divergence of the light rays, the measurement of the interval after the beginning of detonation is no more accurate than this.

Further experiments on the behavior of shock waves are being planned. Of special interest is the presence and the effect of cavitation and a study of the phenomena in the low-pressure area directly behind the wave.

TABLE 1

Figure	Time Interval from Instant of Detonation microseconds	Diameter of Shadow of Shock Wave inches
5	less than 65	2.1
6	65	4.8
12	126	6.2
7	126	6.6
10	126	6.9
11	126	6.9
16	159	9.0
17	176	10.3
8	272	16.6

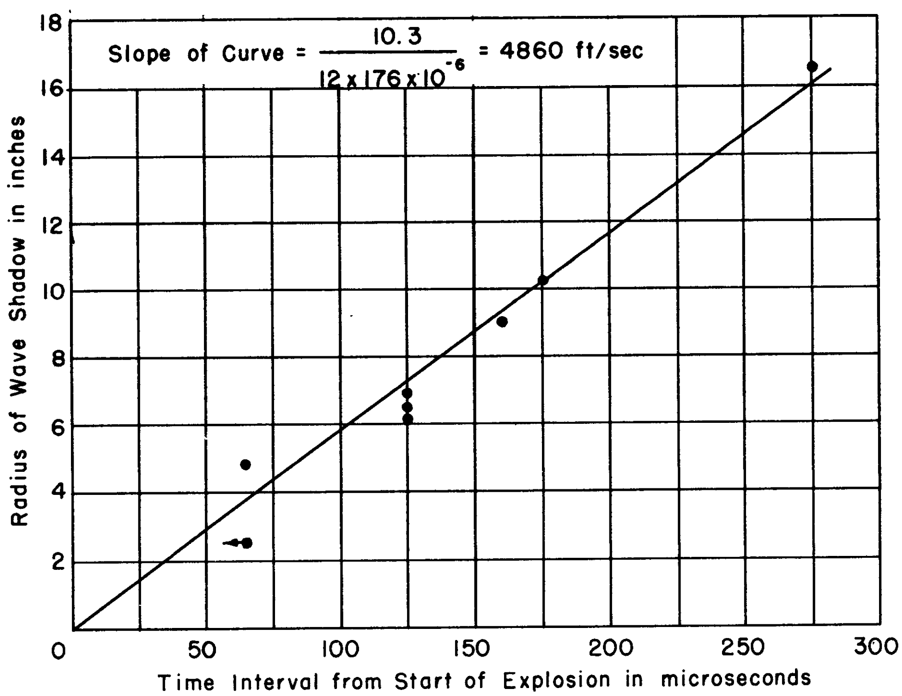

Figure 19 - Curve showing Rate of Travel of a Shock-Wave Front

By plotting the figures of Table 1 and drawing a mean line through the spots, an approximation of the velocity of propagation of the wave front is obtained. It is to be noted that 4860 feet per second is of the same order of magnitude as 5000 feet per second, the accepted value for the velocity of sound in water.

REFERENCES

(1) CONFIDENTIAL TMB Test Report, "A Photographic Study of Small-Scale Underwater Explosions," August 1941.

(2) TMB CONFIDENTIAL letter C-S85-2 of 8 August 1942 to Coordinator of Research and Development, describing Edgerton microflash equipment.

(3) A Taylor Model Basin report describing this device is in preparation.