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EXPLANATORY NOTES TO ACCOMPANY MOTION PICTURES OF UNDERWATER EXPLOSIONS

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REEL 1

SMALL-SCALE UNDERWATER EXPLOSIONS AS SEEN BY HIGH-SPEED CAMERAS 1941-1942*

These photographs form a part of an extended project at the David Taylor Model Basin for study of behavior of circular diaphragms under explosive load. The study of this simplified case is expected to lead to a clearer understanding of the action of underwater explosion on hull structure.

FIRST, A DETONATOR UNDER WATER

A copy of a still picture of a detonator cap in place, followed by the gas globe formed by the explosion as seen after an interval of 1/2 millisecond. The following picture shows the same gas globe after 10 milliseconds. In every instance the gas globe is quite perfect and symmetrical except for local protuberances.

THE GAS BUBBLE PULSATES AS SHOWN BY A HIGH-SPEED MOTION PICTURE (Approximately 1000 Frames per Second)

This high-speed picture shows the pulsations of the gas globe resulting from a detonator, slowed down in the ratio of about sixty to one. The detonator appears in the center of the picture and the globe appears in silhouette. The picture is reversed on the screen, and the motion of the globe toward the surface of the water appears on the screen to be motion downward. About seven or eight distinct pulses can be seen. The detonator was three feet below the surface; at smaller depths the pulsations would be interrupted by the bubbles breaking through the surface.

TO REGISTER DAMAGE, A SMALL METAL CAN IS SUBMERGED NEAR THE CHARGE

This still picture shows the well-developed gas globe 1/10 millisecond after explosion. A small film can in the field at a distance of about three times the radius of the globe shows that damage has already occurred even at this early stage in the action. This is followed by a still showing the can after the action is complete.

ACTION OF SURFACE OBJECTS

A series of light ointment cans were placed on the surface and a detonator was exploded about twelve inches underneath. The slow-motion picture shows the underwater flash, the disturbance of the surface, and the motion of the cans. The picture is shown three times so that details which may be missed at first sight may be seen later.

* Upper case lines repeat the sub-titles in the picture.

THE CANS WERE NOT DAMAGED

This title refers to the cans appearing in the preceding picture.

1/2 OUNCE OF TNT, WHICH IS MORE POWERFUL THAN THE DETONATOR

This shot is similar to the previous one except for the greater charge used. The picture is shown twice.

THE LIGHT FROM THE EXPLOSION IS TOO BRIFF TO BE SEEN. A SLOWER FLASH APPEARS DUE TO BUBBLES FORMED BY THE SHOCK WAVE

The preceding picture is now repeated twice more to make the details of the action completely clear. The flash seen in the picture marks the presence in the water of the shock wave, the earliest phase of the explosive action.

This shot is followed by an angle shot, without title, showing a similar explosion. The surface cans are thrown in the air, and the batten supporting the charge is violently bent although without permanent damage. The flashing lamp by which these pictures were taken appears as a silhouette at the right of the frame. The picture is shown four times in all.

SURFACE CANS NOT DAMAGED. SIMILAR AIR-FILLED CANS PLACED UNDER WATER WERE DAMAGED

In spite of the violent motion of the surface cans no damage occurred. That, therefore, furnished nothing to make a suitable picture. At the same time similar cans were placed under water in the field of the same charge. All these were damaged as shown in the following shot, those nearer the charge more than those at greater distances.

UNDERWATER ACTION WITH 1/2 OUNCE OF TNT

The following pictures were taken under water, reversed on the screen as before. The first shot is a still which shows the relative positions of the charged surface and target. It is followed by a high-speed picture showing the expansion of the bubble and motion of the target. This shot is shown three times in all. In the last repetition the shot is extended to show the target swept back into the field by the inrushing water. This is followed by another underwater picture, without title, of a similar charge. This time, however, the charge was placed under a boat as shown in the following reel, at a depth of 12 inches below the bottom of the boat.

From this point on the underwater pictures are no longer reversed but erect. The shot shows the expansion of the bubble followed by its contraction and strongly developed cavitation in this phase. The shot is shown twice and the second time the upward motion of the gas after the completion of the explosion can be seen.

DAMAGE CAUSED BY EXPLOSION

Shot at 20 frames per second to show character of the damage after completion of the action.

WHEN THE CANS WERE FILLED WITH WATER THEY WERE NOT DAMAGED

REEL 2

A STEEL DIAPHRAGM 3/32 INCH THICK, 10 INCHES IN DIAMETER, IS MOUNTED IN A FLAT BOTTOMED BOAT AND A 1/2-OUNCE CHARGE IS EXPLODED 1 FOOT BELOW

Reel two opens with an explanatory shot at 20 frames per second to show the manner of assembly of the diaphragms in the bottom of the boat. The diaphragms were placed in a heavy steel ring which was bolted to the bottom of the boat so as to produce a flush surface on the under side. The explosion is marked by the flash produced by illumination of the shock wave as before. The flashing apparatus is in the watertight container in the foreground.

THE UNDERWATER EXPLOSION

The following shot is taken under water at about 1000 frames per second and shows the under side of the boat. The first shot shows the relative positions of the clamping ring, diaphragm, and charge. The expansion of the bubble followed by heavy cavitation appears as already seen in the previous shot. The picture is shown four times in all.

THE ACTION OF THE DIAPHRAGM IS VERY RAPID

The same explosion is now seen from inside the boat. The first action is the rejection of surface water from the upper side of the diaphragm, which moves off quickly in a spray. This is followed later by rupture of the diaphragm and a spewing of the water through a small hole in the center of the diaphragm. This rupture occurs in the second pulse about 1/16 second after the initial explosion. Subsequent pulses also are apparent in the motion of the water through the opening. Following this shot is a similar one in which rupture occurs at the first pulse. The effect of the second pulse, however, is to greatly enlarge the hole through which the spray of water pours in a great flood. The broken edges of the diaphragm can be seen silhouetted against the spray.

FINAL DIAPHRAGM DAMAGE

This shows disassembly of the clamping ring after the explosion. The diaphragm in this case was not ruptured.

LARGER CHARGES RUPTURED THE DIAPHRAGM

A special series of views of a single explosion in various phases is now shown. The first shot is at 20 frames per second and shows the rupture followed by water pouring through the opening.

THE SAME DIAPHRAGM IN SLOW MOTION (Approximately 1/75th Normal Speed)

This following shot contains many details worth close attention. The diaphragm was marked with white lines to make it easier to see. The initial deflection of the diaphragm is so fast that it all occurs between two frames of the motion picture, separated by less than 1/1000 second. Following the initial deflection water is thrown up all around the diaphragm. This is mostly water squeezed from the wood of the boat, as loose water in the boat had been carefully removed before the explosion. On the second pulse rupture follows, and a quantity of spray is blown through the opening. Subsequent motion of the water through the opening follows the pulsations of the gas globe.

This is followed by a cartoon showing the successive stages of motion of the diaphragm. This cartoon was made by high-speed observations of the motion of three different points on the upper side of the diaphragm by a process described elsewhere as "smear photography." The cartoon is followed by a repetition of the high-speed picture of the diaphragm.

1/2-OUNCE CHARGE 9 INCHES BELOW THE DIAPHRAGM

The preceding pictures were all made with a charge of 1/2 ounce placed 12 inches below the diaphragm. In order to obtain positive rupture the charge was now moved up to 9 inches with the result that complete and final rupture occurred at the first pulse.

NOTE DOWNWARD FLOW AS UNDERWATER BUBBLE COLLAPSES

The same shot repeated with special attention to the down flow on collapse of the bubble.

Without title, there follows a rather indistinct shot of the pulsating bubble, taken from the identical explosion for which the previous shot showed the effect on the inside of the boat. This is repeated twice.

MOTION AT SIDE OF BOAT

One of the circumstances strongly affecting the results in these explosions is the motion of the boat as a whole; the diaphragm is by no means rigidly fixed in the field of the explosion as the next shot shows. The boat experiences a violent upward motion of three or four inches of travel in a few milliseconds. This is followed by an equally fast downward motion accompanying the collapse of the bubble.

Rupture of the diaphragm at the end of this downward surge is doubtless effected by the motion of the boat which produces a sort of extra hammer blow. After these motions are completed, the outward-moving water begins to appear in the form of a spray under the edge of the boat.