Chapter 3
SHOT UMBRELLA

3.1 INTRODUCTION

Shot Umbrella was the underwater detonation of a 10-kt nuclear device in the southwestern part of Eniwetok Lagoon. The device was detonated 9 June 1958 on the bottom in about 148 feet of water. A target array, consisting principally of three destroyers, an EC-2 liberty ship, a submarine (SSK-3) and a submarine model (Squaw), was moored at various ranges and orientations from surface zero. In addition, naval mines were planted in the vicinity to determine mine reactions to nuclear detonations.

3.1.1 Objectives. The objectives of this test are presented in paragraph 2.1.1. In addition, there was the added objective of determining the mine-crushing capability of a nuclear detonation and the mine-actuating influences of such a detonation.

The test objectives and expected test results may be summarized as follows: (1) document the basic-effects data with regard to initial and residual radiation, air overpressures, underwater-shock pressures, crater measurements, mechanics of base surge, and radiological contaminants; (2) document the response of selected targets to underwater shock pressures; and from these objectives to (1) determine safe minimum-standoff distances for delivery of nuclear antisubmarine warfare weapons by existing vehicles; (2) improve predictions of the lethal range of nuclear antisubmarine warfare weapons against submarine type and surface-ship targets in shallow and in deep water; and (3) determine the mine-field-clearance capability of underwater-burst nuclear weapons.

3.1.2 Background. The background of this test is presented in Section 2.1.2. After consideration of many array plans it was finally decided that three destroyers, placed at ranges from moderate-equipment damage to no damage, an EC-2 liberty ship, and the Squaw (Figure 3.1), placed at a severe hull-damage range, would comprise the array (Figure 3.2). An operational submarine (Bonita) was later added to the array. Barges were included for support of project activities. Coracles collected data around the array.

About 1 August 1957, Chief, Naval Operations (CNO) designated the USS Bonita (SSK-3) as the submarine target for Shot Wahoo. The destroyers and the EC-2 were taken into the Long Beach Naval Shipyard on 1 September 1957. The Squaw and YFNB-12 were made ready at the Naval Repair Facility, San Diego, with work starting about 1 September. For Shot Umbrella, it was planned to use standard mooring buoys and anchors to hold the targets in place.

Tables 2.1, 2.2, and 2.3 list the approved projects, project agencies and funding for the two underwater shots, Wahoo and Umbrella. No attempt has been made to separate the costs between the two underwater shots. Therefore, participation and funding for both are indicated in the tables.

Figure 3.1 and Figures 2.2 through 2.6 show the targets and barges used during Shot Umbrella.

3.1.3 Procedure. The procedure used in preparation for Shot Umbrella is discussed in Section 2.1.3.

3.1.4 Preparatory Operations. The preparatory operations described in Section 2.1.4 are

[redacted]

applicable to Shot Umbrella. In addition, a test of the Squaw submergence system was conducted off San Diego, California, in November 1957.

Following the Special Charge Studies, Project 3.1, a meeting of the Target Positioning Advisory Panel was held in Washington. Distances to the target ships from surface zero were set as: EC-2, [redacted]; DD-474, [redacted]eet; DD-592, [redacted]feet; DD-593[redacted]eet; and Squaw, [redacted]eet (Figure 3.2).

During the time between the test of the Squaw and the time it was towed to the EPG, the David

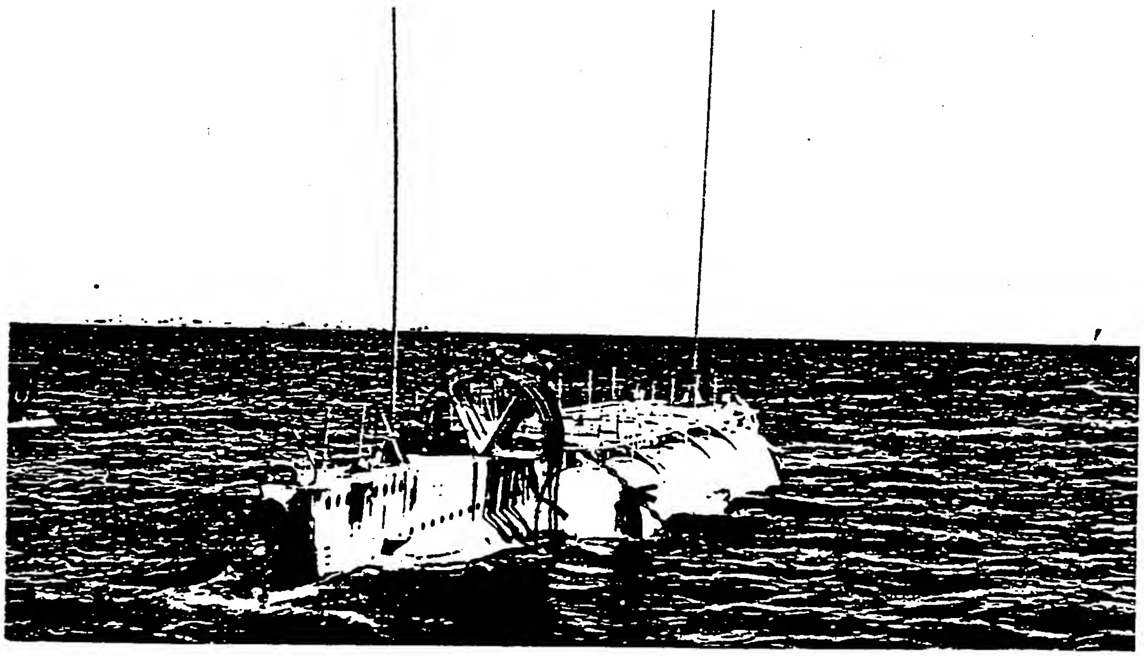

Figure 3.1 Squaw, scale-model submarine construction, previously used during Operation Wigwam, being placed in the target array for Shot Umbrella.

Taylor Model Basin was engaged in installing its instrumentation in the Squaw at the Naval Repair Facility, San Diego, California.

3.1.5 Test Operations. The operational phase of Hardtack began with the movement of personnel and equipment from the United States to the EPG. Ships, barges and equipment were towed or transported from their respective shipyards or ports. More details of the movement of target vessels are found in the previous chapter.

Shot Umbrella was scheduled to follow Shot Wahoo. At 1330 on 16 May 1958, Shot Wahoo was detonated. Early recovery of some data, particularly of a radiological nature, was accomplished before dark on 16 May.

On 17 May the target ships were hosed down, monitored, and data was recovered as safety considerations permitted. When all projects were ready, the ships were taken from their moorings and towed into an anchorage near Site Fred where decontamination was performed using teams from the USS Renville. This was accomplished in about four days.

To assist in target preparation, TG-7.3 again had the repair ship, USS Hooper Island (AR-17),

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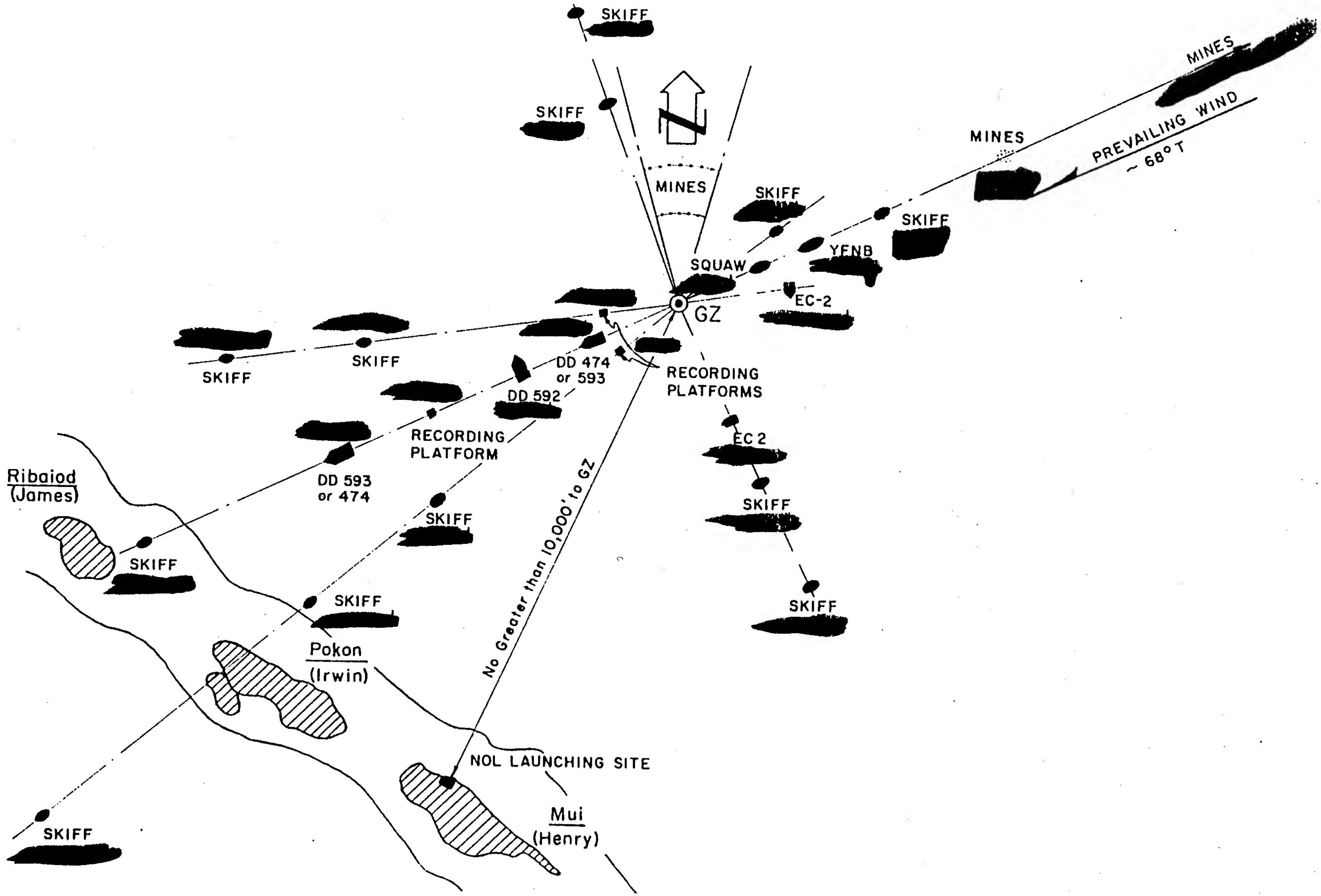

Figure 3.2 Early planning target array for Shot Umbrella.

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moored near Site Elmer. The three destroyers and Bonita were nested alongside the USS Hooper Island for the final field preparations for Shot Umbrella.

While project personnel were readying the targets and other instrumentation, TG-7.3 anchored buoys and barges and made other preparations to place the Shot Umbrella array in proper position.

On 15 April, the Chief, AFSWP, directed that the USS Bonita (SSK-3) be submerged in the Umbrella array at [redacted] feet, bow toward surface zero.

Task Group 7.3 had moored the Umbrella zero buoy on 1 May 1958, to assist those projects making early installations for Shot Umbrella.

On 23 May, the Target Positioning Advisory Panel held a meeting and decided on the following revised distances for the target ships from surface zero: EC-2, [redacted] feet; Squaw, [redacted] feet; DD-474, [redacted] feet; DD-592, [redacted] feet; and DD-593, [redacted] feet. These distances were accepted by the Chief, AFSWP (Table 3.1). Best estimates of exact ranges from surface zero at shot time are shown in Figure 3.3.

Beginning 4 June, the USS Monticello (LSD-35) and the boats assigned from TG-7.3 Boat Pool

TABLE 3.1 TARGET-SHIP DISTANCES FROM SURFACE ZERO FOR SHOT UMBRELLA

All distances shown are horizontal, in feet, from surface zero to the nominal centerline of the ship concerned.

EC-2	[redacted]	Squaw	[redacted]
DD-593	[redacted]	YFNB-12	[redacted]
DD-592	[redacted]	SSK-3	[redacted]
DD-474	[redacted]		

provided transportation to the target-array area and boat service between the barges and ships. The concept was good, but the daily operations were again beset by a series of minor but annoying problems, similar to those encountered prior to Shot Wahoo.

Since some data was lost on Shot Wahoo because of failure to get timing signals, much thought was given to assuring signals during Shot Umbrella. The radio timing central was given two independent sources of power and, in addition, a visual-indicator system was devised to show when y ship lost power supply.

Zero hour of 1100, 8 June, was established.

Following Shot Wahoo, in discussions with technical personnel, it was decided that, if possible, a more stable platform with more antenna room should be provided for the arming and firing operations and for Project 1.11. Investigation disclosed that a surplus LCU was available. Into the well of this LCU, the LCM, with its already installed instrumentation, was placed. Project 1.11 occupied one of the rooms on the starboard quarter of the LCU. The LCU was checked out at Site Elmer and taken on 4 June to the zero buoy where it remained until shot time.

The Squaw and YFNB were moored in the array on 31 May.

The EC-2, DD-474, DD-592, and DD-593 were moored in the array on 1 and 2 June.

On 4 June, a complete rehearsal of procedure of Shot Umbrella was conducted. Token groups of personnel were evacuated from the target array, washdown was in operation, a dummy device was placed in position, the full-frequency full-power dry run was made, and the procedure for early reentry, including the rad-safe survey, was followed. All aircraft missions for U-day were also flown.

Due to an accumulation of delays, it was decided to postpone shot day to 9 June 1958. The remaining days and nights were devoted to last-minute checks and rechecks of instruments,

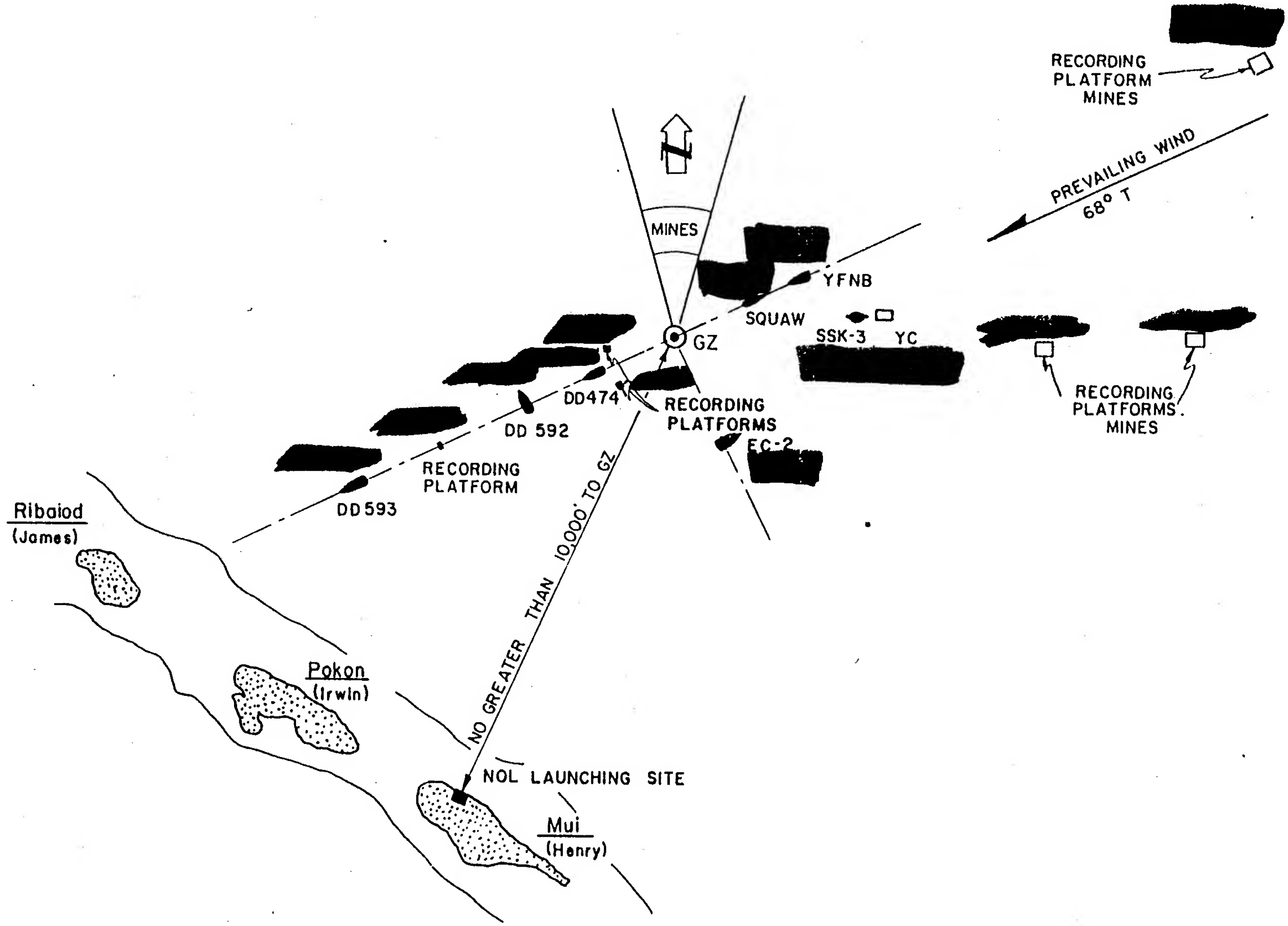

Figure 3.3 Target array for Shot Umbrella.

[redacted]

timing-signal runs, loading cameras, arming coracles, etc.

The Bonita was placed in position on 8 June.

At 0600 on 9 June, the device was lowered into position, final evacuation of the target array was begun, and the USS Grasp left the zero-buoy area about 0900, while ships and boats moved to pre-selected anchorages, generally east of surface zero, to wait for the detonation.

About 1030 a fifteen-minute delay was called to wait for better cloud conditions.

At 1115, 9 June 1958, the Umbrella device was detonated.

It was soon determined that there was not as much radiological contamination as had been anticipated. Using a prearranged entry plan, the early recovery of data and instrumentation was begun within two hours after shot time. By 1600 on 10 June, the early-data recovery was completed and the ships were broken from their moorings. The ships were taken to Site Elmer where the remaining project data was removed, damage surveys were conducted, and the ships made ready for return to the United States.

The EC-2 was found to be too badly damaged for economical repair. Permission was obtained to dispose of the ship, and it was sunk by gunfire in deep water off Eniwetok Atoll.

The USS Bonita was returned to the United States under its own power.

The DD-474, DD-592, DD-593 and Squaw YFNB were towed to the United States.

3.2 BLAST AND SHOCK

Study of free-field blast and shock phenomena from the shallow water shot, Umbrella, was accomplished by six projects. Their general objective was to correlate data obtained with results from Shot Baker of Operation Crossroads and high-explosive tests, with the aim of improving methods of predicting blast and shock phenomena for any underwater burst geometry in shallow water.

3.2.1 Umbrella Preshot and Postshot Bathymetric Surveys.

A preshot bathymetric survey was made of a selected area of Eniwetok Lagoon to facilitate selection of the shot site and for use in placement of equipment and analysis of data. This survey was accomplished under the general direction of the Columbia University Geophysical Field Station in September and October 1957; however, Project 1.13 increased the density of data around surface zero during Operation Hardtack, using a TG-7.3 LCM equipped with a fathometer. Combined results shown in Figure 3.4 indicate the lagoon has an average depth of about 23 fathoms, with numerous coral heads one or two fathoms high.

Interest in the Shot Umbrella crater stemmed from possible use of bottom bursts in such civil applications as harbor construction and possible side benefits from military use of a weapon, such as formation of a crater lip which would make harbors inoperative. A postshot bathymetric survey was, therefore, made to ascertain the extent of the Umbrella crater and lip. An LCM, equipped with a fathometer, was used to document postshot water depths, starting on D + 1 day. Positioning and control of the boat were accomplished by cross bearings from known stations on Sites Keith and Glenn, and appropriate radio communications. Some lead-line soundings were also taken, and these showed little difference from fathometer readings. Four cross sections through ground zero are shown in Figure 3.5. Because of the extremely uneven preshot terrain, values for maximum crater depth and radius can only be grossly estimated. Crater depth appears to be less than 15 feet but is as much as 30 feet in regions where preshot high points existed. Crater radius appears to be about 900 feet. Crater lip height, if any, was too small to be measured by a fathometer. The crater was shallower and wider than TM 23-200 predictions of 100-foot depth and 550-foot radius, thus indicating need for further studies of craters from water-contained explosions.

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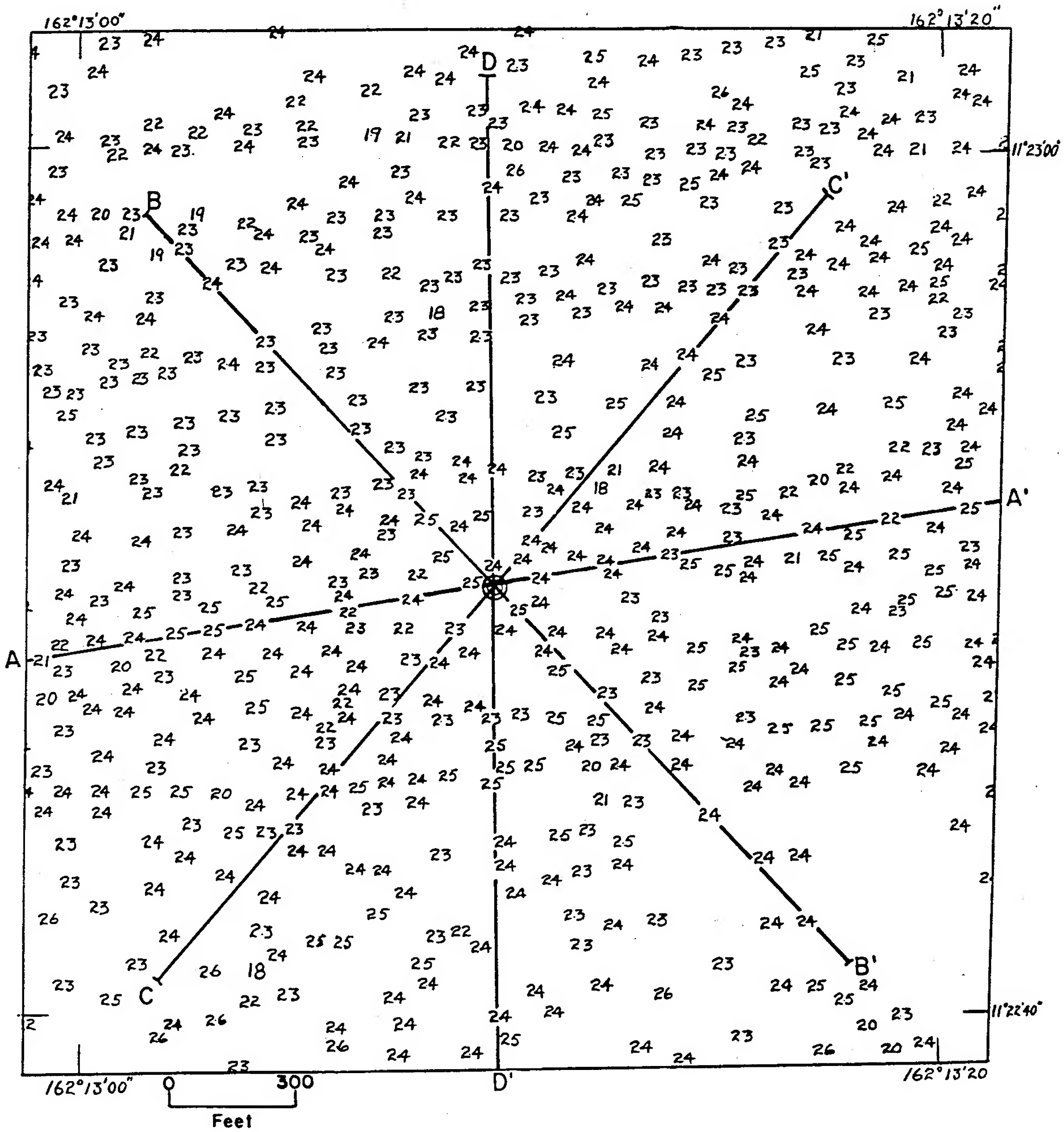

Figure 3.4 Preshot hydrographic survey of the Umbrella area. Soundings in fathoms.

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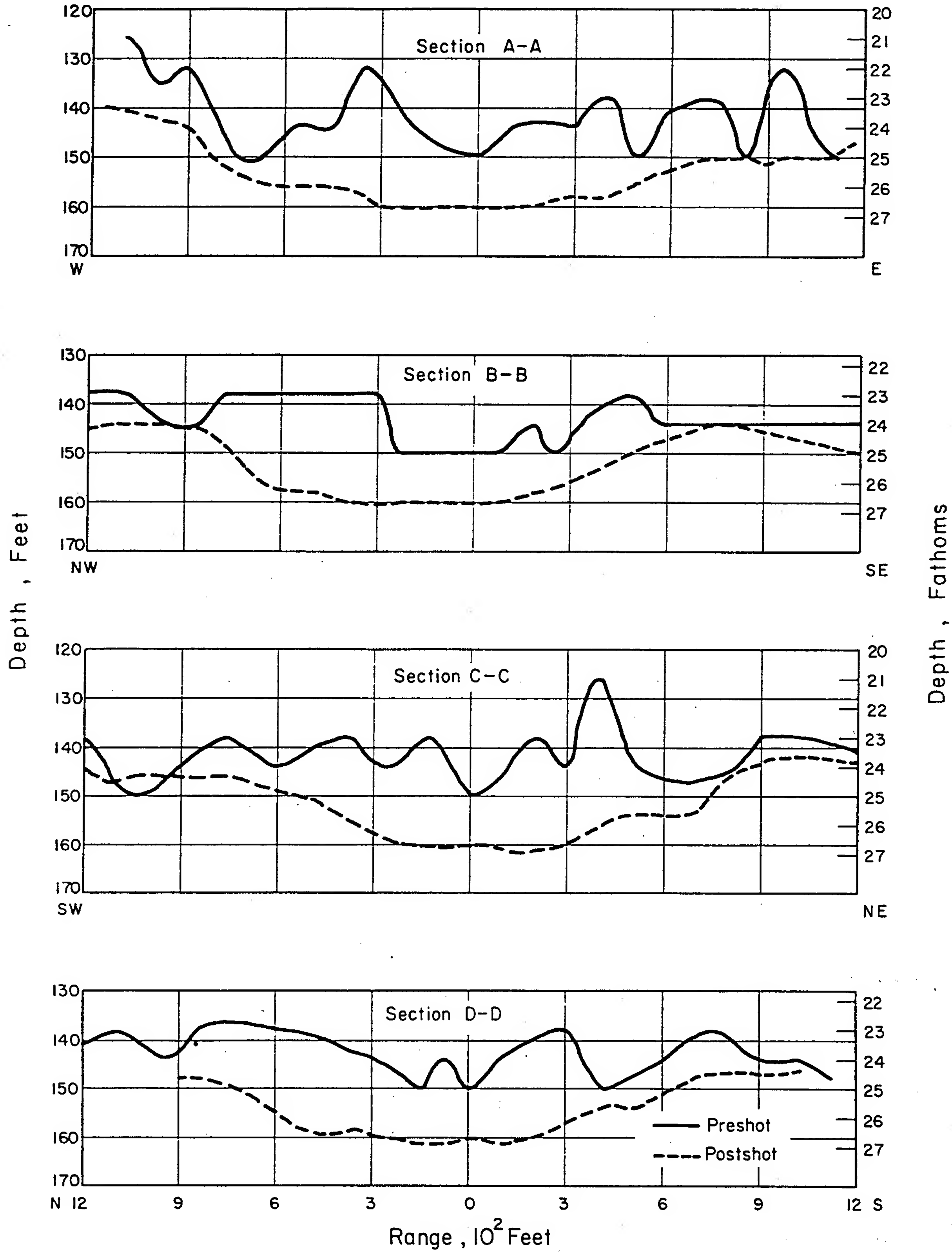

Figure 3.5 Bottom profiles through surface zero prior to and after Shot Umbrella.

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3.2.2 Hydrodynamic Yield Determination. During Operation Wigwam, Armour Research Foundation (ARF) measured the time of arrival of the shock wave at selected points between the underwater shot point and the water surface. From the shock arrival data, ARF computed the shock-wave velocity versus range and then obtained the total-energy release of the device on the basis of theoretical considerations (Reference 14). For Operation Wigwam, the yield computed from this approach was considered to be quite reliable. The Operation Wigwam technique was re-instituted on Shot Umbrella primarily to provide a check on the energy partition between water and ground for the bottom-burst geometry. Shot Wahoo was to provide the free-water pressure-distance curve for the device. Secondary objective on Shot Umbrella was to provide a check on total yield.

Experimental Plan. Instrumentation, as shown in Figure 3.6, was essentially the same as used on Operation Wigwam. Two strings of pressure switches and a doppler cable were attached to the weapon-suspension cable. Closure of the pressure switches by the shock wave triggered a pulse generator whose response was telemetered to a receiving station. Shock-wave velocities were to be determined from the time interval between closures. A doppler coaxial cable was also installed to provide a measurement of shock velocity. A signal from a radio-frequency oscillator, transmitted down this cable, was to be reflected at the end crushed by the shock wave. The reflected signal and oscillator signal were to be mixed, amplified, and telemetered to the receiving station. This telemetered signal, the doppler frequency, would be directly proportional to the shock-wave velocity.

Preshot tests showed considerable interference with reception of telemetered signals from surface zero at Site Parry and adjacent islands. Therefore, a receiving station was set up on an LCU. Use of the LCU permitted movement to a good zone of reception, approximately [redacted]eet north of surface zero.

Results. Of two sets of pressure switches and one coaxial cable installed, only one set of pressure switches provided data. Measured times of shock arrival and computed values of shock velocity, overpressure, and total yield are shown in Table 3.2. As can be seen, a consistent yield was not obtained. At Gage 29, shock velocity was approaching sound velocity, so value of yield computed for this point can be disregarded. An average of the remaining points gives a total yield of 6.45 kt or effective yield of 6.45 × 1.6 = 10.3 kt. This compares to the expected total yield of 10 kt and expected effective yield of 16 kt.

Figure 3.7 compares the Umbrella pressure-distance curve with that predicted from Operation Wigwam. The measured curve crosses the predicted decay line in such a manner that in one half of the region of interest the effective yield appears below, and in the other half above the 16 kt expected. Determination of energy partition between coral and water must await an adequate explanation of this unexpected slope of the measured curve.

3.2.3 Underwater Shock Pressures. Information from peak-pressure measurements and from limited amounts of pressure-time data obtained on Shot Baker of Operation Crossroads was inadequate to enable predictions of loading to ships and submarine targets from underwater shots in shallow water. Work with high explosives indicated general agreement with peak-pressure results of Shot Baker, Operation Crossroads, but left considerable uncertainty as to predictions of impulse for a nuclear shot. As a result, there was a real need for a substantial program for measuring underwater pressures as a function of time and distance from Shot Umbrella. These measurements were to be used by ship-damage projects to provide characteristic loading functions on target ships and so, when correlated with information on ship response and damage, provide a sound basis for determination of pertinent operational techniques. Naval Ordnance Laboratory (NOL) was the project agency for obtaining the pressure-time histories.

Experimental Procedure. NOL established 16 stations, with gages at depths of 10 to 130 feet, at ranges from 473 to 7,900 feet. The primary electronic gages were backed up by

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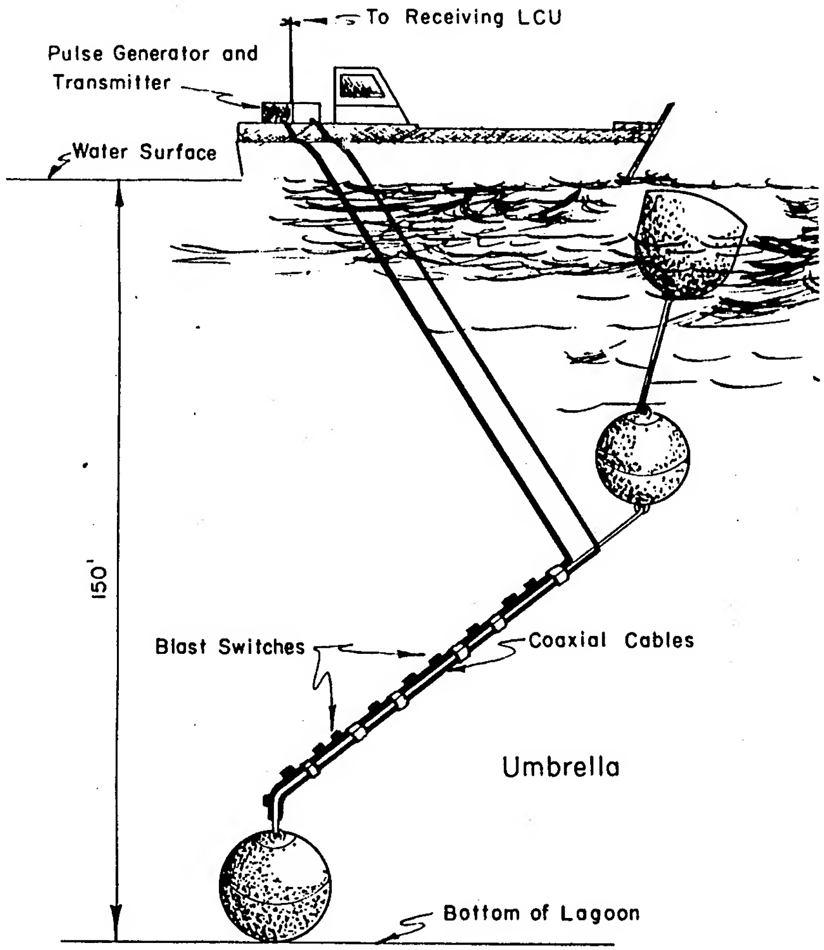

Figure 3.6 Instrumentation for early time-of-arrival data.

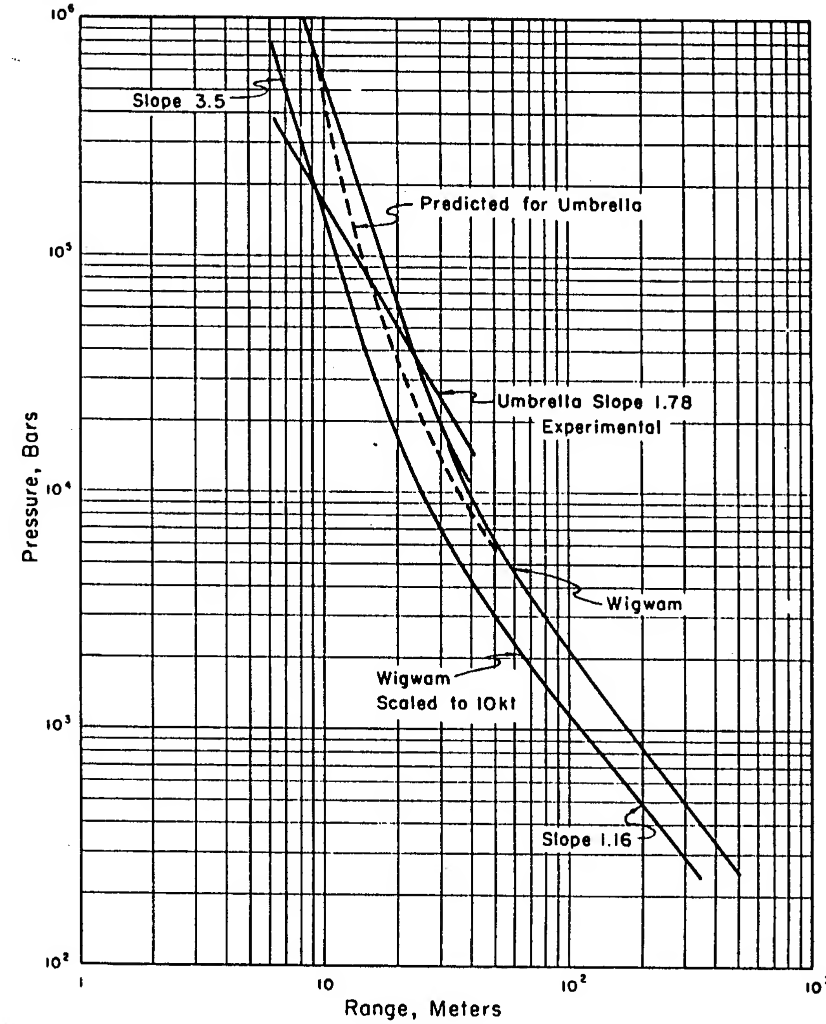

Figure 3.7 Pressure versus distance for Umbrella and Wigwam.

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both mechanical pressure-time (p-t) and ball-crusher (b-c) gages. Vertical gage strings were deployed from all three destroyers, the YFNB, EC-2, 5,500-foot barge, and two close-in linear arrays composed of buoys and barges. Electronic strings, suspended from the close-in buoys, reported to recorders in barges at ranges o[redacted]feet. Alternate electronic gages from each string reported to separate recorders to insure against complete loss of data from any one station.

Results. A typical electronic p-t record obtained is shown in Figure 3.8. Mechanical pressure-time (mpt) and electronic pressure-time (ept) records were in good agreement. The low-amplitude pulse in advance of the main shock, reaching an overpressure of three psi, was found on almost all records. It was due to energy traveling first through the ocean bottom and then transferring into the water and is referred to herein as the ground wave. The direct shock wave was followed by a negative phase during which cavitation occurred. The second positive pulse of 61 psi was caused by cavitation closure. Although not shown, the cavitation pulse was

TABLE 3.2 SUMMARY OF EARLY HYDRODYNAMIC DATA, SHOT UMBRELLA

Gage Number	R = Radius from Bomb	t = Time of Arrival	n*	U = Velocity	P = Pressure	$R/W^{1/3}$	W = Total Yield
	meters	μsec		m/sec	bars	meter/$kt^{1/3}$	kt
11	4.51	16	—	—	—	—	—
15	7.15	238	0.30	9.0×10^3	4.0×10^5	4.4	4.25
17	9.00	451	0.35	6.98×10^3	2.2×10^5	6.3	3.4
21	14.20	1,311	0.45	4.87×10^3	8.5×10^4	8.3	5.0
23	17.9	2,111	0.48	4.08×10^3	5.6×10^4	9.4	6.8
27	23.1	4,951	0.53	3.03×10^3	2.45×10^4	12.0	12.8
29	35.2	7,331	0.54	2.59×10^3	2.14×10^4	12.5	22.0

$$* \; n = \frac{\log (R_2/R_1)}{\log (t_2/t_1)} = U \frac{t}{R}$$

followed by numerous small pulses, more pronounced at greater ranges, which may have been the result of waves reflected or refracted from ground layers deep beneath the ocean bottom. In general, the pressure-time records were similar in shape to those from high-explosive tests.

Arrival times of the main shock, cavitation, and ground-wave pulses versus ground range are shown in Figure 3.9. A weak ground wave was found at all but the 473-foot station. Cavitation pulses were also found at all but the 473-foot station; however, at ranges inside 1,700 feet identification was difficult because of the presence of many small amplitude pulses. Figure 3.9 shows the main shock arrived at greater time intervals after the ground wave as ranges increased. The cavitation pulse appeared first about 500 msec after detonation, approximately 2,000 feet from surface zero, and propagated away in both directions. At ranges beyond 3,000 feet, the cavitation pulse appeared within a few milliseconds after the main shock.

Selected b-c gage peak pressures versus distance are plotted in Figure 3.10. The large variations in pressure observed from Operation Crossroads ball-crusher results were not found. For the first 70 to 80 feet down, pressures, with a few exceptions, were essentially constant. Below 70 to 80 feet, pressures decreased with depth. Pressures at the deepest gages, 130 feet, were 15 to 25 percent less than those near the surface. Readings at like depths and ranges showed a scatter of 10 to 15 percent.

Selected ept and mpt gage peak overpressures versus distance are plotted in Figure 3.11. Ept gage pressures from 25 feet down to mid-depth, 60 to 80 feet, were fairly constant at all stations. Ten-foot-deep ept gages at all stations recorded pressures lower than gages below. Below mid-depth, peak pressures decreased with depth at most ept stations. Shallowest mpt

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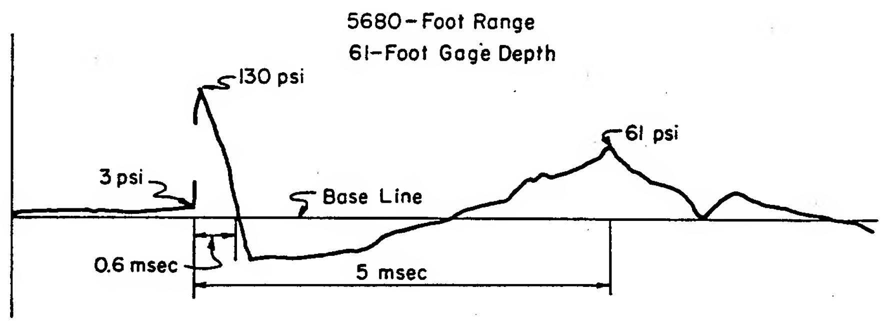

Figure 3.8 Shock-wave record.

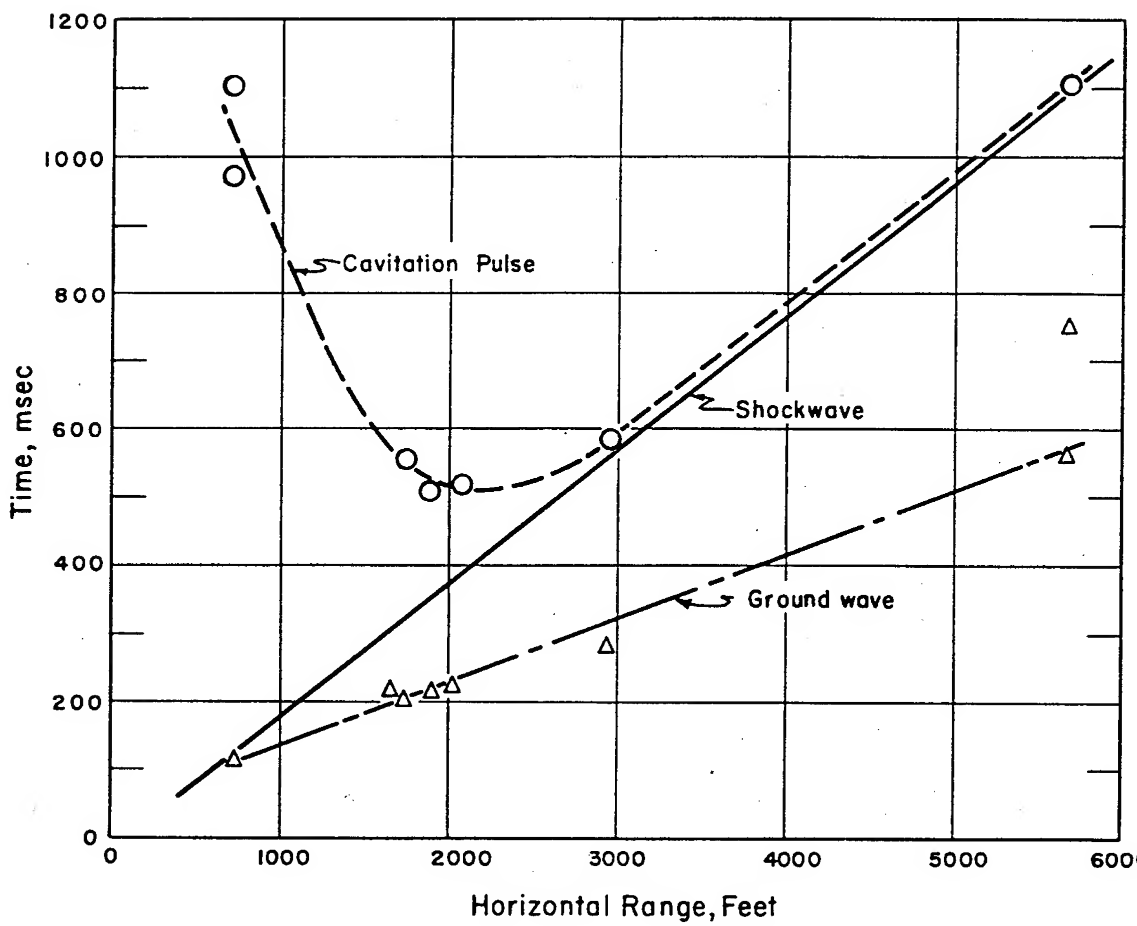

Figure 3.9 Arrival times versus horizontal distance, Shot Umbrella.

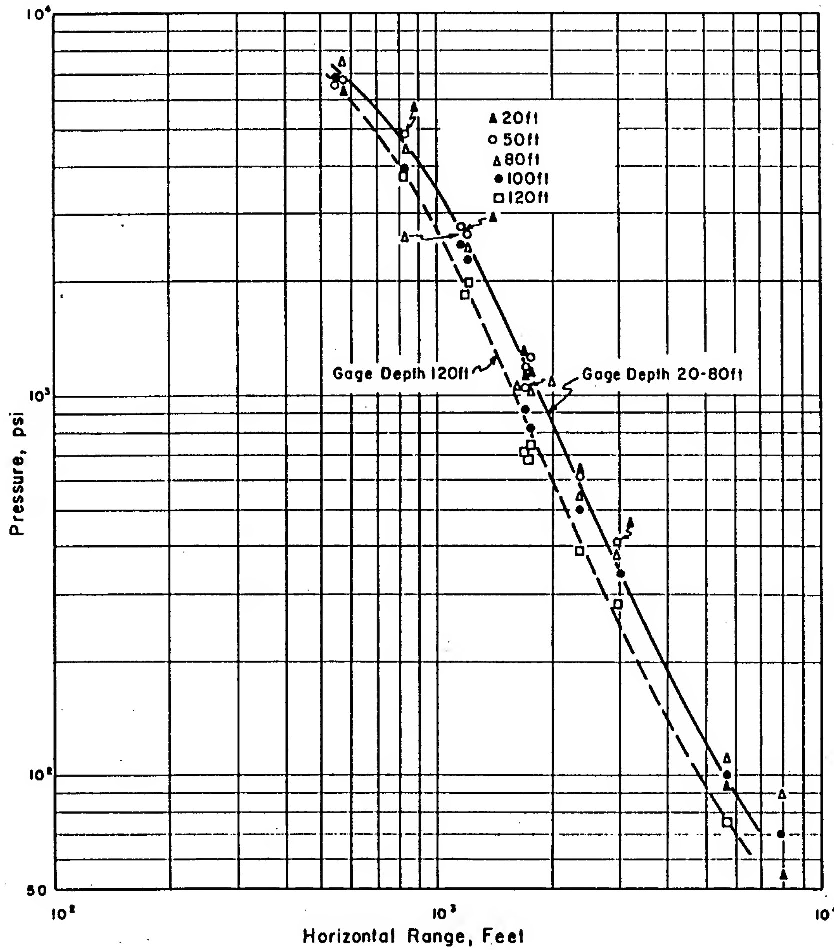

Figure 3.10 BC gage peak pressures at various depths versus distance, Shot Umbrella.

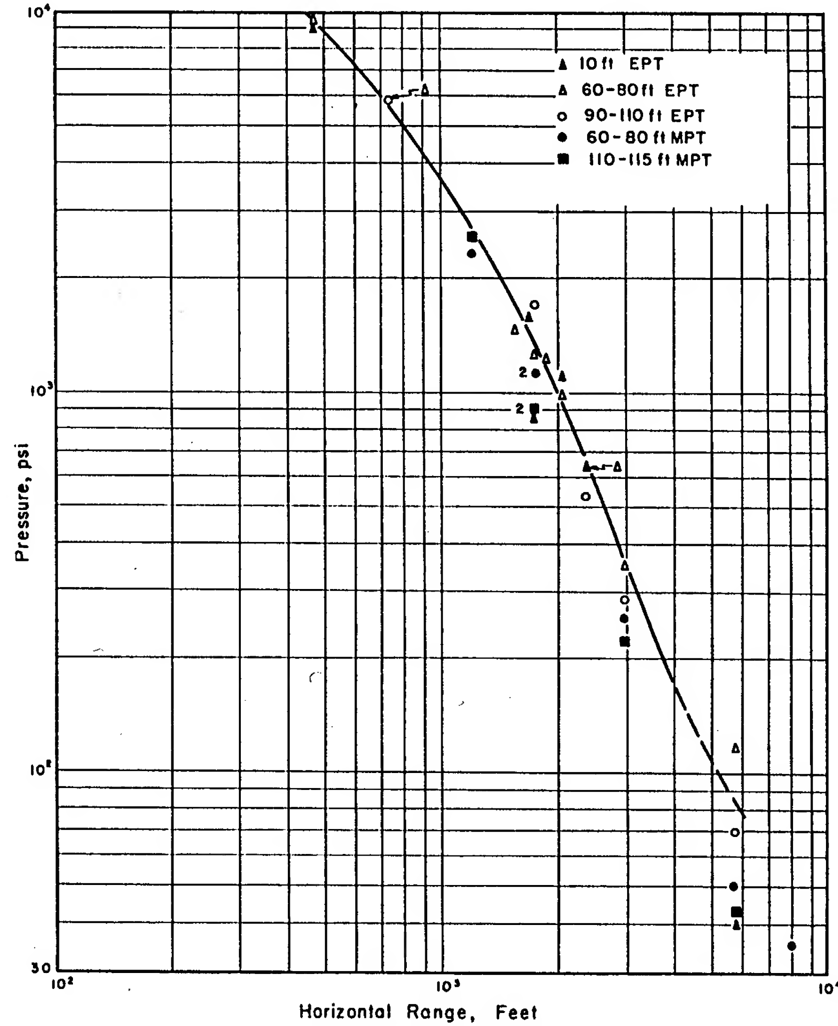

Figure 3.11 EPT and MPT gage peak pressures at various depths versus distance, Shot Umbrella.

gages were at 17 feet; one only of three showed a lower pressure than mid-depth readings. Most mpt stations showed the decrease in pressure in the bottom half of the string found on b-c and mpt results.

Figure 3.12 shows shock-wave durations as a function of distance, as measured on ept records. Duration increased regularly with depth and decreased with range.

Peak overpressures from mid-depth ept gages are compared with predictions and cube root scaled Baker b-c results in Figure 3.13. Plotted circles, values which were predicted by NOL for a 10-kt radiochemical yield under Umbrella conditions, are seen to be in excellent agreement with results.

In summary, Umbrella p-t and b-c gages from 473 to 7,900 feet from surface zero, at depths from 10 to 130 feet, recorded peak pressures ranging from 19 to 9,640 psi. Peak pressures at mid-depths were in agreement with predictions. Pressures decreased with depth in the lower half of the lagoon. A weak ground wave preceding the main pulse was observed on almost all records. Main shock durations at 70-foot depths decreased with range from about ten milliseconds at 474 feet to fractions of a millisecond beyond 5,000-foot range. Shock wave durations increased regularly with depth. A second pulse, due to cavitation, was observed at all but the 474-foot station. This pulse appeared first near 1,900-foot range and then moved toward and away from surface zero. Maximum cavitation pressure recorded was 314 psi, at 1,900-foot ranges.

<u>3.2.4 Visible Surface Phenomena.</u> Main military interest in water thrown up by an underwater burst is in the role it plays in spreading radioactive contaminants. The cauliflower cloud from a shallow burst may be the source of high energy initial gamma radiation. Clouds and base surge may transport contaminants downwind for several miles. It is important, therefore, that the source of these phenomena be understood and that reliable scaling laws be established. Most of existing theory and scaling laws for slicks, water columns, plumes, fallout, base surge, and foam rings are based on high-explosive data. The limited nuclear data which was available from Shot Baker of Operation Crossroads exhibited some pronounced differences from high-explosive results, so extrapolation of high-explosive-developed equations to the nuclear situation was uncertain. NOL accordingly undertook, with photographic support from Edgerton, Germeshausen and Grier (EG&G), to document the formation, growth, and dissipation of the visible surface phenomena of Shot Umbrella with the objective of improving existing scaling techniques. As on Shot Wahoo, visible surface phenomena were recorded by timed technical photography from four surface stations and four aircraft.

R e s u l t s. From the air, subsurface luminosity was visible within two or three milliseconds after detonation and lasted about 10 milliseconds. An expanding white circular patch with dark fringe became visible about 15 milliseconds after detonation. The white patch was the spray thrown up by the impact of the direct shock wave, and the dark fringe, or slick, was the intersection of the direct-shock wave with the air-water surface. The dark fringe was visible out to a radius of 2,200 feet. At about 0.5 second, spray, believed to have been thrown up by the cavitation pulses, began to form with a radius of approximately 1,800 feet. This annulus of spray grew inwardly and merged at 1.01 seconds with the inner, solidly white, spray area at a radius of about 1,300 feet, forming a solid white patch with a radius of approximately 1,800 feet.

Viewed from the surface, the first effect seen was the air shock wave; this was visible for 80 to 100 msec. A bell-shaped dome of spray then began to form. Three stages of development of water throwout are shown in Figure 3.14. During a few tenths of a second, the bell-shaped dome was transformed into a vertical plume formation. Driven rapidly upward by expanding steam generated by the burst, the top of the plume formation reached 3,500 feet at 5 seconds, 5,000 feet at 10 seconds, and a maximum height of 5,800 feet at 25 seconds after surface zero time.

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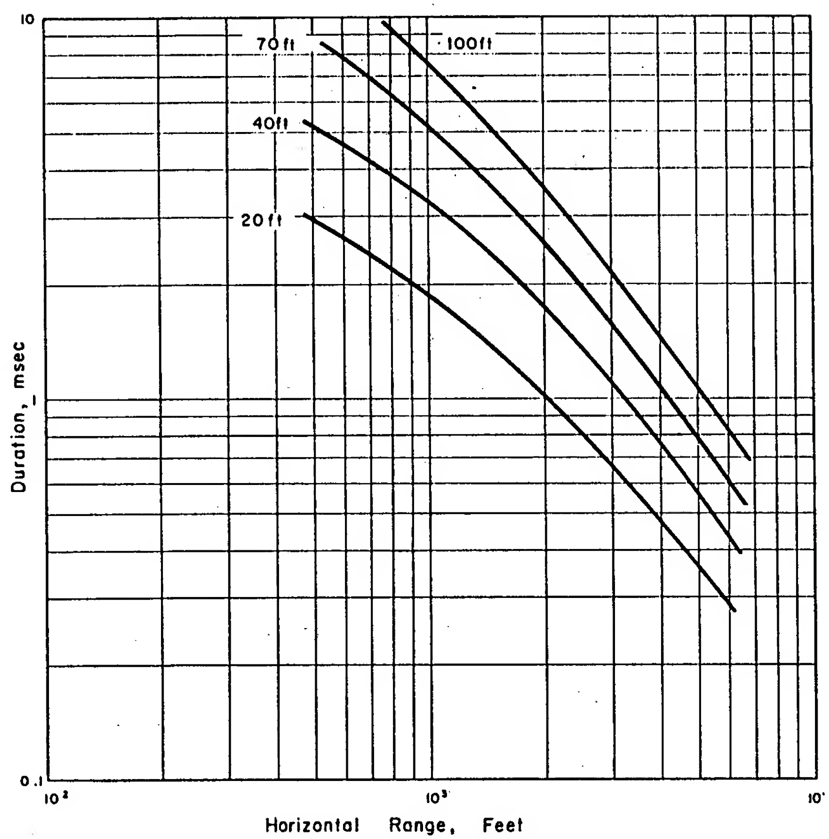

Figure 3.12 Shock-wave durations at various depths versus distance, Shot Umbrella.

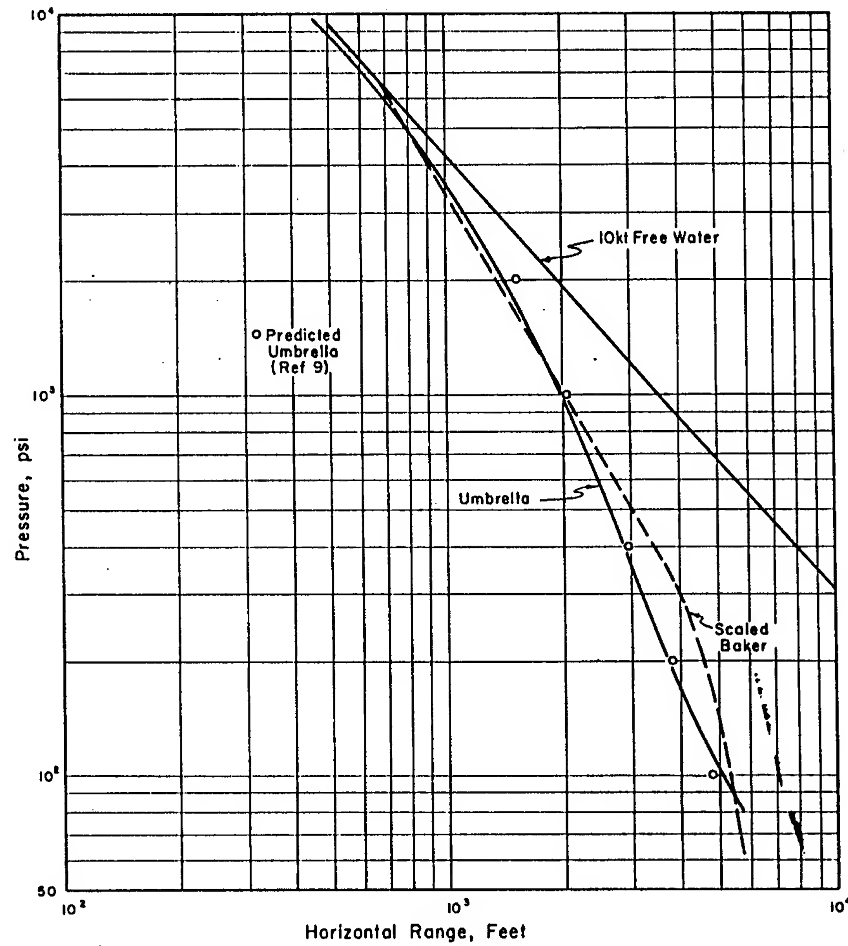

Figure 3.13 Shock-wave peak-pressure comparisons, Shot Umbrella.

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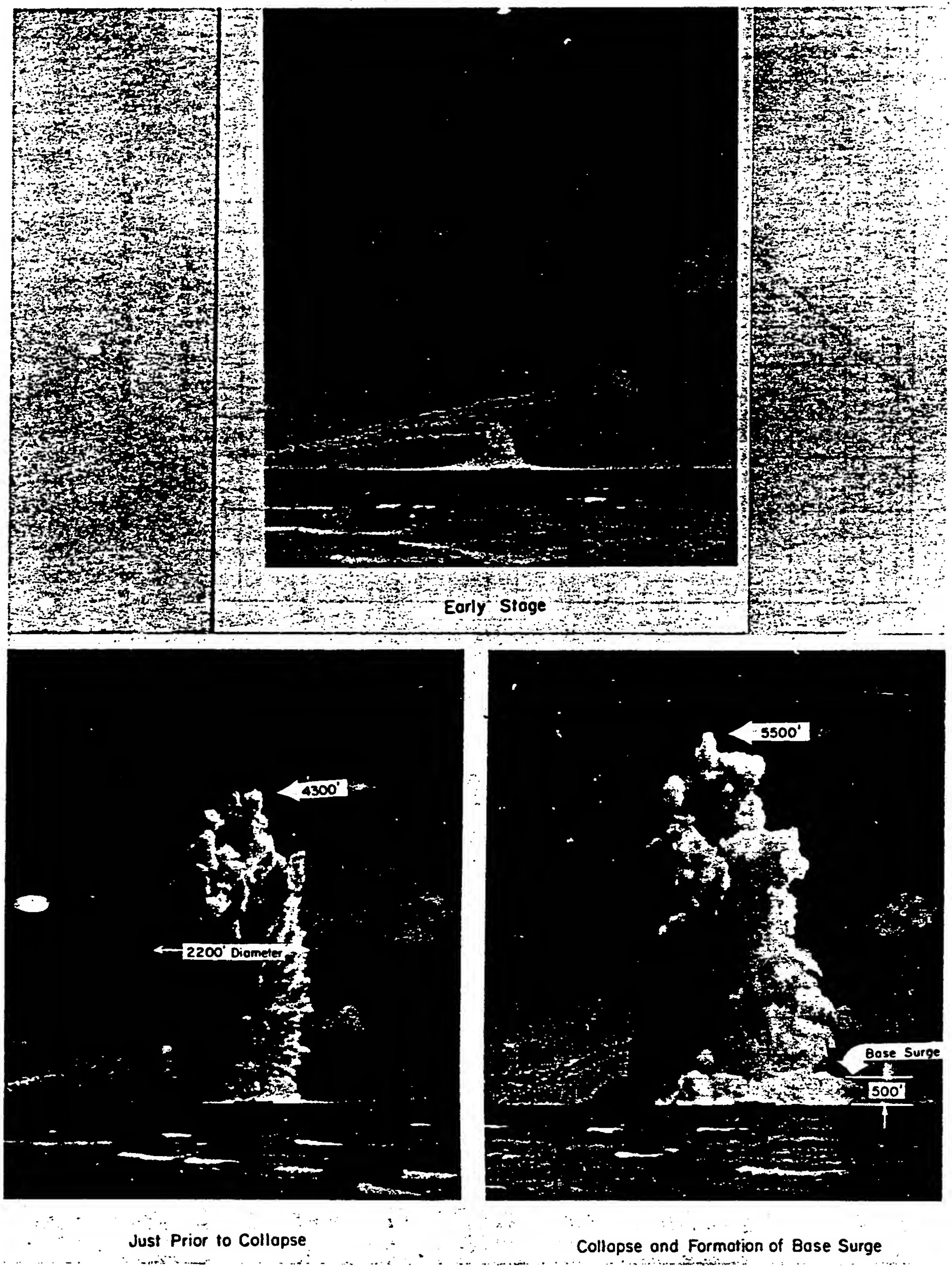

Figure 3.14 Development of throwout, Shot Umbrella.

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First indication of base surge was seen about 13 seconds after surface zero time. The surge was roughly circular in shape but not smooth in outline. By 42 seconds, it was 5,000 feet downwind and 3,400 feet upwind (Figure 3.15) and appeared as an outward moving elliptical ring. At 25 minutes, the longest available record, the surge was still visible as a well defined toroidal cloud.

In crosswind direction, base surge progressed outward at average radial velocity of 55 knots from 20 to 40 seconds, 21 knots from 40 to 120 seconds, and 9 knots from 2 to 5 minutes after surface zero time. By 7 minutes after surface zero time, the dynamic stage of base-surge expansion appeared to have ended, with a crosswind radius of some 9,700 feet having been attained. This was followed by a further, very gradual, expansion by turbulent diffusion.

The height of the surge cloud increased steadily; at 20 seconds after surface zero time, highest parts were at 500 feet, at 40 seconds at 900 feet, and at 75 seconds at 1,850 feet.

Since most of the plume formation falls back into the water rather than into a surge formation, the extent of this fallout was of interest. Visible fallout was observed to extend some 1,000 to 1,500 feet upwind and crosswind of surface zero. As the larger drops fell out, the settling cloud became more and more of a tenuous mist. Fallout mist, distinct from base surge, was visible until three minutes after surface zero time; visible fallout area extended downwind about 7,000 feet in a path some 2,000 to 3,000 feet wide.

A white circular patch of water shown at the top of Figure 3.15 became visible at surface zero as the mist cleared and base surge moved out. Patch diameter was about 5,300 feet at 2.5 minutes, 7,200 feet at 8 minutes, and 8,300 feet at 23 minutes. It was still clearly visible in the last picture taken at 25 minutes, probably because of suspension of considerable amounts of pulverized bottom material in the water.

3.2.5 Air Overpressures. Military interest in air blast from an underwater shot stemmed primarily from the potential use of aircraft for atomic attacks against submarines. Shot Baker of Operation Crossroads provided considerable overpressure data, and a few pressure-versus-time records were obtained near the level of the target-ship decks. Shot Baker data was insufficient by itself, however, to check the validity of scaling relationships developed from more numerous high-explosive test data. It was hoped that comparison of Shot Umbrella underwater and p-t data would lead to an understanding of the mechanism by which energy is transmitted across the water-air interface. This knowledge and comparison of nuclear and high-explosive data were expected to provide better predictions of air blast from nuclear shots in shallow water.

Experimental Plan. The major NOL effort to measure air blast on underwater shots was on Shot Umbrella. Ultradyne and mpt gages were mounted on vertical masts rising 15 feet or more above ship decks, or on horizontal spars extending out from ships. These near-surface gages were on the DD's 474 and 593, EC-2, buoy a[redacted]eet, and barges a[redacted]and [redacted]feet from surface zero. Mpt gages were suspended at 500 and 1,000-foot altitudes from five balloons moored on the three destroyers, and on th[redacted]an[redacted]foot barges. Thirty-two canisters containing mpt gages were deployed by rockets to altitudes up to 15,000 feet, and ground ranges to 8,000 feet. Figure 3.16 shows the two rocket-launching stations, DD-592 and Site Henry, and the photo and radar stations for determining canister positions. Finally, five rockets launched from the DD-592 provided smoke trails. High-speed photographs were taken of the shock interaction with the trails, and direction of flow behind the wave front.

Details of the mpt gage are shown in Figure 3.17. Each gage was calibrated dynamically in a shock tube. Rise times, when critically damped, were found to be 7 msec for 1-psi gages and 3 msec for 5-psi gages. Very little distortion of the applied wave form was found. Also, changes in gage orientation with respect to the shock wave produced negligible changes in readings for pressures less than 2 psi.

The overall rocket canister containing the pressure unit and other elements is shown in Fig-

[redacted]

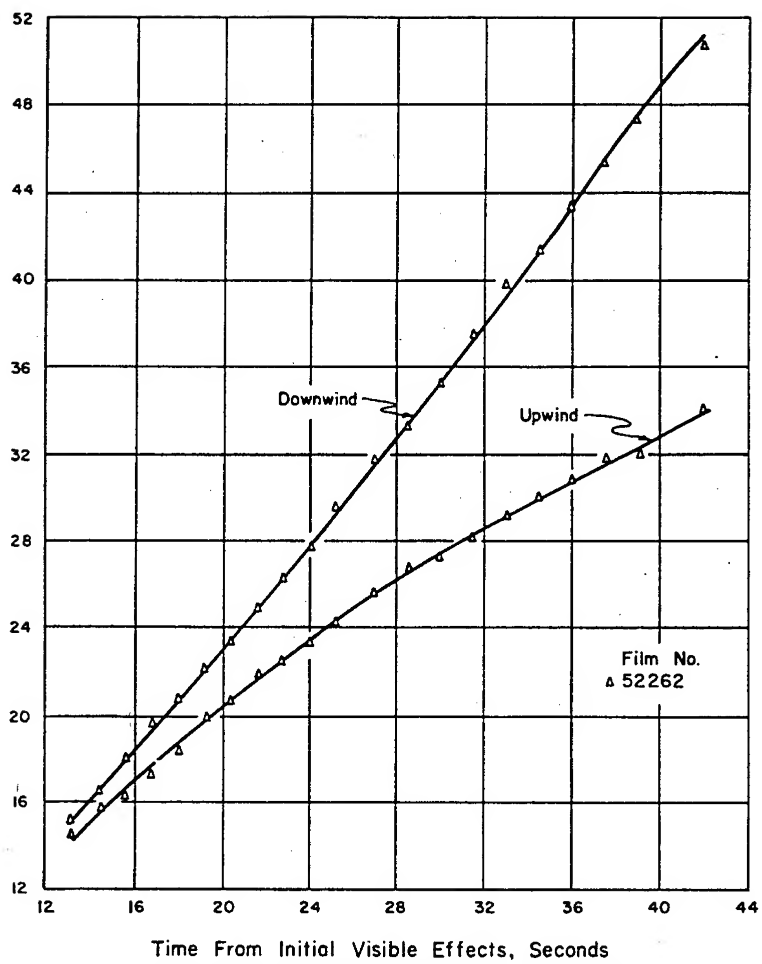

Figure 3.15 Base surge upwind and downwind extent, at early times, Shot Umbrella.

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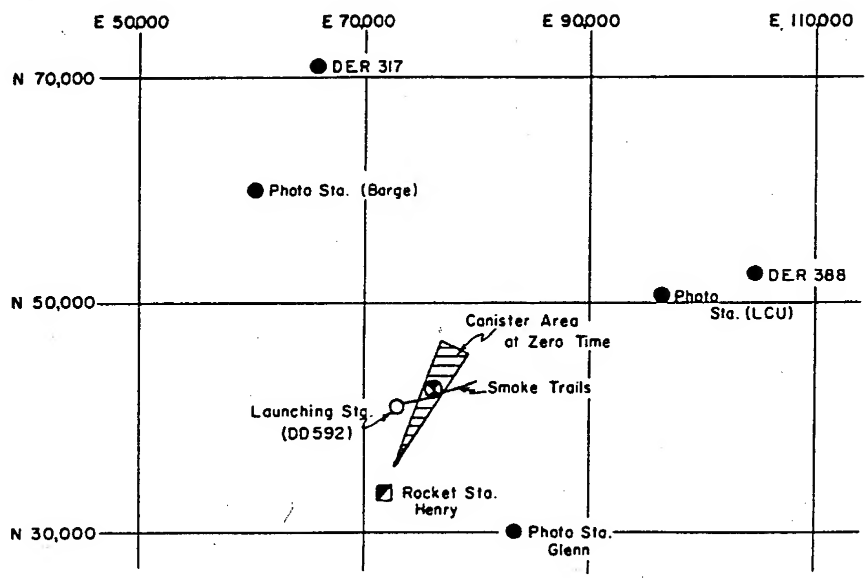

Figure 3.16 Rocket, camera, and radar ship stations.

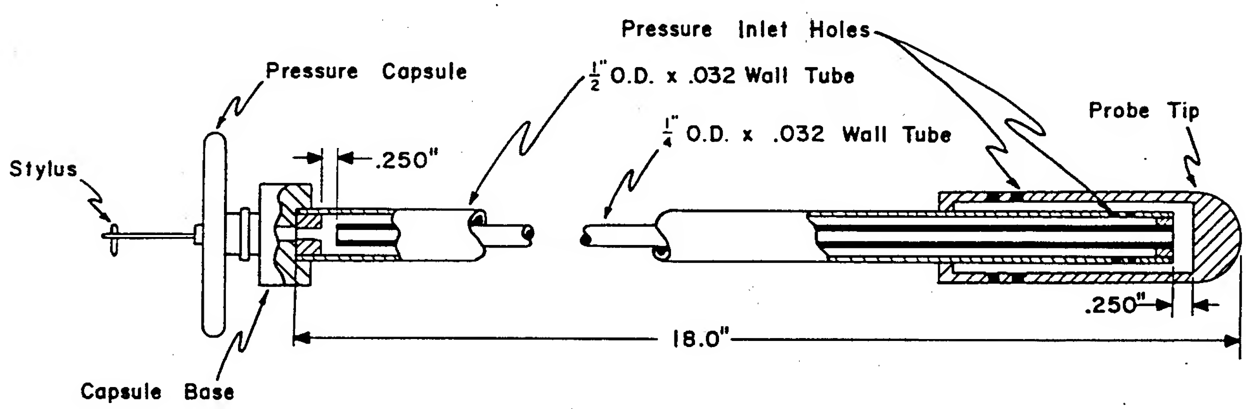

Figure 3.17 Details of pressure probe.

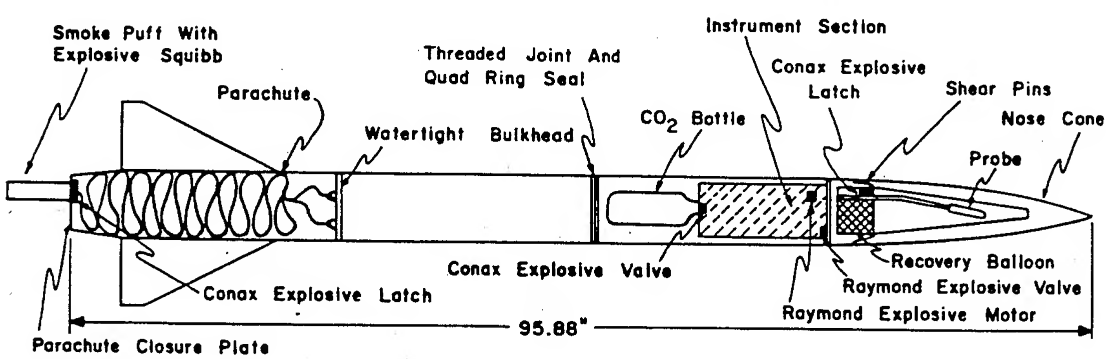

Figure 3.18 General layout of dart.

[redacted]

ure 3.18. The watertight section was to keep the canister afloat. The balloon in the forward compartment was inflated with CO_2, with the explosive valve being set off by a sea switch. The balloon was used to assist in sighting the canister during recovery operations. An antenna was attached so that it would be free of the water when the balloon was inflated. This antenna fed a UHF locator beacon of approximately sardine-can size, which was located in the instrument section.

Results. Three LCM's and one LCU equipped with a DUKW were in the impact area by H + 1 hour and recovered 20 of the 32 rockets deployed. These vessels were assisted by an L-20, equipped with radio-direction-finder (RDF) gear, and an H-21 helicopter. The majority of the units were sighted from the air and marked by smoke flares dropped from the H-21; RDF equipment was used only to recover one unit. It is believed the missing units were damaged and sank. The surface craft also recovered the balloon gages from the DD-592. Of the four other balloons, three were carried away by gusty 35-knot winds prior to shot time, and one broke away immediately after the shot.

Photographic triangulation on the test was successful, although data has not yet been reduced.

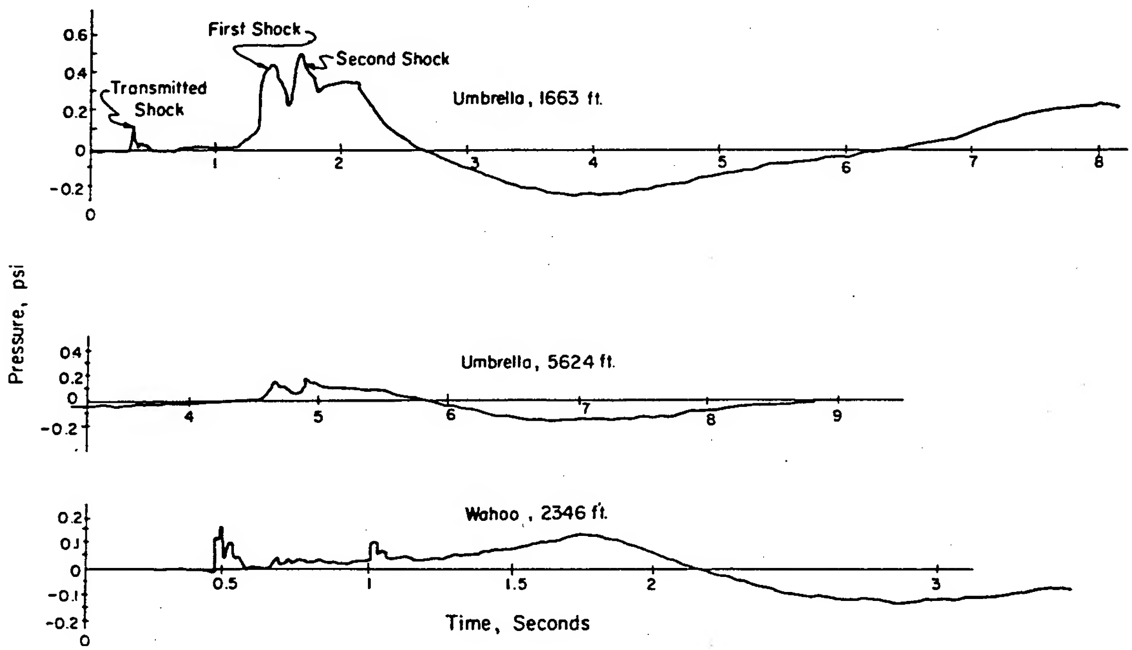

Figure 3.19 Three Ultradyne gage records.

Radarscope photography provided by two DER's failed to show parachute blips until M + 3 minutes because of cluttering by strong side-lobe echoes from other surface vessels.

Mpt records on Shot Umbrella showed only one distinct shock pulse. The typical canister record, which requires correction for fall of the canister, showed slow decay from the peak. Ultradyne records, Figure 3.19, all showed at least two pressure maxima of about the same magnitude, spaced about 230 msec apart, and a gradual descent to a negative-pressure minimum between 4 to 7 seconds after zero time.

Peak mpt overpressures shown in Figure 3.20 were almost all low compared to the high-explosive curves which were based on one-pound charges of TNT fired at scaled depths of 145 feet. High-explosive data were scaled to 10 kt by the cube-root law. Indicated gage positions shown are based on ballistic data and may be radically changed when photographic data becomes

[redacted]

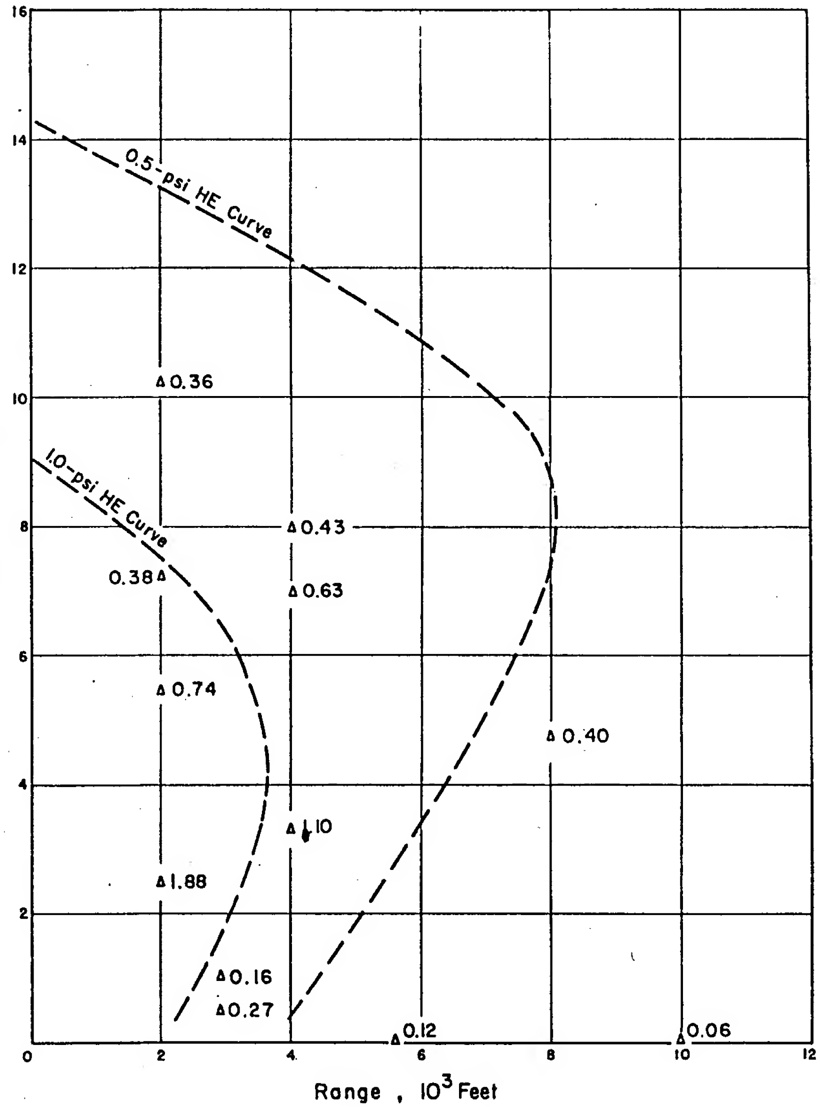

Figure 3.20 Summary of mechanical gage results, Shot Umbrella.

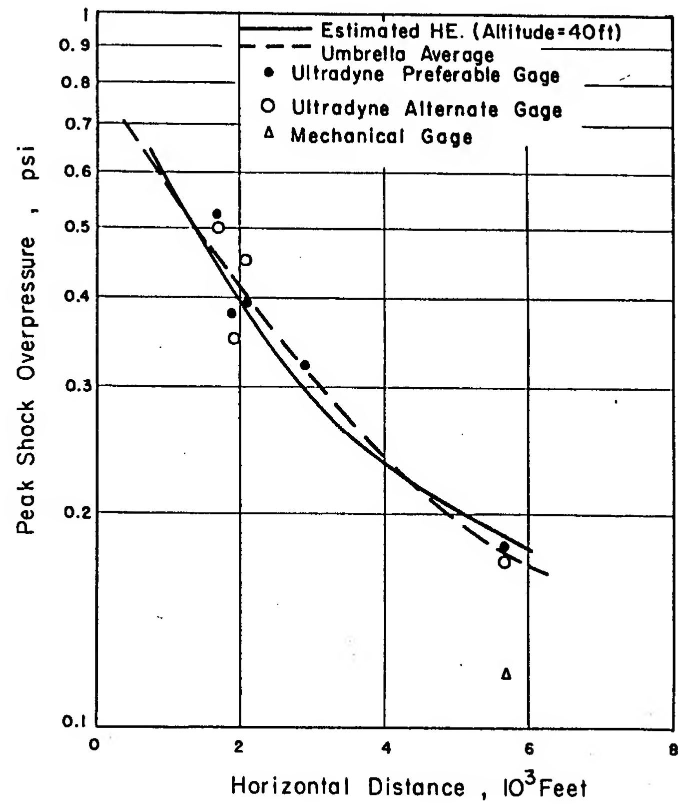

Figure 3.21 Comparison of Umbrella surface data with estimated high-explosive data (maximum pressure data).

available. In contrast, near-surface data compare favorably with predictions from high-explosive data, as seen from Figure 3.21. The predictions themselves involved extrapolations, since very low height high-explosive data were not available. Therefore, any conclusion that underwater chemical and nuclear explosions are completely equivalent in producing air-blast should be viewed with caution.

3.2.6 Water Waves. An objective on Shot Umbrella was to document water waves and inundation of nearby islands. Shot Baker of Operation Crossroads had provided the only available data from an underwater nuclear shot in shallow water. Considerable data was available from barge shots near the water surface and high-explosive shots.

Experimental Plan. Wave-measuring stations are shown in Figure 3.22. The three self-recording gages (turtles) placed on the lagoon bottom at ranges of 1,350 to 1,750 from surface zero consisted of bourdon tubes which moved a stylus over clock-driven smoked-aluminum disks. The recording unit was shock mounted within a high-pressure steel case, which was embedded in a 1,000-pound-lead fairing for locational stability. Instrumentation other than the turtles was identical to that used on Shot Wahoo and described in Section 2.2.6.

TABLE 3.3 SUMMARY OF FIRST WAVE DATA, SHOT UMBRELLA

Depth of device submergence = 150 ft. Preliminary yield = 10 kt.

$\frac{H_1}{H_2} = \left(\frac{d_2}{d_1}\right)^{1/4}$, where, d = Water depth, ft.
H = Height of first crest to following trough, ft.

Station	Range from Surface Zero	First Crest Height	First Trough Depth	First Wave Height	Depth of Water	Wave Height * Water Depth	Time of First Crest Arrival
	ft	ft	ft	ft	ft	150 ft	min:sec
163.02	[redacted]	+ 10.0	− 17.7	27.7	152	27.7	:21
163.01	[redacted]	+ 11.0	− 12.5	23.5	162.2	23.5	:27
163.03	[redacted]	+ 10.7	− 11.0	21.7	154.8	21.7	:21
160.01	[redacted]	+ 4.7	− 5.1	9.8	64.9	7.9	1:45
DD 593 †	[redacted]	+ 3.0	− 2.0	5.0	114.0	4.7	1:42
Project 6.8 No. 1	[redacted]	+ 2.3	− 3.8	6.1	140.0	15.1	1:58
Project 6.8 No. 2	[redacted]	—	—	—	145.0	—	4:51
Project 6.8 No. 3	[redacted]	+ 1.1	− 1.9	3.0	152.0	3.0	9:58
160.02	[redacted]	+ 0.59	− 1.12	1.7	44.3	1.2	12:57

* Wave heights from the various depths of measurement were adjusted to common water depth of 150 ft by Green's

† Amplitude data subject to revision upon further analysis.

Results. The three bottom turtle pressure records are shown in Figure 3.21. These and other subsurface pressure records have not been corrected for gage depth and wave period; actual wave heights at the surface may be about 25 percent higher for 150-foot-depth measurements. The initial disturbance shown in Figure 3.23 was a crest which arrived at the 1,750-foot station first, indicating considerable wave asymmetry. First crest heights at the two stations near 1,700 feet were essentially the same, as were first trough depths. In fact, there was considerable similarity between all three records.

Data on the first wave at each measurement station is tabulated in Table 3.3. A wave record from the Mk VIII wave recorder, Station 160.01, is shown in Figure 3.24. At thi[redacted]foot range, the second crest had started to gain prominence. Pitch and yaw records from the DD-593, [redacted]oot range (also shown on Figure 3.24) indicated the second crest was the highest. Inspection of other records indicates the highest wave shifted progressively to later crests with increasing distance from surface zero. At the southwest end of Site Fred, 40,450-foot range, the fifth crest was the highest.

Postshot survey of islands to the south of the shot showed that inundation was negligible and

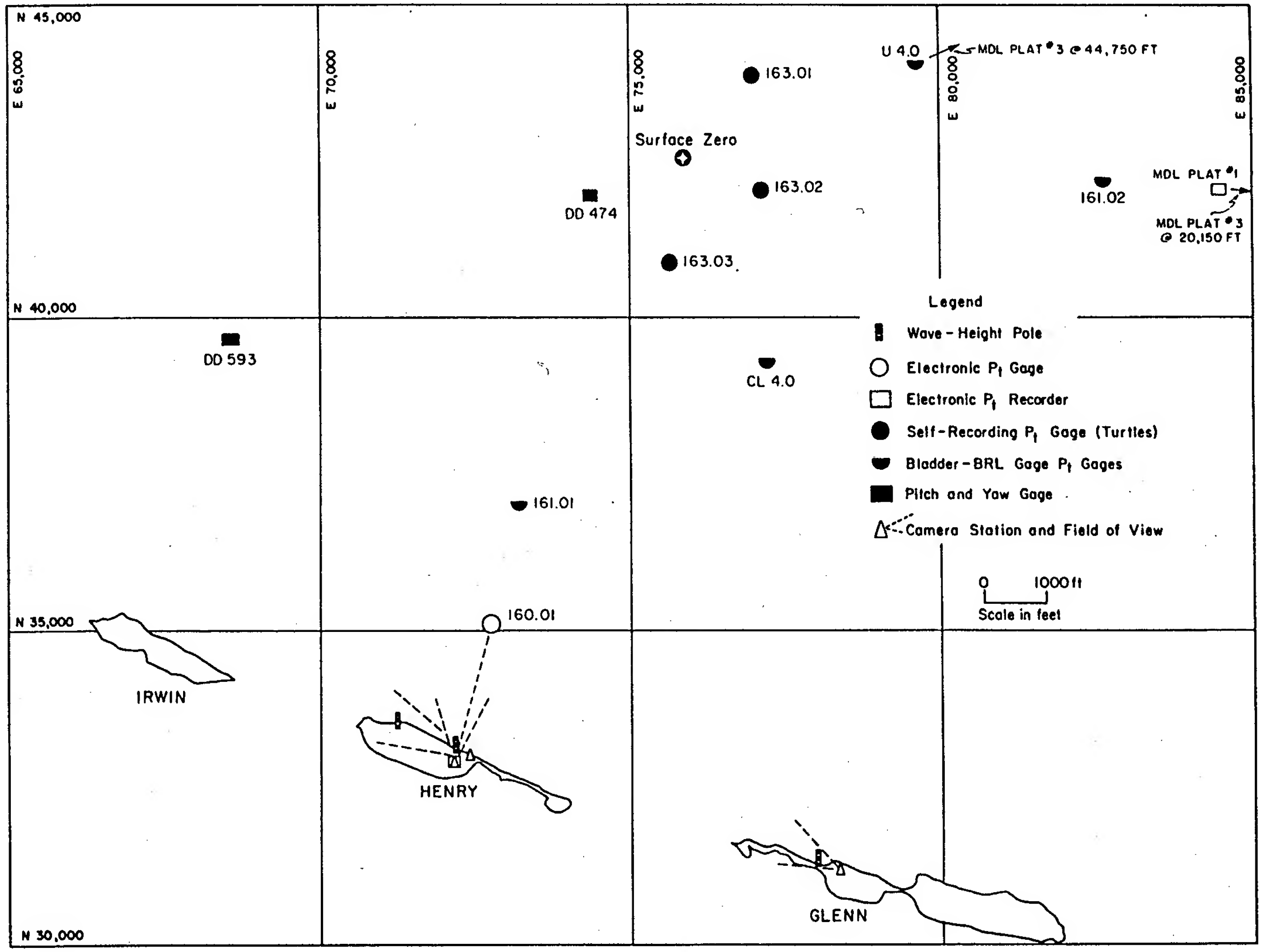

Figure 3.22 Water-wave measurement stations, Shot Umbrella.

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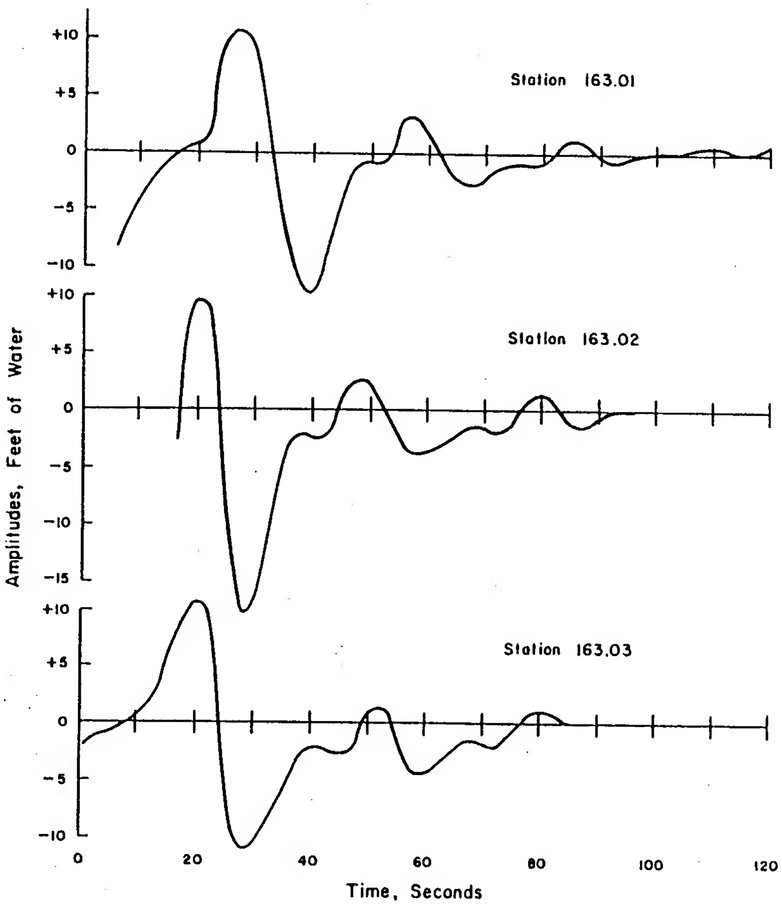


Figure 3.23 Subsurface pressure as a function of time near stations, Shot Umbrella. Surface-zero latitude, 11 deg 22 min 49.9 sec north; longitude, 162 deg 13 min 9.6 sec east. Shot time was 1115 on 9 June 1958. Station 163.01; bearing, 39 deg 26 min true; range [redacted] feet; instrument depth, 162.2 feet. Station 163.02; bearing 112 deg 50 min true; range [redacted] feet; instrument depth, 152.0 feet. Station 163.03; bearing 189 deg true; range [redacted] feet; instrument depth, 154.85 feet.

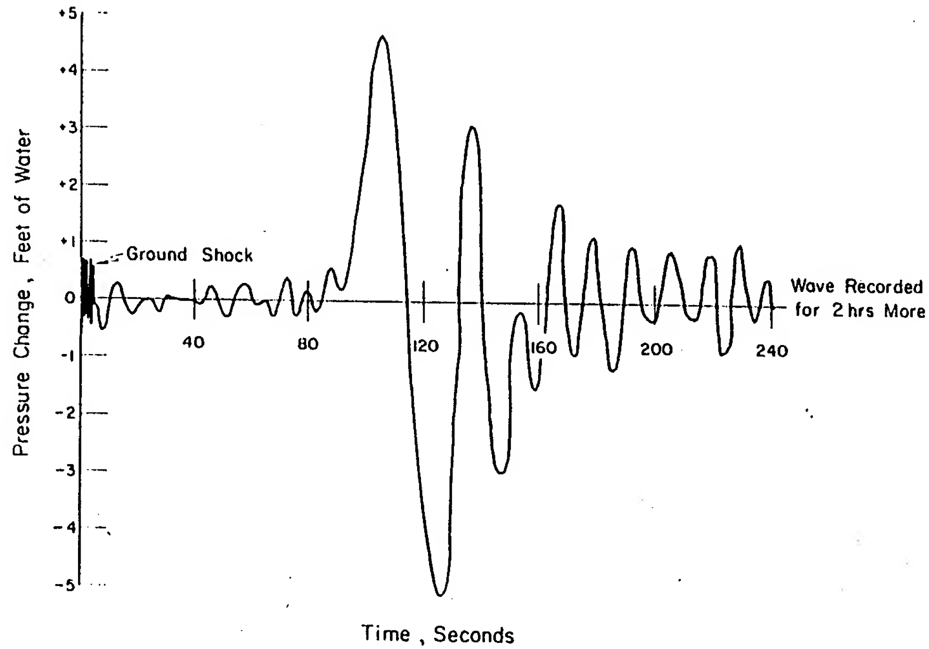


Figure 3.24 Wave record for Station 160.01, Site Henry, Shot Umbrella. Time was 1115 on 9 June 1958; range from surface zero was [redacted] feet on bearing 157 deg 38 min true; tide stage at shot time was plus 3.1 feet; depth of transducer was 64.9 feet.

[redacted]

generally less than that which occurs with high tides. It appears the shoal area adjacent to the islands effectively shielded them from inundation. Photographs indicate the waves broke between 2,000 to 3,000 feet from the Site Henry shore line. Breaking was not continuous along the advancing wave front, and it appears first breaking was initiated by coral heads in advance of the shoal area.

3.3 NUCLEAR RADIATION EFFECTS

3.3.1 General. The Nuclear Radiation and Effects Program had basically the same objectives and participation during Shot Umbrella as it had during Shot Wahoo. The general purpose of the three nuclear-radiation projects was again to document the gross-gamma-free fields about the point of burst, to measure the consequent dose rates and dosages generated on destroyer-type target ships, and to evaluate the hazard generated by the ingress of the resultant contaminant into the interior of these ships. Although certain modifications were made as the result of experience gained on Shot Wahoo, these modifications were generally minor in nature and were primarily concerned with improving instrumentation reliability and obtaining more complete instrumentation coverage of critical areas.

3.3.2 Objectives. The specific objectives of the nuclear radiation projects for Shot Umbrella were the same as those presented in Section 2.3.2 for Shot Wahoo.

Although the project objectives were identical for both shots, the results to be obtained were not expected to be the same because of the inherent differences in shot conditions. Shot Wahoo simulated a deep underwater burst on the open sea, while Shot Umbrella was to approximate a bottom burst in relatively shallow water.

3.3.3 Background. Since less than two months separated Shots Umbrella and Wahoo, the state of knowledge pertaining to underwater-shot nuclear-radiation effects was essentially the same as it had been prior to Shot Wahoo. Little data had been reduced from the first shot by the time preparations were essentially complete for Shot Umbrella. Furthermore, the differences between Shots Wahoo and Umbrella were of such a nature that the results of one would probably give no sound basis for predicting the effects of the other. Therefore, both shots were required on the basis of obtaining extensive and detailed information for operational analysis of a deep-water, open-sea-type burst and a shallow-water bottom-type burst.

Although some gamma-field data was obtained during Operation Crossroads (References 15 and 16) on a shallow lagoon shot, the available pre-Hardtack information was fragmentary and insufficient for accomplishment of a satisfactory operational analysis. Any projections of gamma-dose contours from pre-Hardtack data would have been unreliable. The specific information, therefore, required from Shot Umbrella was the documentation of: (1) the various radiation sources generated by an underwater detonation on the bottom of a lagoon, including remote, enveloping or surrounding, and shipboard sources; (2) the attenuation afforded by ship's structures and machinery; and (3) the ingress of contamination into the ship's interior and resultant radiological hazards incident thereto.

3.3.4 Experimental Method. The experimental method for Shot Umbrella was essentially the same as for Shot Wahoo, with minor modifications dictated by experience gained from Shot Wahoo. A mechanical safety was installed on each coracle to prevent accidental activation of the instruments during timing-signal dry runs. More-accurate data concerning preshot and postshot instrument positions were obtained by using radar positioning on Shot Umbrella, instead of the photomosaic mapping used on Shot Wahoo. Helicopter recovery of floating film packs was also developed and utilized, thereby greatly improving the recovery probability of those instruments.

[redacted]

Because of the relatively short duration of the gamma radiation phenomena on Wahoo compared to the recording time on the GITR's, it was decided to manually activate the shipboard GITR's upon evacuation of the ships before the shot. This provided additional reliability, in that no dependence was placed on radio-timing signals.

Documentation of the Gross Gamma Fields (Project 2.3). As in Shot Wahoo, the primary documentation of the gamma fields generated by Shot Umbrella was accomplished by the use of the GITR and high-range, high-time resolution recorders described in Section 2.3.4. These instruments were located at 26 coracle stations and on the major target ships. The use of coracles had proven highly successful on Shot Wahoo, and the number of coracles used was increased by five for Shot Umbrella in order to obtain more complete instrument coverage of critical areas. This increased coverage was permitted through use of coracles which had been retained as spares.

Twenty-one coracles were moored inside the lagoon by standard Naval techniques at depths less than 30 fathoms, while the other five coracles were deep moored outside the lagoon in a manner identical to that used for Shot Wahoo. After the last timing-signal dry run and before evacuation, all coracles were manually armed. The coracle instrumentation was activated by radio-timing signals just prior to the event.

The time-dependent measurements were again supplemented with total-dose measurements made with NBS film-pack dosimeters. The film packs were distributed throughout the target array on coracles, as floating film packs (FFP), and at various positions aboard the three target destroyers and the EC-2. The FFP's placed inside the lagoon prior to the shot were anchored in place, while those in deep water were free floating as they had been for Shot Wahoo. Self-anchoring FFP's were also air dropped into the array after the shot. To achieve a more complete recovery of the FFP's than that achieved on Shot Wahoo, helicopter recovery was utilized. This proved to be a highly successful recovery method and a high percentage of the Shot Umbrella FFP's were recovered.

Fallout samples were again taken by means of incremental collectors (IC) located on the coracles and ships.

The Shot Umbrella instrument array included 26 coracle stations, the three target destroyers and the EC-2, and approximately 70 FFP's distributed throughout the array.

Following the detonation, all instrumentation was recovered as early as radiological and operational conditions permitted. In contrast to Shot Wahoo, the FFP's for Shot Umbrella were located by radar before and after the shot, and as has previously been noted, recovery was accomplished by helicopters.

Documentation of Shipboard Radiation. The instrumentation for the measurement of shipboard gamma-radiation fields was essentially the same as for Shot Wahoo. The gamma-radiation-dose rates and doses aboard the three target destroyers were measured by GITR's and NBS film packs, respectively, at locations representing major battle stations. Unshielded detectors were again located on weather decks and in several compartments to obtain total-radiation fields at these locations. A directionally-shielded detector was located on the fantail of each destroyer to measure remote-source (transit) radiation. Another detector was suspended underwater beneath the fantail of each destroyer to measure radiation in the nearby water. Figure 3.25 presents the location of GITR detector stations aboard the destroyers.

To provide early-decay information, a fallout collector connected to a fully shielded (6-inch lead) GITR was employed. This installation was on the DD-592 only.

The GITR's were started manually at H – 3 hours. All recorders had at least a 12-hour running time, at which time they shut off automatically as their recording tape ran out. As soon after as was feasible, the record tapes and film badges were recovered and processed for data reduction.

Contamination Ingress Documentation. For the purpose of evaluating the inhala-

[redacted]

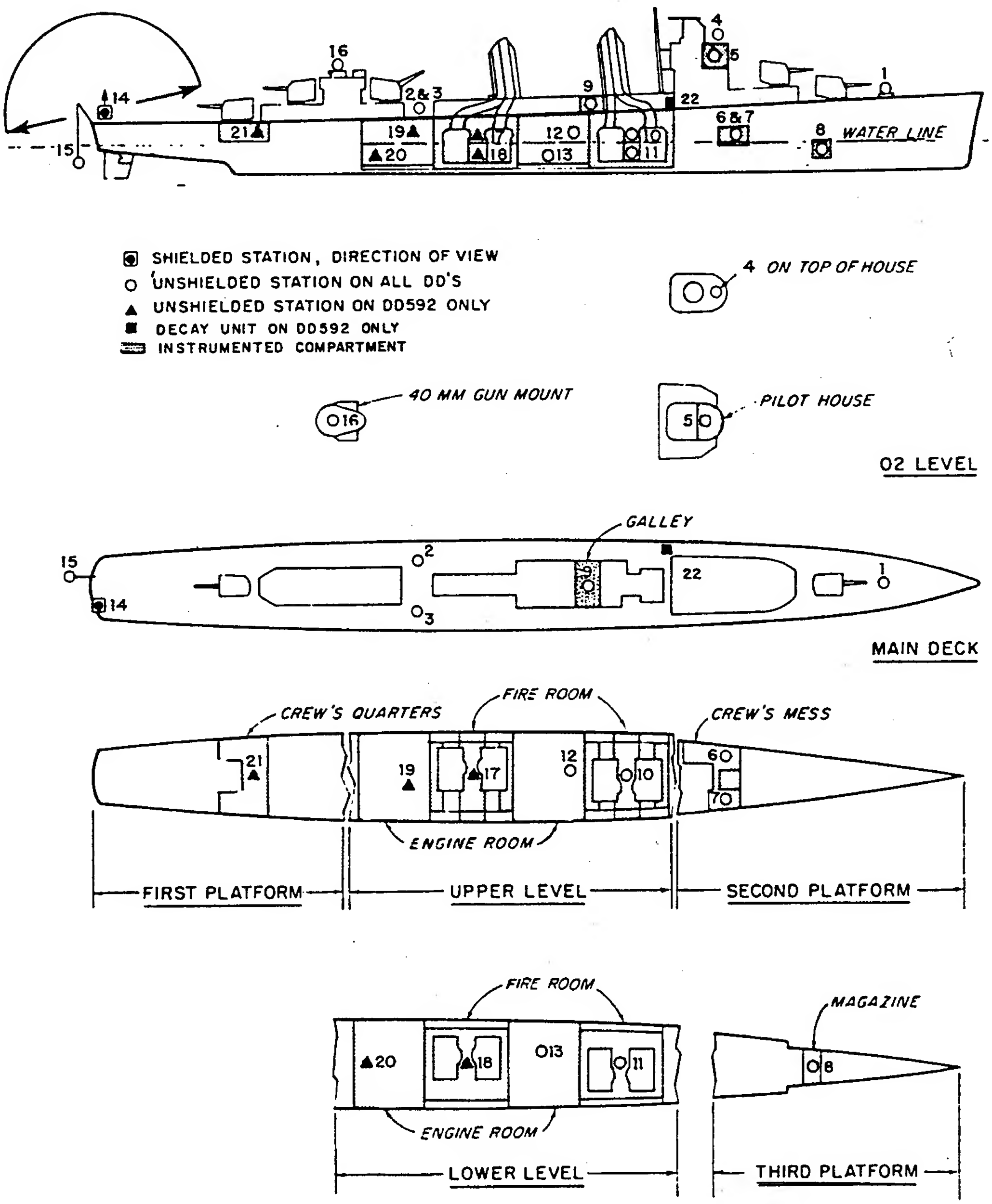


Figure 3.25 Location and designation of GITR stations on target destroyers.

[redacted]

tion and external gamma-radiation hazards from contamination ingress into a ship's interior, the DD-592 was again instrumented with GITR's, incremental air samplers, total air samplers, and surface samplers. As before, guinea pigs and mice were used for inhalation studies. Test spaces represented or simulated stations that would be manned under general quarters. The ventilation system was maintained at 20 percent of rated air flow to simulate a blowers-off condition, wherein the only air flow would be due to the movement of the ship. Full-power air flow was maintained through the unfired boiler to represent maximum operation of the boiler system. Instrument locations are shown in Figure 3.26.

The washdown system, activated before shot time, washed the entire weather surfaces of the ship, with the exception of an instrument platform above the forward gun director. This gun-director instrumentation was to provide data on the basic weatherside phenomena, while the washdown system was to minimize the effect of deposited radioactive debris on the shipboard gamma-radiation measurements.

Consistent with radiological safety, the animals and collected samples were recovered as soon after the detonation as possible. Following recovery, the animals were sacrificed on a predetermined schedule, and tissue counts made. The air and surface samples were counted as soon as they were received at the project-counting facility. GITR tapes were recovered after instrument run down.

3.3.5 Results and Discussion. After inspection of the partially reduced data, it was estimated that approximately 78 percent of the maximum possible data was recovered from the coracle and FFP array. Aboard the ships, satisfactory data was obtained on shipboard radiation and contamination ingress from all the instrumented ships.

Gamma Field Documentation. As in Shot Wahoo, no gamma radiation was observed at the time of venting of the shot bubble. A typical gamma trace is shown in Figure 3.27. Inspection of this trace revealed that, for about the first 30 seconds after detonation, no gamma radiation was observed at a station located approximately one-half mile downwind from surface zero, indicating that direct gamma radiation, either from the nuclear reaction or from shine directly from the water column or plumes, was either extremely low or completely non-existent. As on Shot Wahoo, the dose-rate peak became apparent at the time that the base surge reached a particular location, usually within a minute at stations out to one mile from surface zero. In this respect Shots Wahoo and Umbrella show marked similarity. However, it should be noted that, whereas Shot Wahoo produced many successive dose-rate peaks following the initial arrival of the base surge, Shot Umbrella produced basically one peak, after which the activity rapidly decreased, essentially to zero. For close-in stations, the Shot Umbrella dose rates appeared to be somewhat higher than the Shot Wahoo dose rates, but the total dose was somewhat lower. This is understandable because of the longer duration of the radiation phenomena for Shot Wahoo. A map of the Shot Umbrella array, showing the total dose received at various stations within one minute after detonation, is shown in Figure 3.28. The use of a one-minute dose is arbitrary in view of the continuity of the contributing event. However, at stations within a half mile, most of the total dose was received within one minute. At all points of observation, the free-field gamma activity was over about 17 minutes after zero time.

The outermost instrument location was over four miles from surface zero, and at that point the total dose received was of the order of 30 r.

Although the difference in the gamma traces of Shots Wahoo and Umbrella indicate dissimilar mechanisms of cloud formation, both shots indicated that surface winds are the primary means of transport of the radioactive cloud at distances greater than 7,000 feet. At distances less than 7,000 feet, the Shot Umbrella cloud appeared to move radially outward from surface zero at approximately 100 ft/sec, as had been observed on Shot Wahoo.

Incremental Sampling of Deposited Debris. The collection of samples of ra-

[redacted]

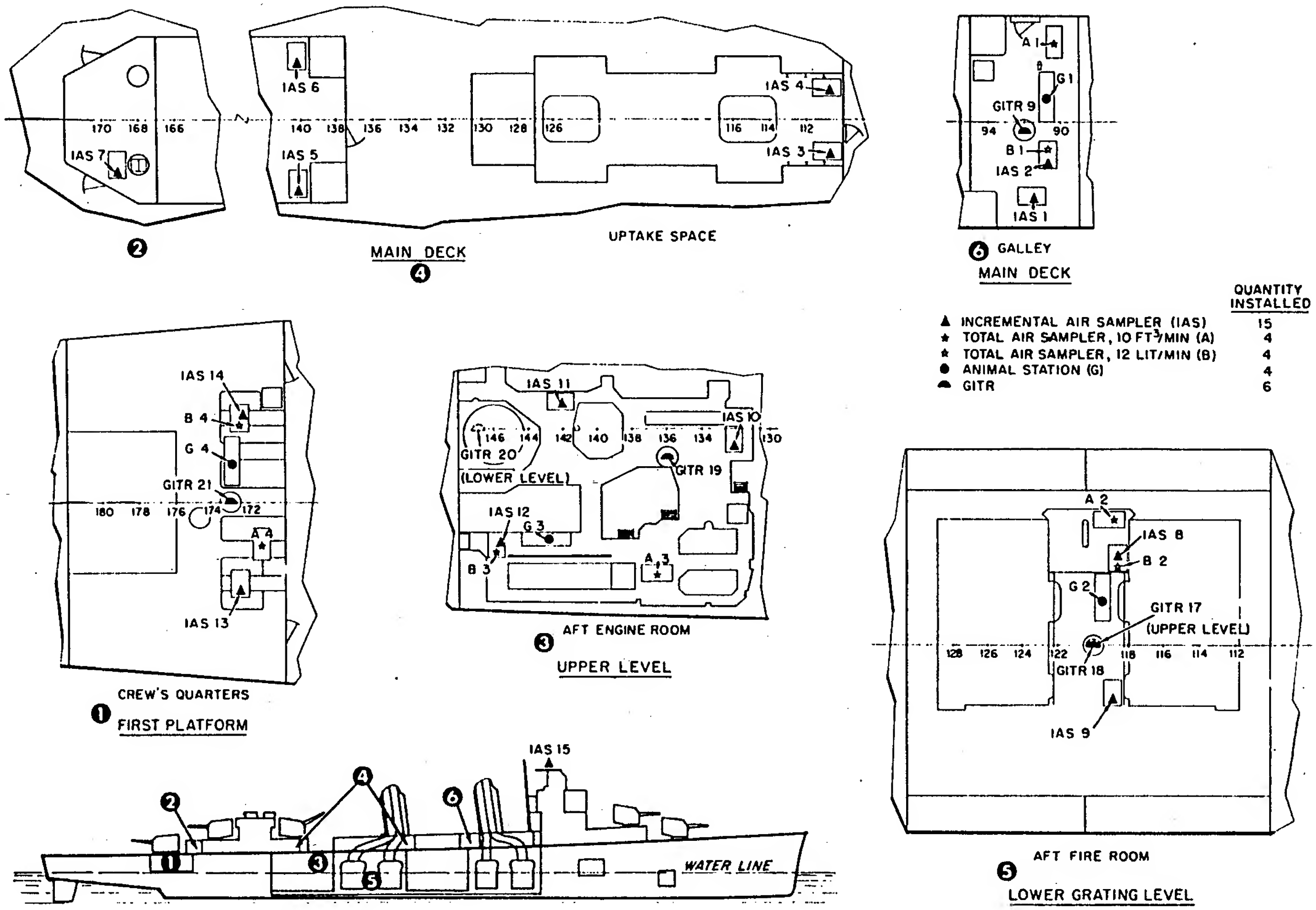


Figure 3.26 Instrument locations on DD-592.

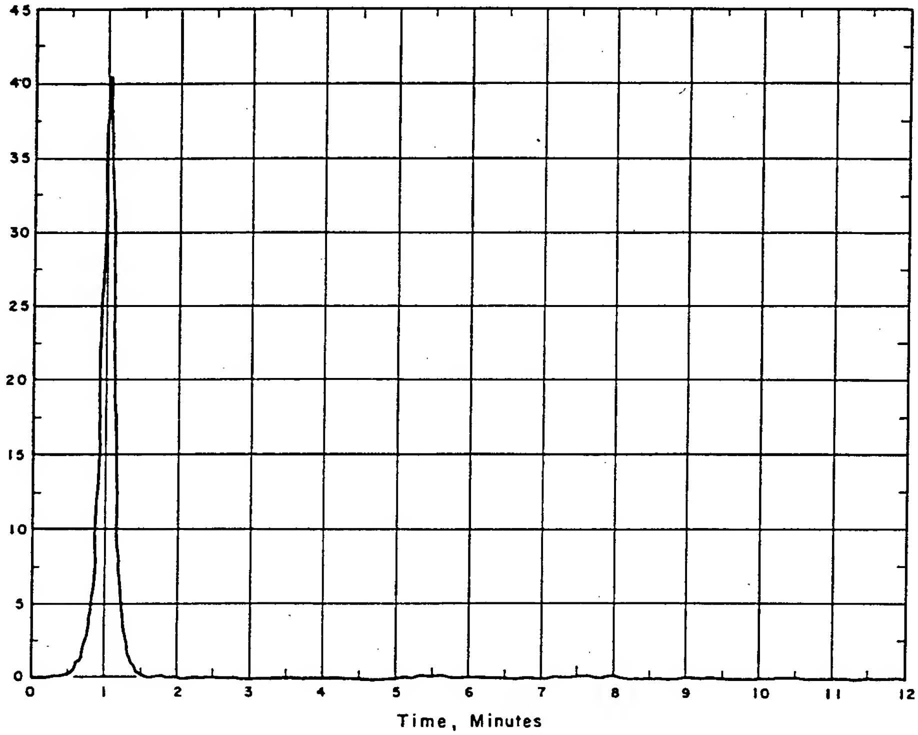


Figure 3.27 Dose rate versus time for std-GITR. Coracle at D 4.5 (247.9 deg T, 4,770 feet) Tape 450. Cumulative dose from GITR trace: 1 min 67.2 r; 3 min 123 r; 5 min 123 r; 8 min 127 r; 12.5 min 127 r; 25 min 128 r. Film pack dose: tripod 85 r, float 145 r, Shot Umbrella. Note: this coracle capsized.

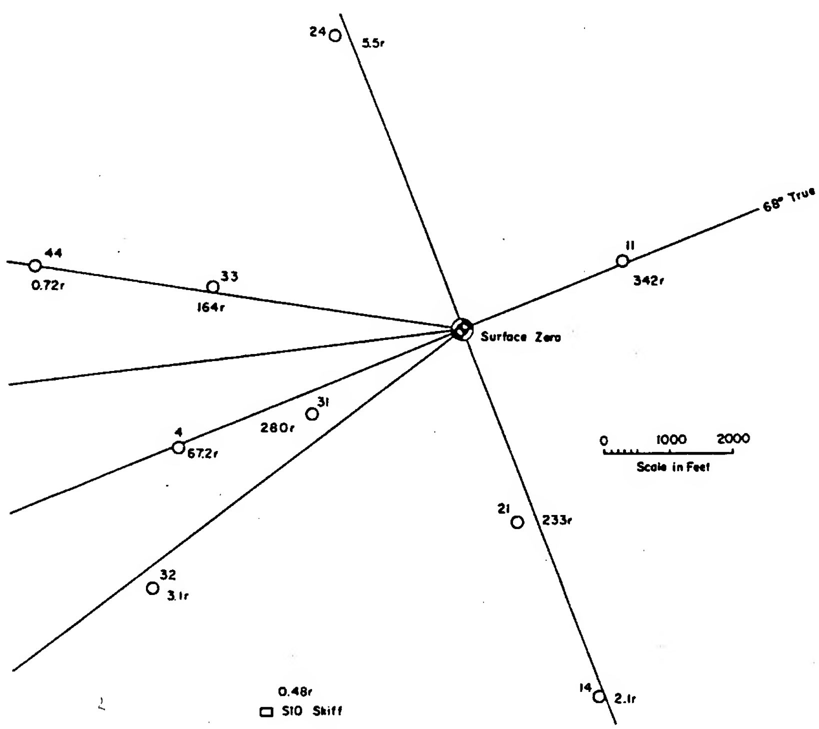


Figure 3.28 Map of Umbrella array showing doses received at coracle (and SIO skiff) stations within one minute after shot time.

[redacted]

dioactive debris deposited on coracle and ship surfaces was repeated on Shot Umbrella. As before, the collected samples were to have been used to correct the GITR readings if the dose-rate contribution to the measured total-dose rate was found to be significant. The deposited debris-dose rate proved to be negligible, and the collected samples were used to study the deposit of activity throughout the array and to obtain decay data. As on Shot Wahoo, the period of deposition was found to be short in the upwind and crosswind directions. Unlike Shot Wahoo, however, a single peak in deposition rate was found at practically all stations, and no deposition period exceeded 7 minutes.

Shipboard Gamma-Radiation Fields. Gamma traces recorded on the weather decks of the target ships again compared favorably with those dose-rate traces obtained on nearby coracles. A significant rise in gamma activity occurred from 30 seconds to one minute after zero time, again indicating the arrival of the highly radioactive base surge.

The salient feature of the total dose curves (Figure 3.29) shows the rapid acculuation of essentially the complete dose. For example, it is observed that the total dose of over 700 r was accumulated on the weather deck of DD-474 within one minute after detonation. This ship was located about [redacted] feet from surface zero. Comparison of Shot Wahoo (Figure 2.35) presented in Section 2.3.5 with the previously mentioned Figure 3.29 shows a faster build-up but smaller accumulation of dose on DD-593 after Shot Umbrella. The DD-593 was located [redacted] feet downwind from surface zero on Shot Wahoo and [redacted] feet downwind from surface zero on Shot Umbrella.

The shipboard washdown systems were operating throughout the time of passage of the airborne debris, thus greatly reducing the probability of the instruments' being affected significantly by deposited contamination.

The influence of the superstructure on external radiation fields is demonstrated by comparison of the total dose measured and estimated solid angle of cloud subtended at film pack locations as shown in Figure 3.30. It can be seen that the superstructure definitely modifies the free-field doses and dose rates at different locations on the weather deck. As indicated by this comparison, the modification appears to be dependent on the cloud solid angle seen at each position.

Below decks, the gamma radiation was attenuated to varying degrees, depending on the specific location. In all cases, locations anywhere except on the main deck afforded some degree of protection from radiation, while the best protection was offered at locations below the waterline. Table 3.4 shows the doses received at film-badge locations on each ship for Shot Umbrella. The Shot Wahoo doses are also presented for comparison purposes. It is obvious from inspection of this table that the doses received from Shot Umbrella were much less than those for Shot Wahoo, and in each case the corresponding ship was closer to surface zero in Shot Umbrella than it was in Shot Wahoo. Approximate exposure distances are given below:

Target Ship	Shot Wahoo	Shot Umbrella
	feet	feet
DD-474	[redacted]	[redacted]
DD-592		
DD-593		

For comparison, it might be noted that the DD-474 on Shot Wahoo was approximately the same distance from surface zero as was DD-592 on Shot Umbrella. In contrast to Shot Wahoo, where the main-deck dose of the DD-474 at a distance of [redacted] feet was 1,000 r, the main-deck dose on the DD-592 located at [redacted] feet for Shot Umbrella was only 430 r.

It can also be observed from Table 3.4 that the main-deck dose on the DD-474 at less than one

[redacted]

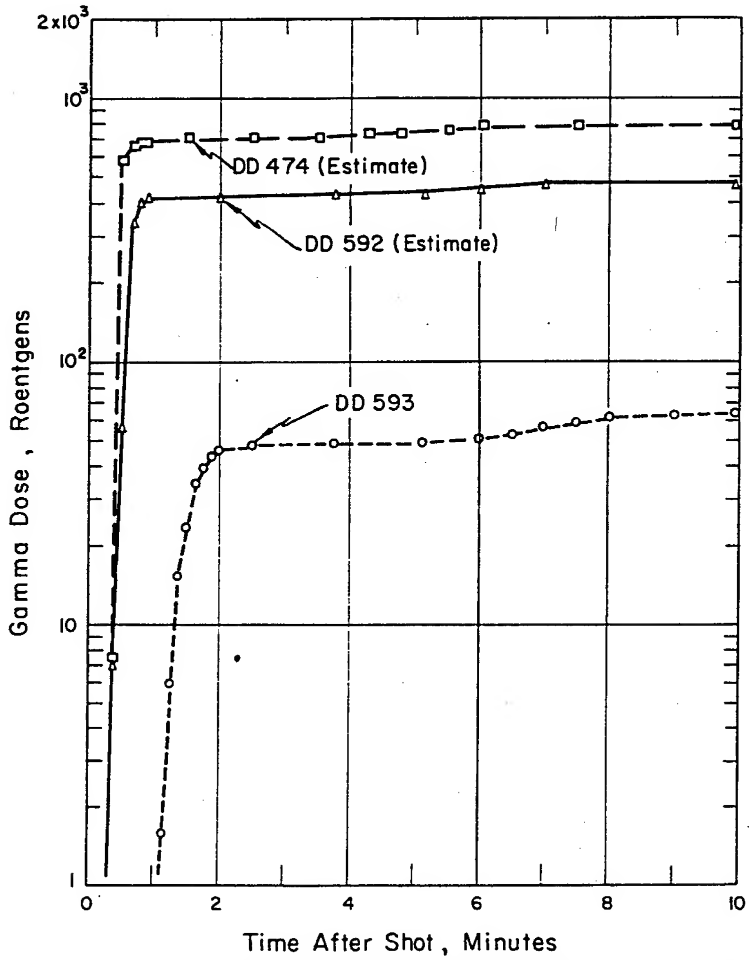


Figure.3.29 Total gamma doses on decks of target destroyers after Shot Umbrella. These values also represent estimates of transit doses.

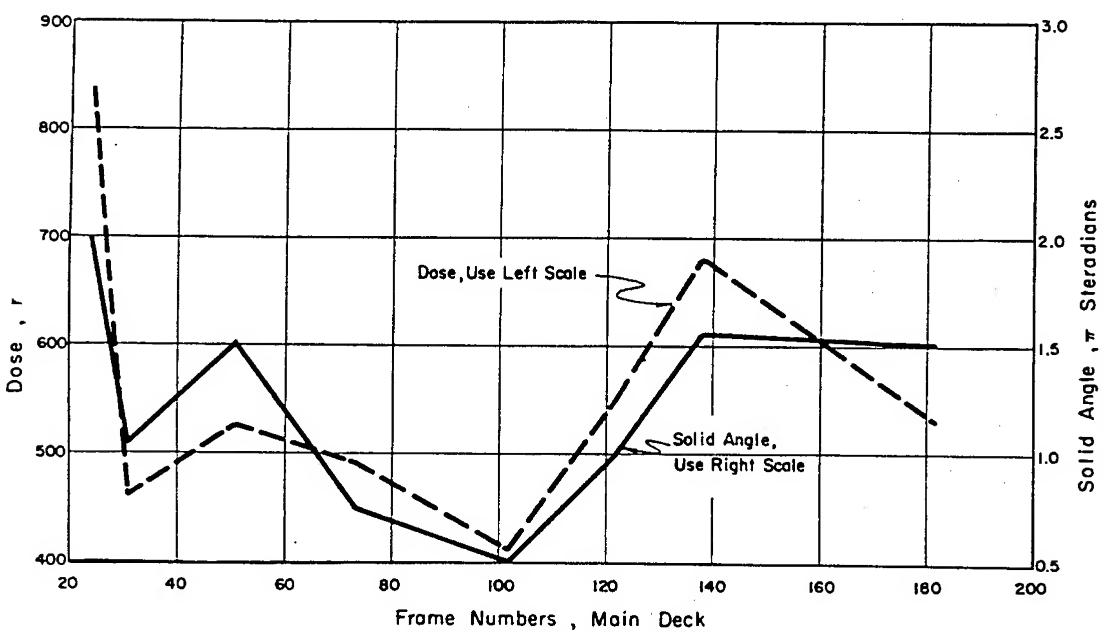


Figure 3.30 Plots of film pack dose and estimated solid angle of radioactive cloud subtended at film packs at various locations on main deck of DD-474, Shot Umbrella.

[redacted]

half mile for Shot Umbrella was comparable to that measured on the DD-593 located at a distance of approximately one and one half miles for Shot Wahoo.

Shipboard Transit and Contaminated Water Radiation Fields. By comparing Figures 3.31 and 3.32, it is seen that the transit-radiation source is the only significant radiation source. Total gamma-dose rates (Figure 3.31), including those from transit sources and

TABLE 3.4 AVERAGE 24–HOUR GAMMA DOSES ABOARD TARGET SHIPS BASED UPON FILM–BADGE DATA

Compartment or Area	Shot Wahoo			Shot Umbrella		
	DD-474	DD-592	DD-593	DD-474	DD-592	DD-593
	r	r	r	r	r	r
Above Waterline, 33 ft						
Bridge Complex	610	420	180	310	220	28
Above Waterline, 11 to 16 ft						
Forward Quarters	650	420	160	300	190	26
Radio Central	580	400	150	230	180	23
Galley	730	460	200	300	270	35
Main Deck	1,000	630	340	360	430	57
Crew's Washroom	730	500	170	260	290	31
Above Waterline, 2 to 4 ft						
Crew's Mess	400	210	72	160	87	13
Forward Fire Room	290	170	67	140	90	14
Forward Engine Room	230	110	45	89	100	12
Aft Fire Room	—	180	—	—	96	—
Aft Engine Room	—	170	—	—	110	—
Aft Quarters	590	370	140	220	210	28
Steering Gear Room	490	300	98	180	210	23
Below Waterline, 3 to 6 ft						
Magazine	310	210	65	160	81	12
Forward Fire Room	110	37	19	41	19	2.6
Forward Engine Room	76	29	10	17	12	1.9
Aft Fire Room	—	54	—	—	22	—
Aft Engine Room	—	66	—	—	39	—

deposit sources, are hardly distinguishable from dose rates due to transit sources alone (Figure 3.32). The curves could virtually be superimposed on one another within the limits of accuracy of the as yet incomplete data.

Because the ships' washdown systems were operating, it could be surmised that the washdown systems were highly effective in removing deposit sources from the ship before they could contribute significantly to the total gamma dose. However, film-pack dose data from stations above the washdown area show approximately the same results as those in the washdown area, thereby indicating that a high percentage of the total dose was due to remote-source radiation.

Attempts to measure radiation in adjacent water met with little success. Underwater detectors were submerged off the fantail of each target destroyer at the time of evacuation. The instruments on DD-474 and DD-592, however, were damaged by shock before any data was recorded. Therefore, data was obtained from DD-593 only. Figure 3.33 presents the results, which may be slightly overestimated because of arbitrary corrections made for shielding and geometry.

[redacted]

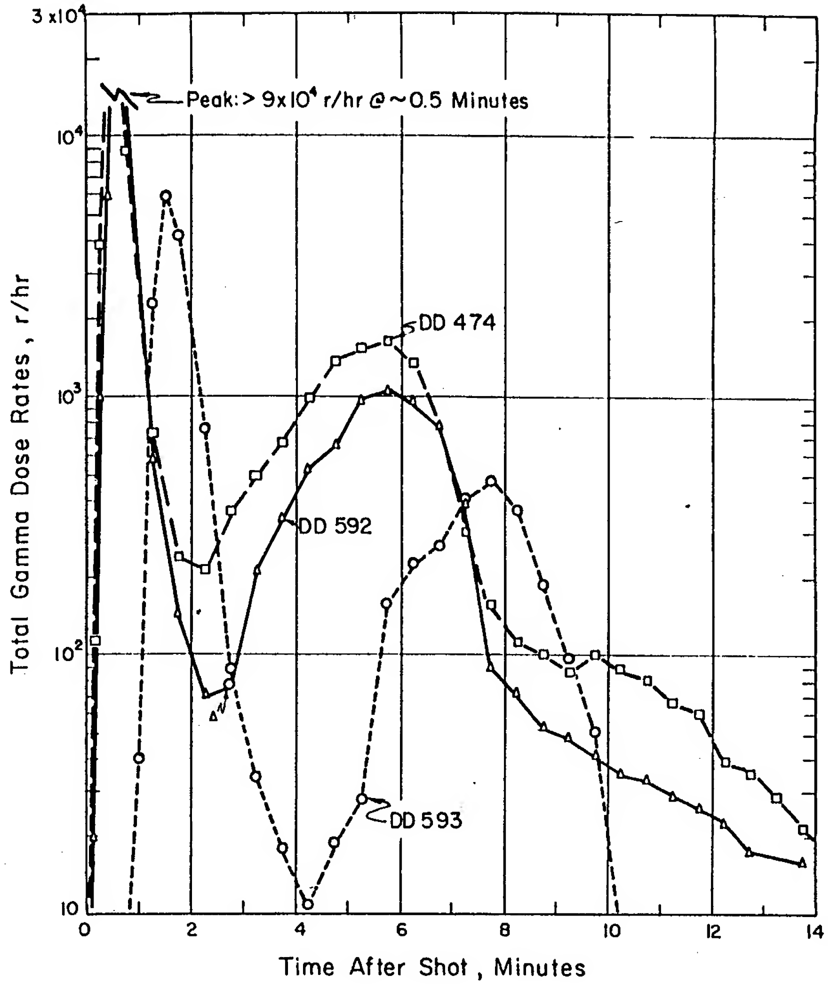


Figure 3.31 Total gamma dose rates on decks of target destroyers after Shot Umbrella. Averaged data from GITR stations 1, 2, 3, and 4 which include effects from both transit and deposit radiation sources.

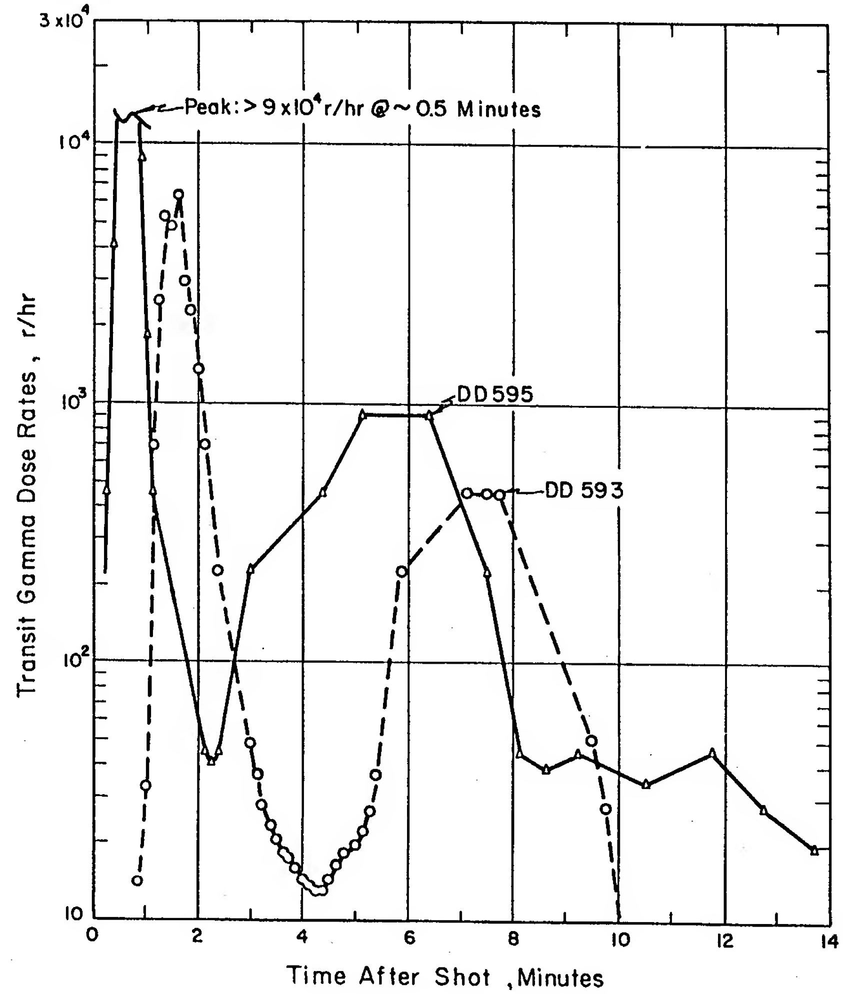


Figure 3.32 Transit gamma dose rates on decks of DD-592 and DD-593 after Shot Umbrella. Transit dose rates result only from radiation sources remote from the ships.

[redacted]

The first two series of peaks are probably due to fallout, while the peaks after six hours are likely caused by the contaminated water drifting past the ship. The low dose rates measured appear to be of little significance.

Shipboard Fallout Gamma Decay. Figure 3.34 shows the curve for gamma-ionization decay of a debris sample collected in a six-inch-thick lead cave on DD-592 after Shot Umbrella. It is seen that a smooth plot was obtained when deck-dose rates were subtracted from the fallout-dose rates. Later times than those shown in the figure yielded the following results: from 8 to 11.5 hours after shot time the slope of the decay curve was −0.61, and from 23.2 to 34.8 hours the slope of the decay curve was −1.46.

Inhalation Hazards Due to Ingress of Contaminants. For Shot Umbrella, contamination hazards were again studied aboard DD-592, which was located 3,000 feet from

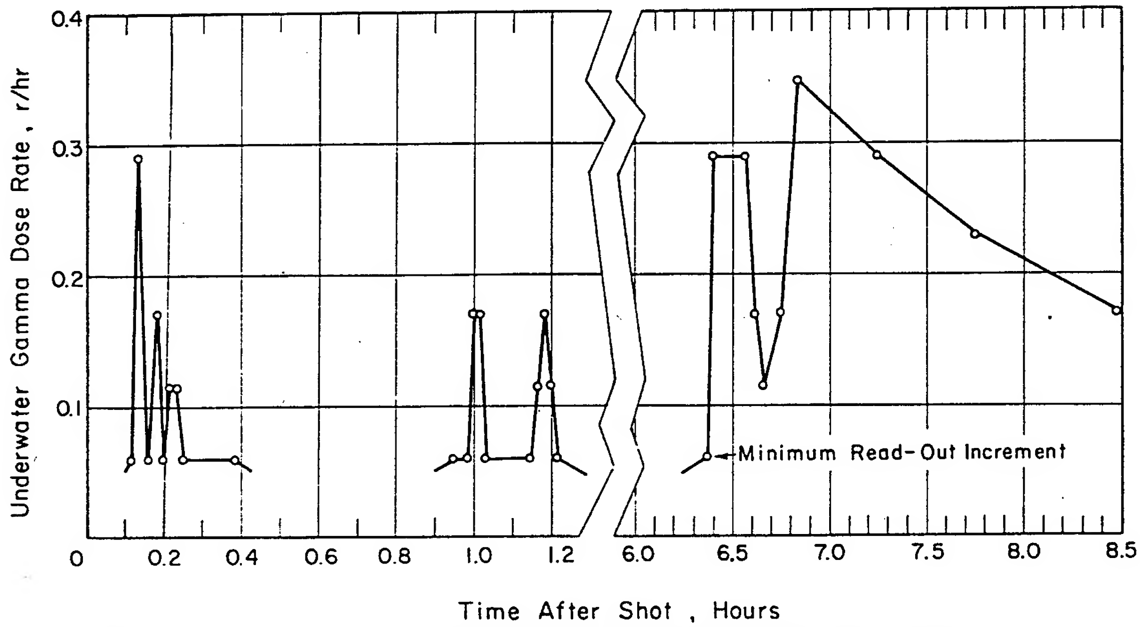


Figure 3.33 Gamma dose rates in water below DD-593 after Shot Umbrella. Detector was submerged 15 feet below water surface.

surface zero. Mice and guinea pigs were exposed at various locations aboard the ship and subsequently sacrificed on a predetermined schedule.

At unprotected weatherside locations, zero to 50 hour internal doses received by the mice were about six rads, as compared to about one rad sustained internally by the guinea pigs. All zero to 50 hour internal doses sustained at interior locations were 0.9 rad or less.

It is interesting to note that the internal doses received from Shot Umbrella were much less than those received from Shot Wahoo, even though the target ship was located closer to surface zero for this event. It may have been that the ventilation system, which operated at 20 percent of rated air flow for Shot Umbrella, scavenged the compartments of some of the contaminated air after passage of the base surge. All Shot Umbrella doses were lower than those sustained during Shot Wahoo, including those internal doses received at unprotected weatherside locations.

External Gamma Radiation Due to Ingress of Contaminants. External radiation due to ingress of contaminants was estimated from the sum of the radiation from airborne activity and the radiation from deposited activity within various compartments aboard the DD-592. At ten minutes after zero time, the following dose rates were recorded: galley, 17 r/hr; aft fireroom, 6.2 r/hr; aft engine room, 12 r/hr; aft crew's quarters, 24 r/hr. At H+2

[redacted]

hours, the dose rates had decayed to 0.8 r/hr, 0.12 r/hr, 0.03 r/hr, and 0.04 r/hr in the respective compartments. By comparing these dose rates with the total dose rates discussed in Section 3.3.5, it is readily seen that contamination ingress does not contribute significantly to the total external gamma-dose rates as recorded in the same compartments.

Particle Size Distribution of Contaminants. While the incremental air sampler did not function to yield time-dependent particle-size information, the percentage of contam-

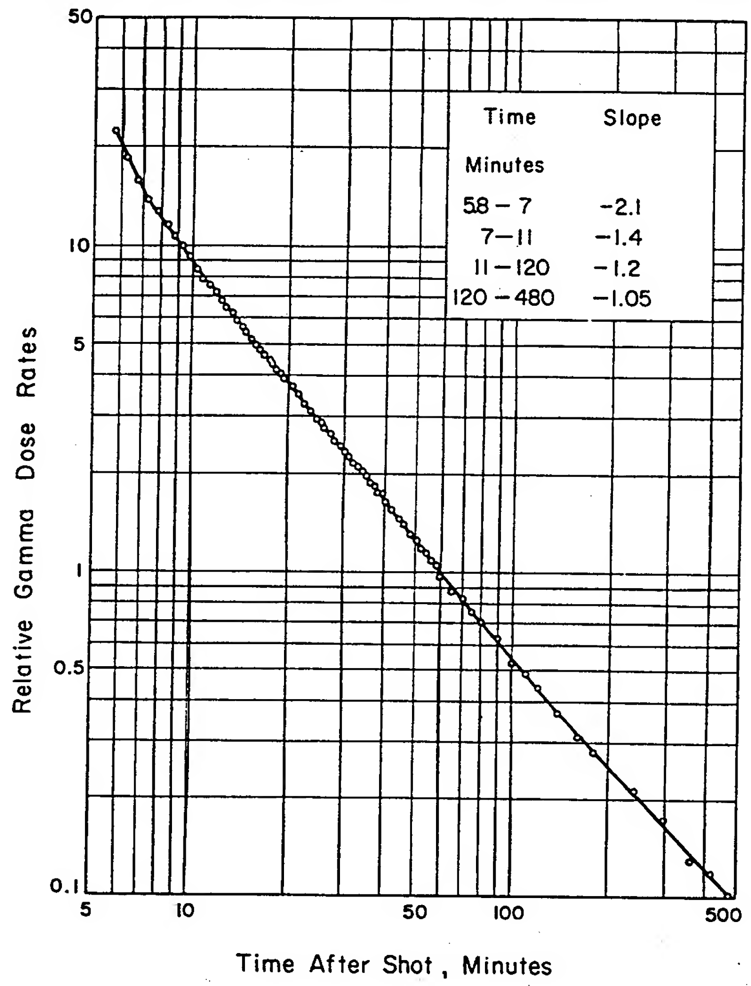


Figure 3.34 Gamma-ionization decay of contaminant collected in 6-inch-thick lead cave on DD-592 after Shot Umbrella, values corrected for background.

inants passing the filters indicated that most of the particles were below one micron in size, in the total air samples obtained. It can be seen that the contaminant was readily air-borne and in the respirable-size range.

3.3.6 Conclusions. As was the case during Shot Wahoo, the primary radiation from Shot Umbrella was found to be the radiation from the base surge as it passed a particular location. The intensity and time of arrival of this radiation was dependent on the distance from ground zero, the nature of the surface winds, and, to some extent, on the nature of the shot. In a shallow-harbor type burst, similar to Shot Umbrella, there appears to be less transport of the gamma-

[redacted]

radiation sources than from a deep-water burst. This may be due to the large-size particles which are picked up from the lagoon bottom by the burst. These relatively large particles absorbed a great amount of radioactive material and, because of their weight, settled quite rapidly before they were carried any considerable distance. This would account for the rapid decrease in activity of the base surge at increasing distances from surface zero. In contrast, Shot Wahoo picked up no particles from the ocean bottom; therefore, the radioactive material was carried by the base surge in a suspended state, and settlement of this mist was much slower than if there had been solid particles contained therein.

Normal sea operations can be resumed after passage of the base surge, which would be within 20 minutes at locations less than four miles from surface zero. During passage of the base surge, some protection from radiation is afforded at interior locations of a ship, but at distances less than one half mile the gamma activity from the base surge is so high that even the protective environment of a ship will not reduce this activity to acceptable levels.

Shipboard-contaminant deposition appears to have contributed little to the total gamma dose, and this hazard can be all but eliminated by an effective washdown system on all weather surfaces. Contamination ingress is not particularly important as a contributor to the total gamma dose below decks, but this ingress acquires some significance when inhalation hazards are considered. Particle sizing information revealed that most of the ingress particulate could be easily inhaled. The internal exposure at all animal stations below decks was 0.9 rad or less, in the first 50 hours after the shot. Above decks, the internal exposure reached six rads for mice and one rad for guinea pigs during the same period.

Gamma doses in excess of 100 r will be sustained in the open at distances less than about two miles downwind from surface zero. Because the surface winds appear to be the primary mechanism of transport of the base surge at distance greater than about 7,000 feet, the 100-r dose distance will probably be substantially reduced in the upwind direction. A study of the downwind gamma records would indicate a tentative conclusion that a downwind distance of approximately 23,000 to 28,000 feet from surface zero should be maintained in order to assure a total free-field dose of less than 25 r.

3.4 SHIP RESPONSE AND DAMAGE STUDIES

3.4.1 Introduction. The general need for a re-evaluation of ship response and damage predicability for underwater nuclear explosions, to give required answers to questions of the safe range for delivery of such nuclear weapons by surface ships and submarines, has been discussed in Section 2.4.1.

The Shot Umbrella geometry, a nuclear shot detonated on the ocean bottom in relatively shallow water (i. e., 148-foot depth), represented an operationally important environment. Many important strategic areas,such as the North American continental shelf, the European North Sea approach, etc., are of approximately this same water depth. Thus, information regarding safe ranges for delivery of nuclear weapons in such water configurations was also vitally required.

Previous small scale underwater high-explosive tests and theory predicted that pressure pulses for this shallow water geometry would be markedly different from the deep-water case. The closeness of both the air-water surface interface and the sea-bottom-reflection boundaries for the shallow water burst geometry influenced the pressure histories to such an extent as to make theoretical and small scale high-explosive treatment quite complex and difficult. Therefore, the full-scale pressure pulses from a nuclear detonation as predicated by theory and small-scale high-explosive tests were subject to much question.

These uncertainties in the prediction of the underwater free-field pressures for a shallow water shot made predictions of ship damage ranges doubly uncertain. Surface ship and submarine responses to the complex shallow water pressure pulses could not be readily extrapolated from the deep-water case, i.e. Shot Wahoo geometry, even if the actual pressure pulses could be predicted.

Shot Baker of Operation Crossroads was the only prior underwater nuclear detonation in this shallow environment, but that detonation was at mid-depth in a 180-foot depth of water and, as discussed in Section 3.1, left many questions to be answered.

In addition to the safe-delivery problem of nuclear weapons by surface ships or submarines in shallow water, the submarine lethality ranges in shallow water were uncertain. Submarine-lethality predictions for the very-deep-water-geometry case were verified on Operation Wigwam. However, theory was inadequate to reliably extrapolate the lethality ranges to a submarine hull in shallow water.

Of the submarine hull-lethality prediction methods proposed and available, the so-called excess impulse method appeared to be the most promising. The excess impulse is defined as the impulse delivered by that portion of the shock overpressure which is in excess of the static hull-collapse pressure minus the hydrostatic pressure. The applicability of this method is partly theoretical and partly intuitive. It is reasoned that some amount of excess impulse is needed to collapse a submarine hull, the exact value of which is not overly critical since the variation of excess impulse with range is quite rapid. Therefore, it would be expected that with any reasonable assumed value, the range computed should be within the other uncertainties inherent to the problem. As an example, one value of excess impulse which has been used to define lethality for a submarine-like model, the Squaw, is 2.5 psi-sec. Such value is intended to indicate the range where there is a 50 percent probability the submarine will be lethally damaged.

However promising the excess-impulse method appeared for submarine lethality predictions, differing opinions existed on the applicability of its concept, especially with the very short-duration pressure pulses. Therefore, to provide a check point for submarine lethality predictions in shallow water, it was considered necessary to place a submarine-like model, the Squaw, target at a range predicted to be near-lethal to assess the reliability of the prediction methods. The shallow-water depth was such that it would also be possible to retrieve the damaged Squaw subsequent to the shot for study of the mode of failure.

Therefore, the shallow water event, Shot Umbrella, was required to determine both the safe ranges for surface ships and submarine delivery of underwater nuclear weapons and the lethality range for submarines in shallow water. Shot Umbrella simulated the firing of an antisubmarine nuclear depth charge or torpedo in waters of depth representative of our North American continental shelf and other strategically important areas. It was intended that the answers obtained from Shot Umbrella, of course, eventually be such as to cover not only the particular geometry of this one shallow water shot but other shallow water geometries, other yields, other types of ships, and other orientations.

The Program 3 effort on Shot Umbrella consisted of three general categories: (1) hull response and damage studies of surface ships, (2) hull response studies of submarines, and (3) shipboard machinery and equipment shock damage studies. Each of these categories is described successively in the following sections.

3.4.2 Hull Response and Damage Studies of Surface Ships. Objectives. The objectives of the hull response and damage studies of surface ships on Shot Umbrella were similar to those on Shot Wahoo, except that their application was to shallow-water geometries. The objectives on Shot Umbrella, therefore, were to: (1) determine from the hull-deflection standpoint, the safe-delivery range for surface-ship delivery of an underwater nuclear weapon in shallow water; (2) determine from the hull-deflection standpoint, the lethal range for merchant ships attacked by an underwater nuclear weapon in shallow water; (3) obtain basic information on hull response as related to free-field pressures and loading measurements in shallow water, so as to provide check points for model experiments and high-explosive shaped-charge tests.

[redacted]

Background. The problem of making predictions of response and damage from underwater nuclear-weapon effects for surface-ship hulls under general conditions has been previously discussed in Section 2.4.3. The increased difficulty in making such predictions when the surface ship is in relatively shallow water, compared with deep water, has been further discussed in Section 3.4.1. The closeness of both the air-water surface interface and the ocean-bottom-reflection boundaries for the shallow-water burst geometry influence the pressure histories to such an extent as to make theoretical and small-scale explosive treatment quite complex and difficult.

Procedure. For the hull response and damage studies on Shot Umbrella the same surface target ships were exposed as for Shot Wahoo, i.e., the DD-593, DD-592, DD-474 and the EC-2. These ships were located stern-on at [redacted] feet, broadside at [redacted] feet, stern-on at [redacted] feet, and broadside at [redacted] feet from surface zero, as shown on Figure 3.3. The three destroyers were the principal targets; the EC-2 was a contingency target for Shot Umbrella. Since it had sustained only light, rather than lethal hull damage on Shot Wahoo, it was possible to re-expose the EC-2 on Shot Umbrella. On Shot Umbrella, the EC-2 was exposed with its port side toward surface zero. On Shot Wahoo, the starboard side was exposed.

The relatively highly instrumented hulls of these four target surface ships included the same gages and gage-recording equipment for Shot Umbrella that had been previously installed for Shot Wahoo. The description of this instrumentation has been included in Section 2.4.3. The only modification was to transfer several of the hull-side-deflection gages in the EC-2 from the starboard to port side of the ship, since that was the side exposed to the burst on Shot Umbrella. It was not feasible, however, to similarly reorient the three heavy lead shields for the high-speed cameras which had been installed to record hull and bulkhead deflections within the EC-2 on Shot Wahoo. On the other hand, the other 40 high-speed cameras installed in the target ships primarily for the purpose of recording shock damage to machinery and equipment were installed so that they did function on Shot Umbrella as they had previously on Shot Wahoo. These cameras are described in Section 3.4.3. In general, all hull instrumentation installed for Shot Wahoo was also used for Shot Umbrella.

Results. For Shot Umbrella, good quality records of measurements of hull response were obtained on all instrumented ships. Records on the EC-2 were good quality throughout the time of chief interest, until passage of the direct shock wave; thereafter, severe mechanical shock motions of the recording equipment occurred because the recording unit platform went beyond the motion anticipated and hit bottom on the supporting springs. However, the vital response information for the EC-2 was obtained.

A few of the records from the DD-474, DD-592, DD-593 and EC-2 are shown on a compressed time scale in order to reveal an overall view of the response to underwater phenomena, in Figures 3.35, 3.36, 3.37, and 3.38. During Shot Umbrella, as shown by these records, the most significant loading phase, insofar as surface ships were concerned, was the direct shock wave. It may be noted that the maximum recorded ship-bottom velocity on the DD-474 was about 8 ft/sec; on DD-592 about 4 ft/sec; on DD-593 about 2 ft/sec; and on EC-2 about 13 ft/sec. The velocities measured over the cross section of the EC-2 hull are shown in Figure 3.39. Note that the maximum recorded side-frame velocity was about 45 ft/sec, which corresponds to the maximum side-frame displacement discussed below. The longitudinal distribution of response along the length of the DD-474 is illustrated in Figure 3.40.

The response upward through the DD-474 as indicated by a few velocity records at positions on the forward fireroom bulkhead is shown in Figure 3.41. Note that maximum response at this bulkhead was about 5 ft/sec at keel and 4 ft/sec at upper-deck levels. However, longer rise times at the upper-deck levels would greatly reduce acceleration and damage effects by as much as a factor of 20 or more.

The vertical displacement of the DD-474 is shown by the records of three gages in Figure

[redacted]

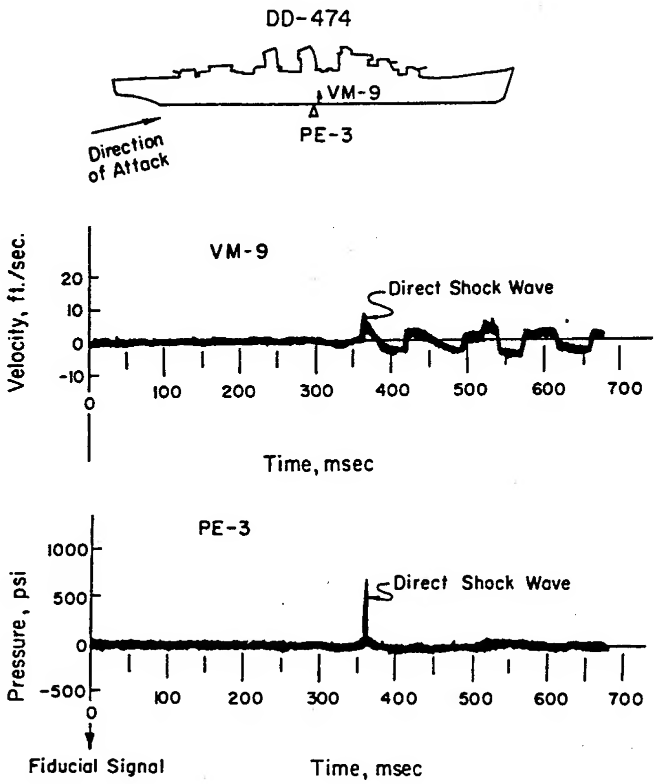


Figure 3.35 Overall underwater phenomena, DD-474, Shot Umbrella.

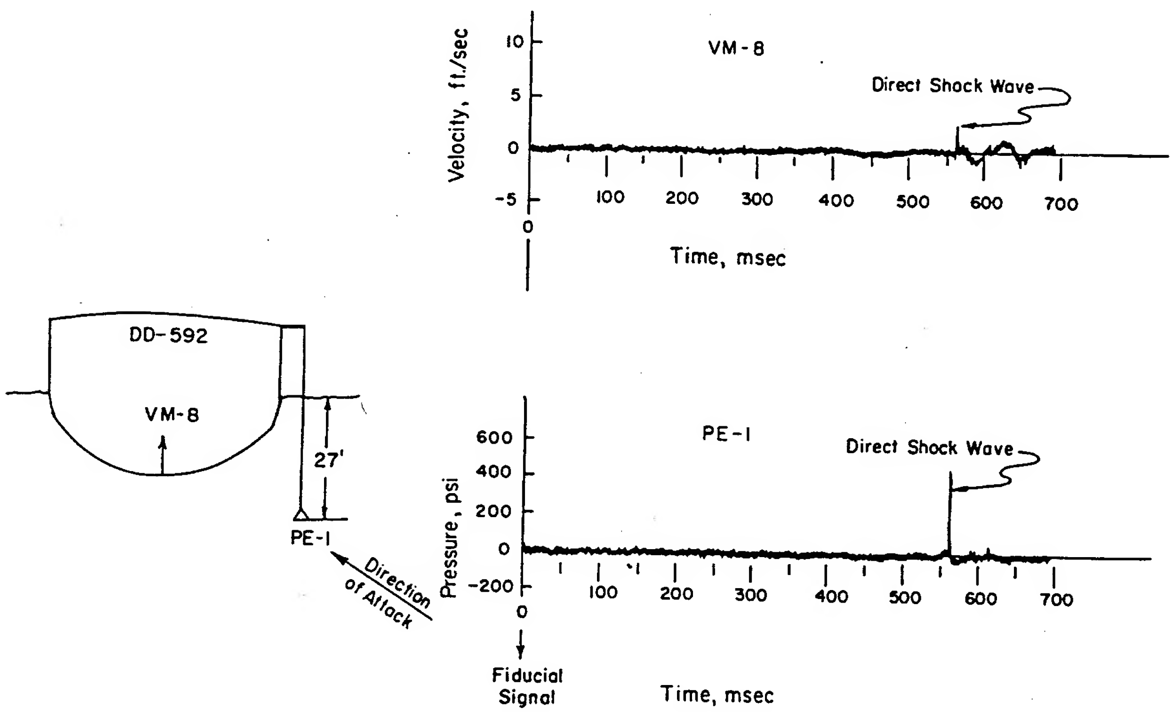


Figure 3.36 Overall pressure phenomena, DD-592, Shot Umbrella.

[redacted]

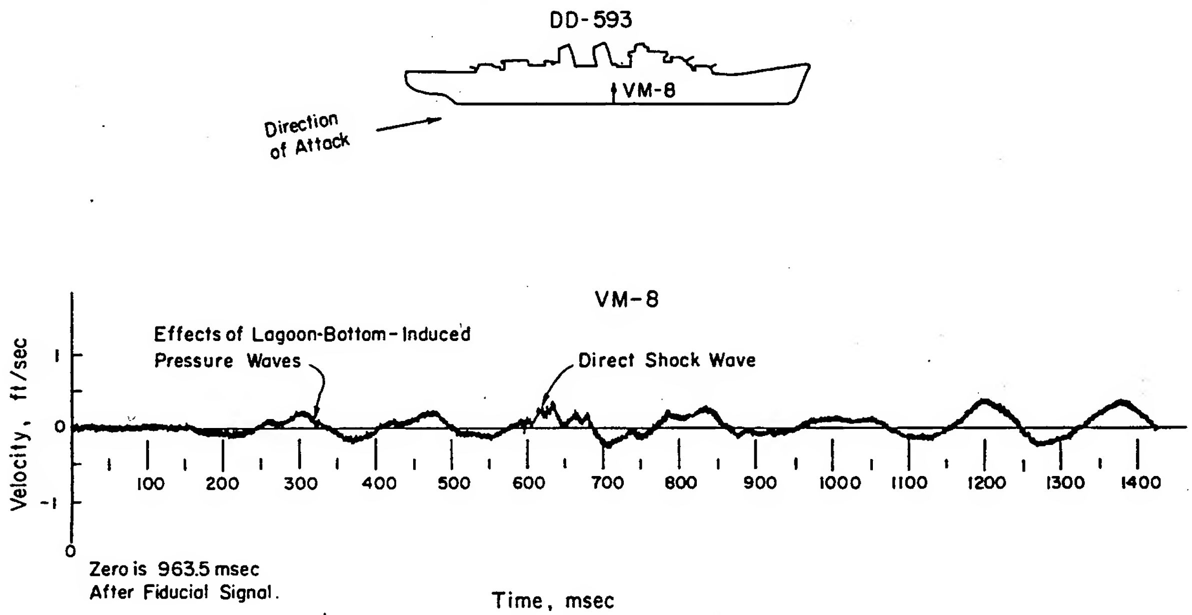


Figure 3.37 Overall pressure phenomena, DD-593, Shot Umbrella.

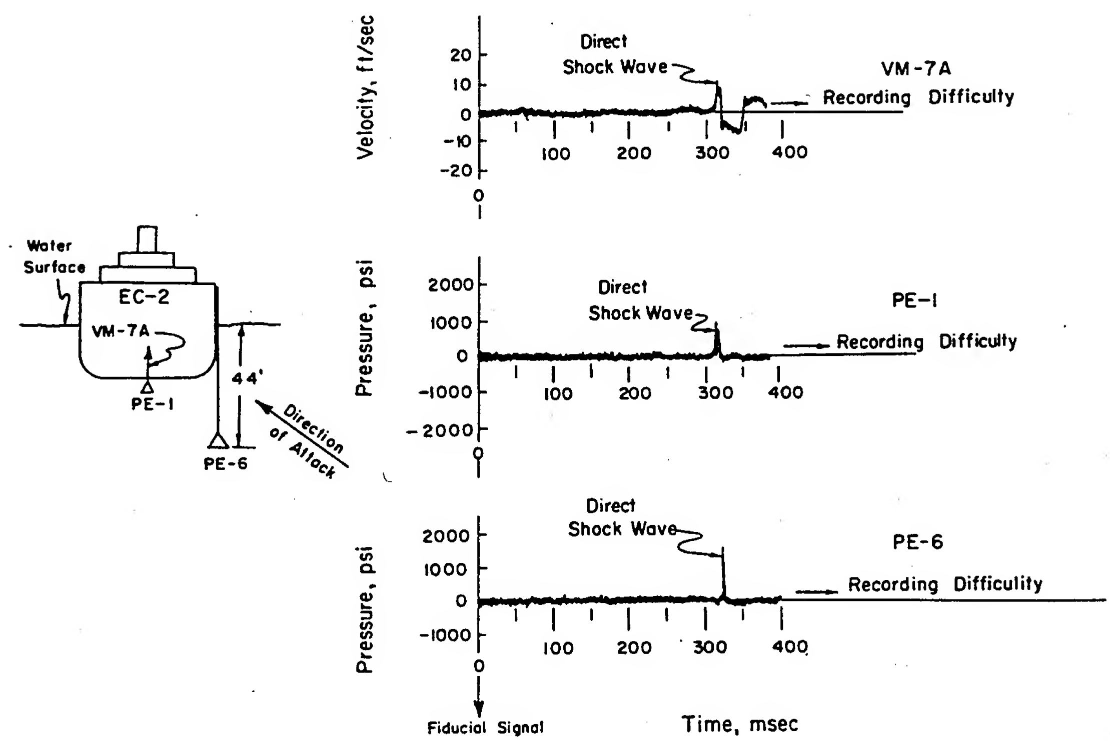


Figure 3.38 Overall underwater phenomena, EC-2, Shot Umbrella.

[redacted]

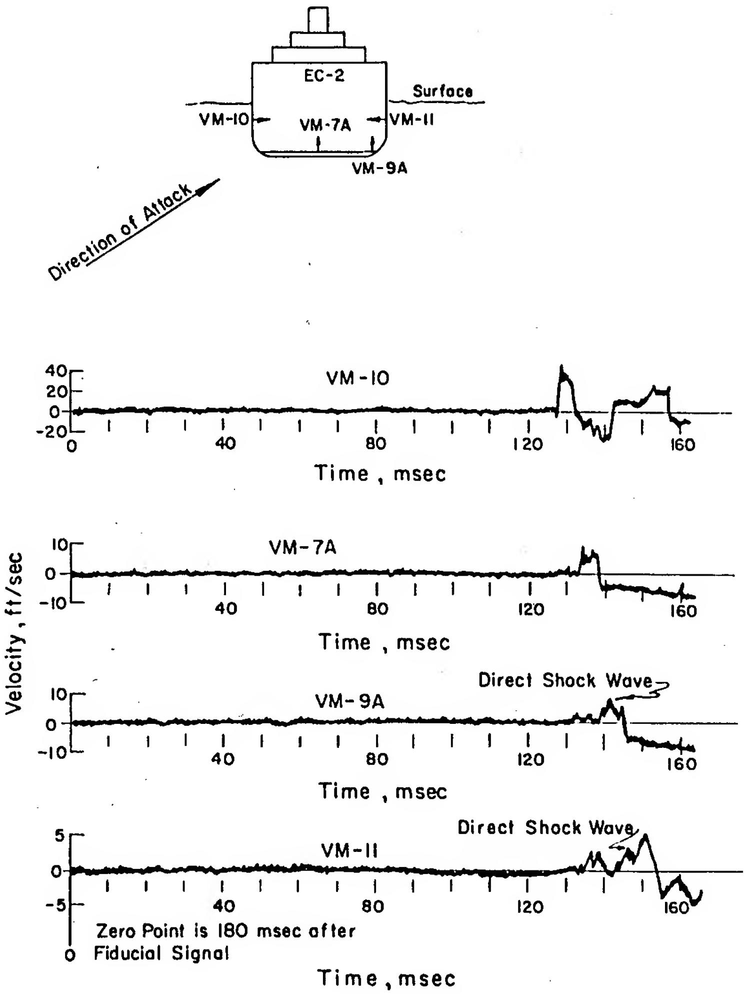


Figure 3.39 Cross-section distribution of initial hull response, EC-2, Shot Umbrella.

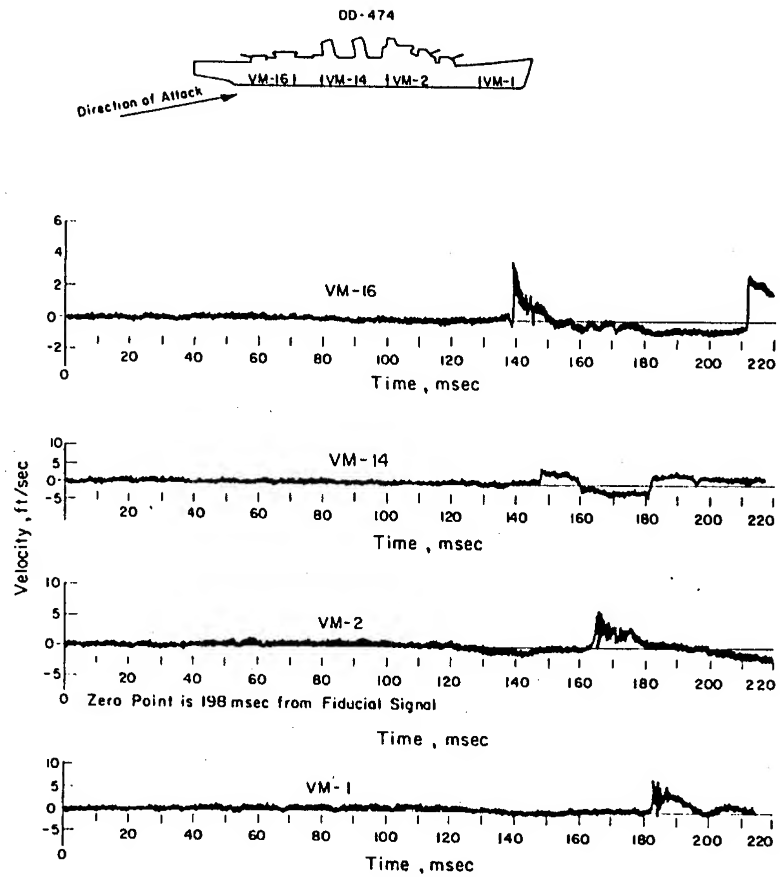


Figure 3.40 Longitudinal distribution of bottom (keel) velocities, DD-474, Shot Umbrella.

[redacted]

3.42, which indicate a maximum of about three inches of whole ship vertical bodily motion due to Shot Umbrella. A maximum vertical bodily motion of the EC-2 of about six inches is indicated in Figure 3.43.

The hull-damage survey of the EC-2 revealed hull damage characterized as light, similar to that found after Shot Wahoo. The maximum transient displacement of approximately 4 ½ inches occurred in the hull vertical side frames, with a maximum permanent displacement of about 1 ½ inches. In the same side area, maximum permanent hull-plating deformations between the side

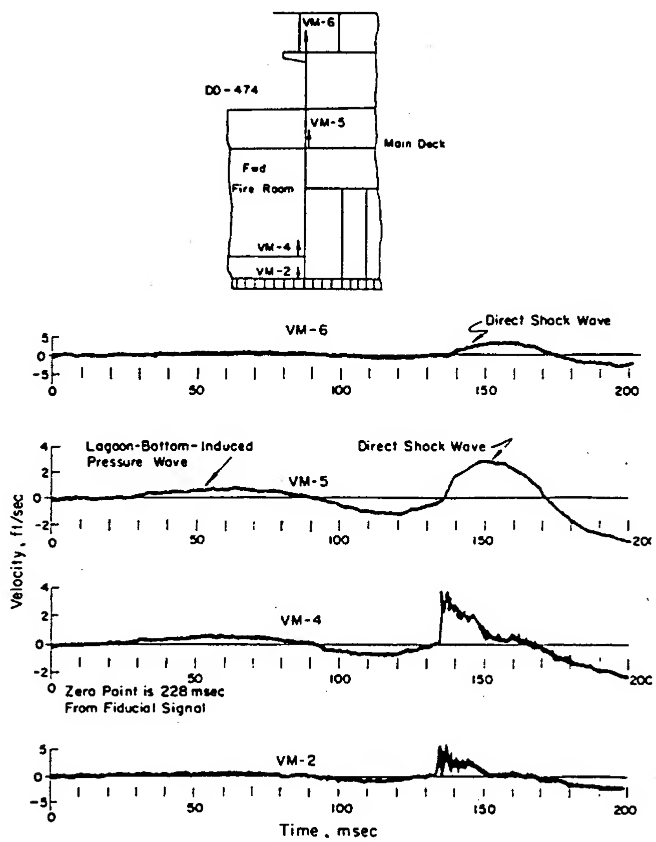


Figure 3.41 Response distribution upward along bulkhead, DD-474, Shot Umbrella.

frames were about ¾ inch. Hairline fracture cracks at various minor locations of the steel hull deck and superstructure were found. The propeller shaft alley tunnel was further seriously distorted to a maximum of about 12 inches. Other damage was essentially the same as that after Shot Wahoo; however, previous damage was accentuated. Diver examination of the hull bottom revealed that most of the hull bottom plating dishes between frames did not exceed ½ inch; the maximum reported was 1 ½ inches in depth. As after Shot Wahoo, minor hull flooding caused by leaks in the hull was controllable by periodic pumping.

An examination of the hull of the DD-474 revealed no hull damage, dishing, or other hull deformation that could be ascribed to Shot Umbrella. However, a slight buckle in the after stack of the DD-474, bent bulwarks around the after-gun tubs, and a slightly buckled mast were produced by a combination of shock and the surface-water wave passage over the stern which faced the detonation. No hull damage occurred on the DD-592 or DD-593.

Conclusions. The hull responses and damages of the EC-2 and the DD-593, DD-592, and

[redacted]

DD-474 were about as expected on Shot Umbrella. However, considerable detailed study and analysis of all data collected is required. The following preliminary conclusions apply to the hull response and damage studies on surface ships in shallow water. It should be understood that Shot Umbrella conditions include yield, shot geometries and to a lesser extent, bottom reflection and thermal-gradient characteristics for these tests.

1. From the standpoint of hull deflection, a safe-delivery range for destroyers of [redacted] feet for Shot Umbrella conditions has been demonstrated. The minimum safe range, from the standpoint of hull deflections, is considerably smaller than this figure.

2. From the standpoint of hull deflection, it can now be estimated that the lethal range for the EC-2 is [redacted] feet under Shot Umbrella conditions.

3. Considerable basic information on hull response as related to free-field pressures and

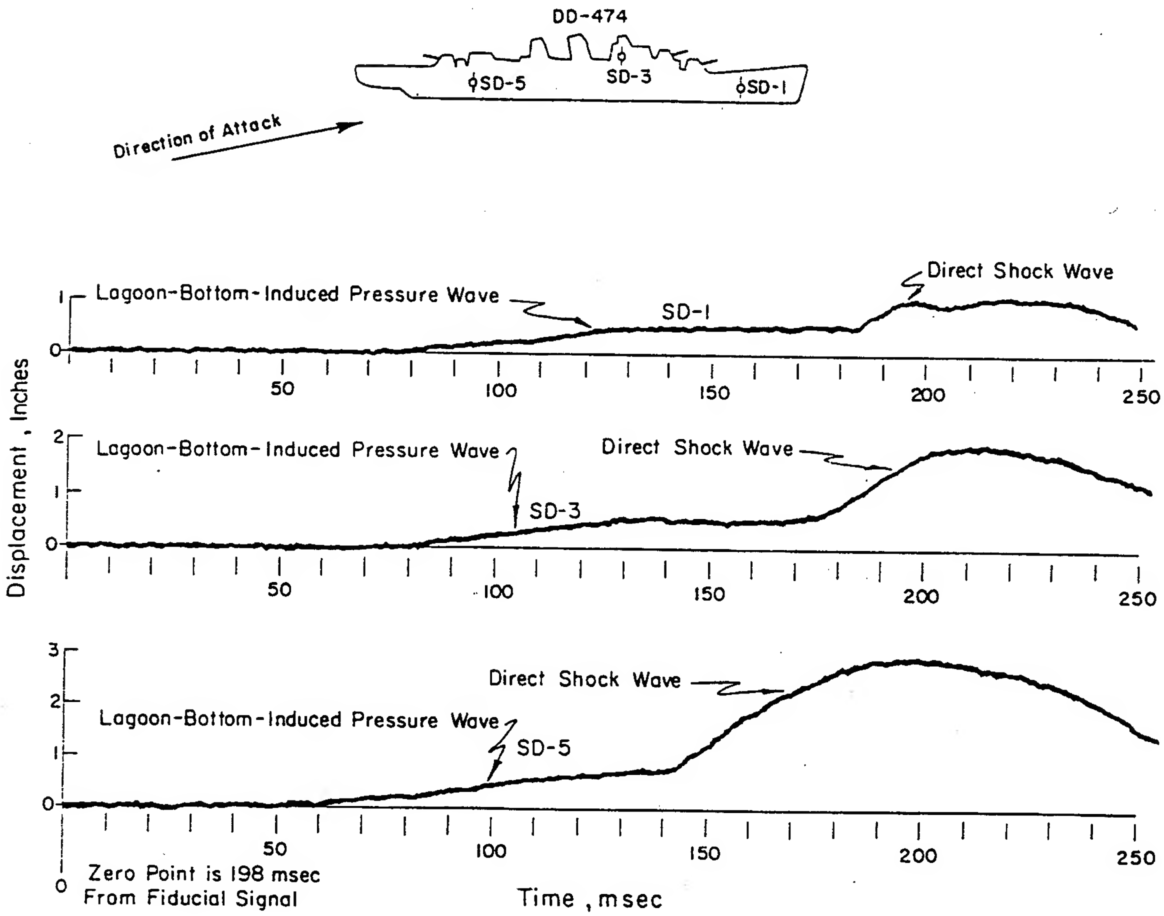


Figure 3.42 Vertical displacements on DD-474, Shot Umbrella.

loading measurements was obtained. This has provided check points for small-scale ship model experiments which confirm developed theories and, upon further analysis, is expected to prove valuable in extrapolating the results of Shot Umbrella to other conditions. Some of the other features of this information are given in the additional conclusions below.

4. During Shot Umbrella the direct-shock wave was the principal loading phase for surface ships within the close ranges of primary interest. Bulk cavitation-reloading effects following the direct shock wave were much smaller than those due to the direct shock wave itself. Vertical

[redacted]

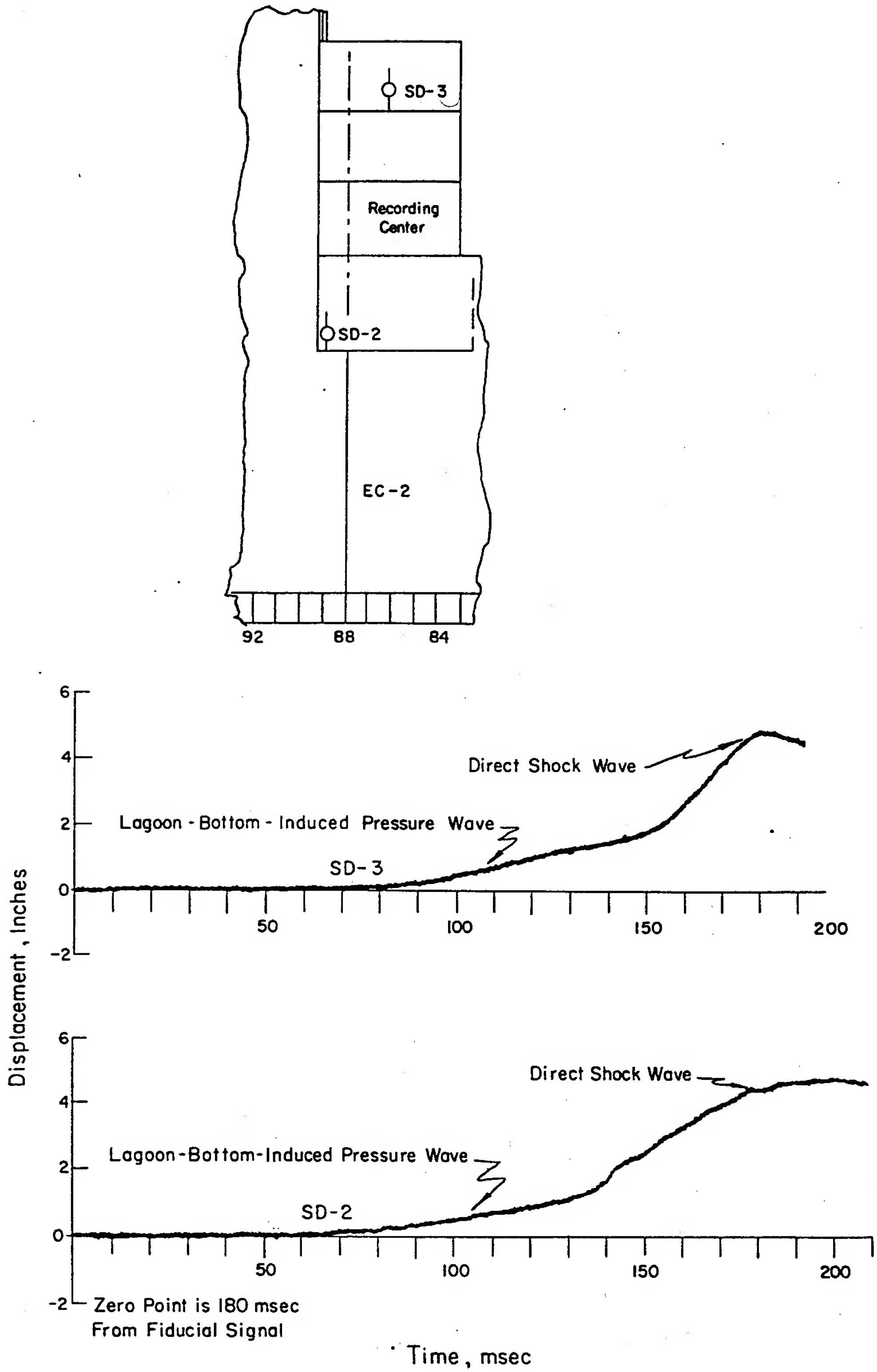


Figure 3.43 Vertical displacements on EC-2, Shot Umbrella.

[redacted]

velocities associated with the lagoon-bottom induced-pressure waves were negligible.

5. Under side-on attack, the bottom vertical and horizontal velocities are not uniform over the length of the ship; despite uniformity of loading, velocity response is critically dependent upon precise location of the structure to which the gage is attached.

6. During Shot Umbrella, vertical velocities measured at the keels of the target ships were considerably higher than corresponding water-particle velocities. The maximum vertical bottom velocities measured were: EC-2, 13 ft/sec; DD-474, 8 ft/sec; DD-592, 4 ft/sec; and DD-593, 2 ft/sec.

7. The severity of the shock motions in a surface ship diminishes considerably from bottom to the upper superstructure decks. The damaging initial accelerations can be reduced by a factor of 20 or more, even though the peak velocities are the same because of the slower rise time at the higher deck levels.

8. The character of the EC-2 hull damage under Shot Umbrella conditions was similar to small scale tests on the EC-2 models. The magnitude of side damage may be predicted, therefore, with an accuracy sufficient for predicting lethal ranges, on the basis of these small-scale tests.

3.4.3 Hull Response Studies of Submarines. Objectives. The principal effort of the submarine hull-response studies on Operation Hardtack was on Shot Umbrella. The effort involved measurement of the loading, strain, deformation, and damage of a submarine-like target, the Squaw-29, and also of the operating submarine, SSK-3. The objectives were to: (1) determine the range for lethal damage to a submarine-like (Squaw) target under attack in shallow water by an antisubmarine nuclear weapon; (2) study the process of hull damage to a submerged target for correlation with observed underwater phenomena and theory, and (3) determine the response of the hull of a submarine in a simulated attack position in shallow water.

Background. As previously discussed in Sections 3.4.1 and 2.4.4, Shot Baker of Operation Crossroads first tested submerged submarines (SS-212 and SS-285 class) exposed to nuclear attacks in shallow water. However, lack of instrumentation on this test made the obtained data questionable and, therefore,unsuitable for extrapolation to other shallow-water geometries. Further, the later Shot Wigwam results regarding submarines exposed in very deep water were not applicable to the shallow-water case. However, the submarine models (Squaws, 4/5 full-scale SS-563 class submarines in cross sectional dimensions) which were utilized in Operation Wigwam tests had been quite useful in determining safe ranges for submarines in very deep water.

On the other hand, the shallow water case was unique in that the close proximity to the burst of both the air-water surface interface and the sea-bottom-reflection boundaries introduced variations so that the prediction of underwater pressure-time histories was very difficult. However, even if the pressure-time history were known, that alone was insufficient to make an estimate of lethal range because of unknowns in plastic response of submarine hulls. Several theoretical methods relating the plastic response of a submarine hull to the short-duration pressure waves had been proposed, and several empirical rules had been suggested. However, none had been satisfactorily verified by experiment, particularly for the shallow-water geometry. As was previously discussed in Section 3.4.1, of the several hypotheses or methods suggested for determining submarine-hull lethality, the excess-impulse method appeared to be the most promising. However, opinions differed on the applicability of the excess-impulse concept, especially with the short duration pulses expected in the shallow-water case.

Thus, there were two difficulties which made theoretical estimates of lethal range of submarines in shallow water uncertain: (1) the variation in underwater pressure versus time was unknown and (2) the theories of plastic response of submarine hulls had not been confirmed.

By placing a submarine-like model (Squaw) target at a range expected to be near-lethal in the

[redacted]

Shot Umbrella geometry, it was expected that the reliability of the lethality-prediction methods could be assessed. Measurements of hull response of the Squaw during Shot Umbrella were also considered desirable to record the progress of the damage process. Correlation with the underwater pressure-time history would cast light on existing theories and serve as a guide for acceptance or rejection.

The operating submarine, SSK-3, was also to be exposed in a simulated attack position on Shot Umbrella, at a range expected to be safe for delivery of an underwater nuclear weapon.

Procedure. The Squaw-29 was the only surviving one of three submarine-like (Squaw) targets previously built for the Operation Wigwam test. Design of the Squaw test sections was based on the SS-563-class submarine, built on a 4/5 scale in cross section but of shortened length. The inside diameter of the pressure hull was 14.4 feet; length of pressure hull, 121.5 feet; hull plating, one-inch-high tensile steel with an average yield strength of 60,000 psi; frame spacing 30 inches; length of each test section, 29 feet. Major items of propulsion machinery inside the Squaw were simulated on 4/5 scale by cast-steel weights. These items included the three main engine generators, 11,900 pounds each, and the two simulated motors, 25,000 pounds each.

During Shot Umbrella, the Squaw-29 was submerged at periscope depth, located stern-on at [redacted] foot range from surface zero. Submergence was accomplished by remote-control venting of ballast tanks through hoses connecting the Squaw with associated instrument barge, YFNB-12, located at [redacted] foot range. Weights (clumps) totaling 10 tons were attached to chains hung from the bow and stern of the Squaw. When the weights rested on the lagoon bottom, the Squaw was suspended at the proper depth, with a positive buoyancy of about five tons.

The operational submarine SSK-3, without crew aboard, was located bow-on at [redacted] foot range on Shot Umbrella, also submerged to periscope depth. To more realistically simulate an attack position, two of the four bow torpedo-tube doors were open, one with and one without a torpedo in position. Submergence for test was accomplished by venting ballast tanks, such that when weights (clumps) attached to chains from the bow and stern rested on the lagoon bottom, the SSK-3 was suspended at the proper depth with a positive buoyancy of about 10 tons.

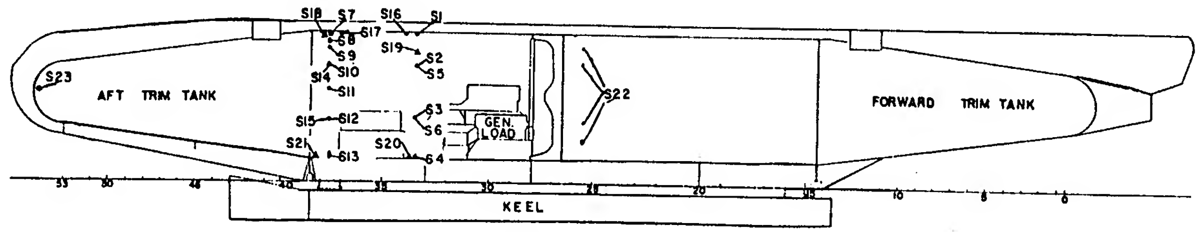
Instrumentation on Squaw-29 was essentially the same as for Operation Wigwam. Deformations of hull plating and stiffeners at typical locations were measured by 24-strain (SR-4) gages and four variable-reluctance-displacement gages. The pressure near the hull, as well as inside the ballast tanks, was measured by 16 piezoelectric-pressure gages. Overall motions of the hull and stiffeners were photographed with nine high-speed motion-picture cameras. The 14 roll, pitch, depth, and flooding gages also recorded those conditions. Figure 3.44 shows principal locations of gages and cameras on the Squaw. In addition, velocity-meter and shock-spectrum-recorder gages were installed for the shipboard machinery and equipment-shock studies. Measurements on the Squaw were recorded on oscillographic and magnetic-tape recorders located on the YFNB barge, after transmission through 850 feet of three special $2\frac{8}{10}$-inch diameter multi-conductor instrument cables from the Squaw to the YFNB-12. The oscillograph recording units on the YFNB barge were protected from radiation by three-inch-thick lead shields; all recording units were located on shock-attenuating spring mountings.

Instrumentation on the SSK-3 hull consisted of seven strain gages and three high-speed cameras, which were identical to those installed for Shot Wahoo, as shown in Figure 3.45. The signals from the gages were recorded on an oscillograph in the submarine.

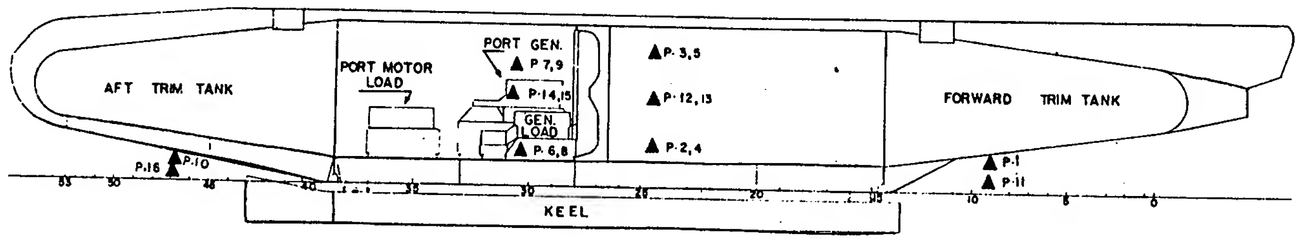
Operation of all instruments on both targets was triggered by radio-timing signals. The timing signals for the Squaw were transmitted to the YFNB-12. The signals for the SSK-3 were transmitted to an adjacent YC barge and were then relayed by cable to the submarine.

Results. Instrumentation functioned well on both the Squaw-29 and the SSK-3 during Shot Umbrella. Squaw hull damage was less than expected; lethal damage to and flooding of the pressure hull did not occur. However, four of the ten external ballast tanks ruptured, and all

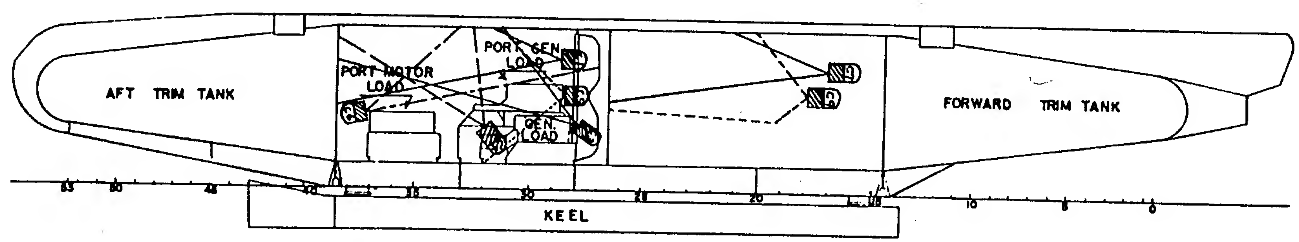
[redacted]



SQUAW STRAIN GAGE LOCATIONS



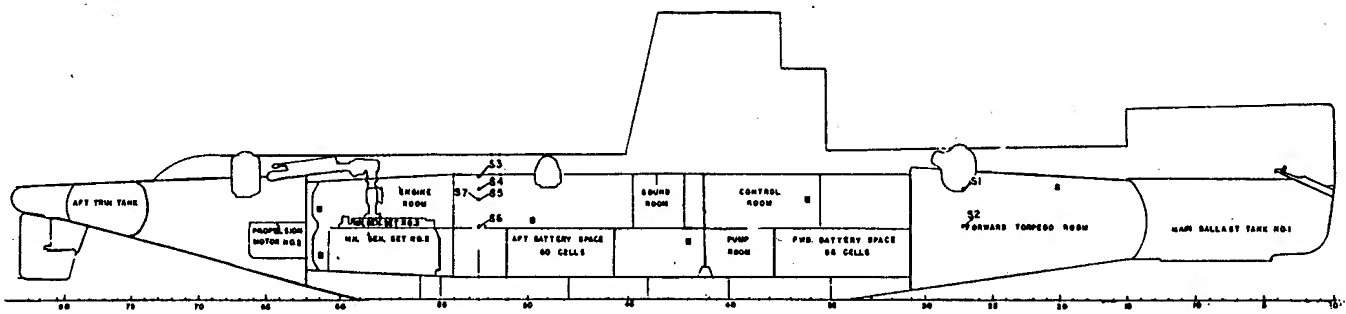
SQUAW PRESSURE GAGE LOCATIONS



SQUAW MOTION PICTURE CAMERA LOCATIONS

Figure 3.44 Squaw submarine hull instrumentation response.

[redacted]



SSK3 INSTRUMENTATION

Legend

S-•_ Strain Gage
■ _ High-Speed Motion Picture Camera

Figure 3.45 SSK-3 instrumentation and hull response.

[redacted]

were seriously dished. This resulted in some loss of buoyancy, and complicated resurfacing the Squaw after the test. Preliminary inspection of the Squaw hull after Shot Umbrella showed a maximum permanent plastic deformation of the hull plating of $\frac{1}{4}$ inch between frames and one inch local buckling of three internal bulkheads because of hull deformation. As expected, there was no hull damage to the SSK-3 from Shot Umbrella.

Pressures recorded near the Squaw are indicated in Figure 3.46. Records of strain from the reflected shock wave on the Squaw and SSK-3 are shown in Figures 3.47 and 3.48, and the peak values of strain are shown in Tables 3.5 and 3.6.

The peak recorded free-field pressure near the Squaw was about 1,530 psi a[redacted]foot range; the predicted free-field pressure was 1,600 psi a[redacted]foot range. Thus, the actual pressures were slightly less than predicted. Note the positive pressure duration of about 6 msec. The peak pressure measured inside the ballast tanks of the Squaw-29 was 1,300 psi. This was twice the static hull-collapse pressure of 660 psi; after 1 msec this reduced to half of the peak value then increased to a value of about 950 psi for about 5 msec. The duration of that portion of the pressure pulse which exceeds the static collapse pressure was less than 2.5 msec. It is of interest to observe that approximately the same pressure, acting for 10 msec, caused collapse of a similar Squaw during Operation Wigwam. It appears that the pressure loading on the hull was too short to cause failure. One prediction was that an excess impulse of 5 psi-sec was required to collapse a submarine at shallow submergence. The excess impulse in the water near Squaw-29 was only about 1.3 psi-sec.

The maximum strains measured on the SSK-3 hull during Shot Umbrella were well within the non-damage range. The highest dynamic strain recorded was 1,160 μin/in, which only approximates the static yield strength.

A subsequent detailed hull survey of Squaw-29 (in dry-dock) was planned, in order to accurately determine the hull deformations. After detailed comparison of data results with results of that survey, it is hoped a further understanding of submarine hull collapse and verification of the submarine hull lethality excess-impulse concept will be possible.

Conclusions. The following are the preliminary conclusions of this submarine hull study on Shot Umbrella. It should be understood that these conclusions apply to Shot Umbrella conditions.

1. The range for moderate hull damage to a 4/5-scale-submarine model, the Squaw, i[redacted]feet under Shot Umbrella conditions. In order to estimate safe or lethal ranges for Shot Umbrella conditions, the pressure field must be known and an adequate theory such as the excess impulse, or another concept correlating the plastic response of a submarine hull to pressure waves of short duration, must be confirmed or developed.

2. The SSK-3, under Umbrella conditions, at[redacted] was shown to be well beyond the minimum safe range for hull damage.

3. Strains as large as 13,000 μin/in, which is six times the known yield strain of the plating, may be sustained without rupture in the hull plating of a Squaw. On the basis of Operation Wigwam experience, these strains should have produced much larger hull deformations, and this result will also be further analyzed prior to the final (WT) report.

3.4.4 Shipboard Machinery and Equipment Shock Damage Studies. Objectives. The objectives of the shipboard machinery and equipment shock-damage studies on Shot Umbrella were similar to those on Shot Wahoo, except that their application was to shallow-water geometries. The objectives on Shot Umbrella, therefore, were to: (1) determine safe ranges and moderate damages for delivery of antisubmarine nuclear weapons by destroyers in shallow water, from the standpoint of shock damage to machinery and equipment important to combat capability; (2) determine safe ranges for delivery of antisubmarine nuclear weapons by submarines in shallow water, from the standpoint of shock damage to machinery and equipment important to combat capability; and (3) determine the intensity and shock-motion data on ships' machinery, equipment, and foundations for correlation with free-field phenomena, hull loading, and theories so that results of a nuclear test in shallow water could be extrapolated to other burst geometries and ships.

Background. The problem of making predictions of shock response and damage to ship-

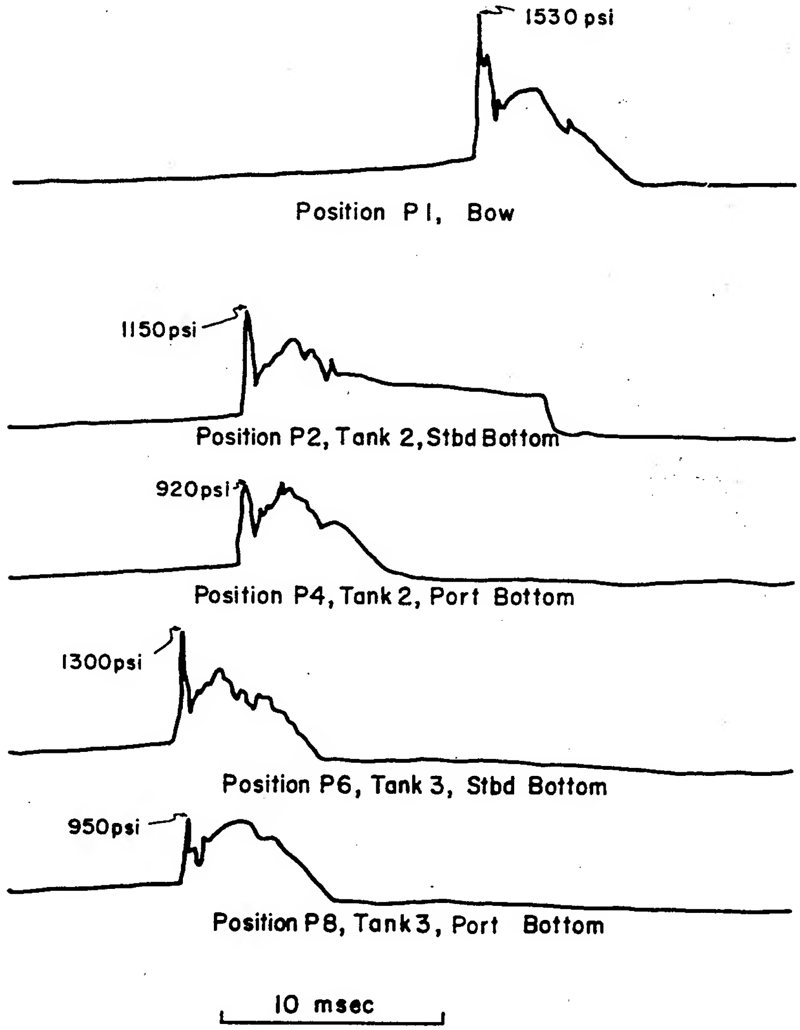


Figure 3.46 Pressures measured under the bow and near the bottom of the ballast tanks in Squaw-29 during Shot Umbrella.

board machinery and equipment from underwater nuclear weapon effects has been previously discussed in Section 2.4.5. The increased difficulty in making such predictions when the ship is in relatively shallow water compared with deep water has been further discussed in Section 3.4.1. The closeness of the burst to both the air-water surface interface and ocean bottom reflection boundaries for the shallow water geometry influences the pressure histories to such an extent as to make theoretical and small-scale explosive treatment quite complex and difficult.

As has been previously discussed, previous underwater nuclear detonations and high-explosive

[redacted]

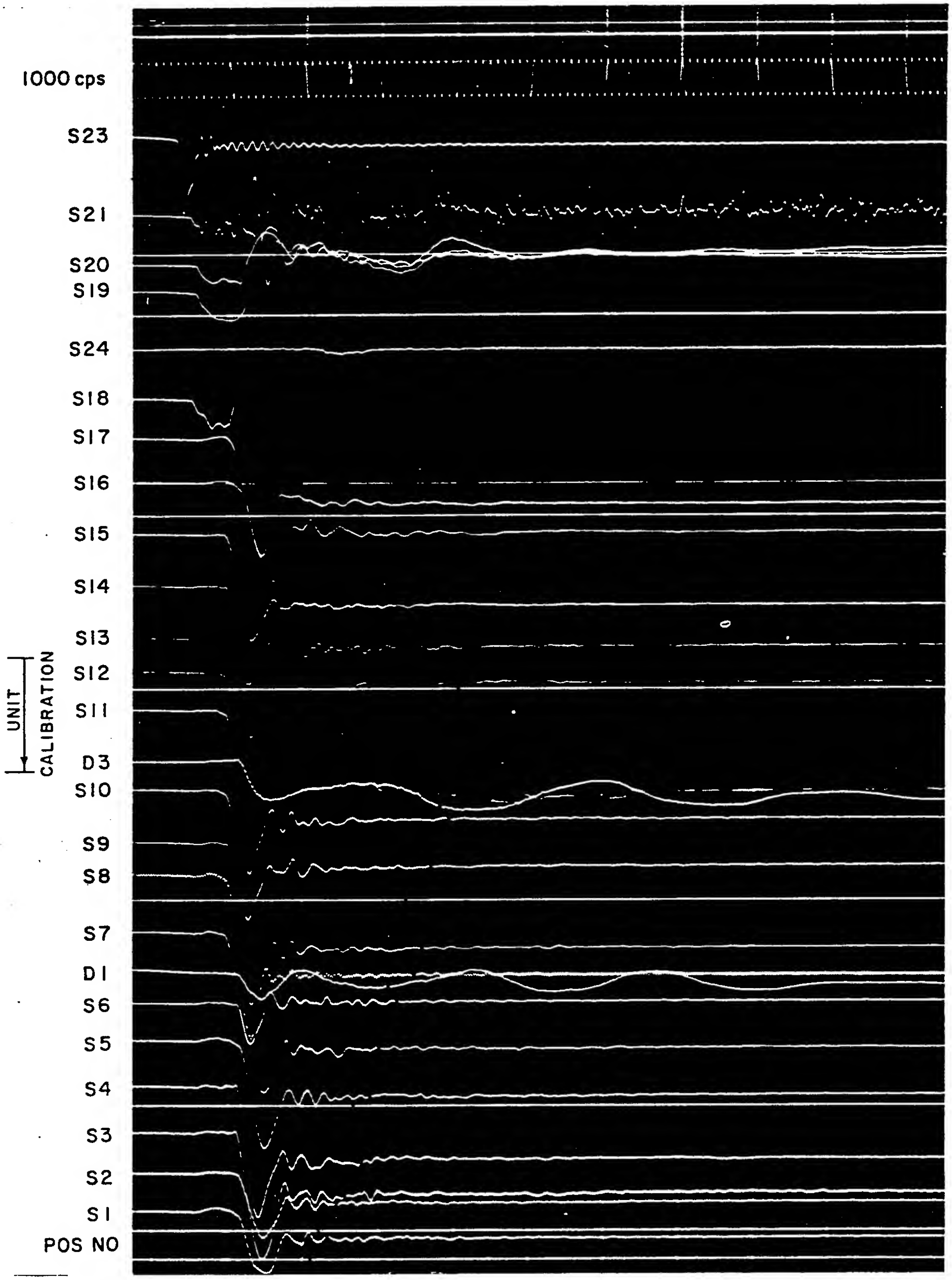


Figure 3.47 Oscillogram of direct shock wave on the Squaw-29 for Shot Umbrella.

[redacted]

tests have left many questions unanswered. Furthermore, existing data with which to correlate a given response from such a nuclear detonation in shallow water, with a given amount of damage, was still lacking. To permit improved shock-hardening design of future ships' machinery and equipment, such response data was urgently required.

It had become clear, therefore, that a full-scale nuclear underwater test in shallow water

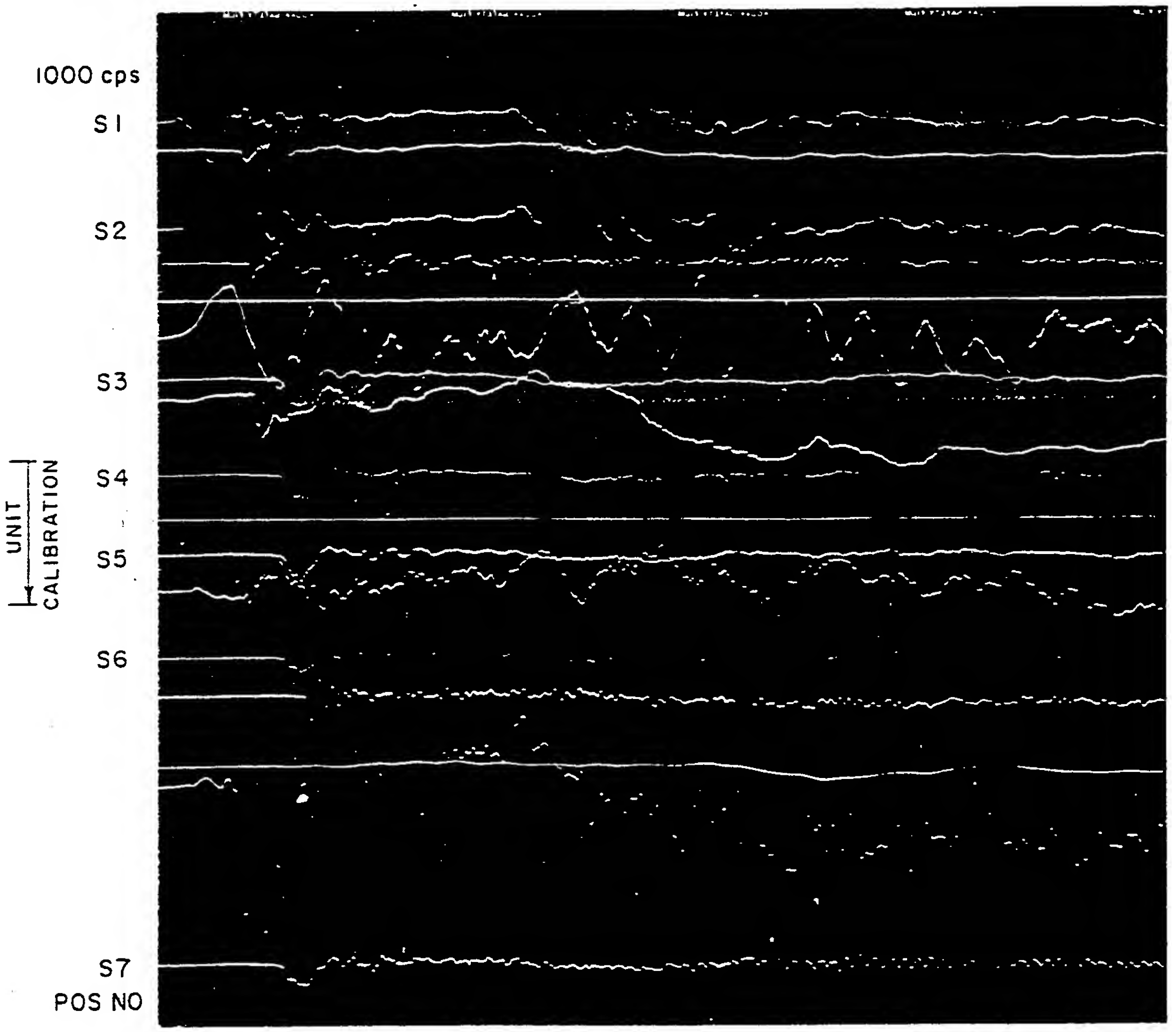


Figure 3.48 Oscillogram of direct shock wave on the USS Bonita (SSK-3) for Shot Umbrella.

was required to gather the necessary data on response and damage to ships' machinery and equipment.

Procedures. For the shipboard machinery and equipment shock-damage studies on Shot Umbrella, the same principal four surface target ships and one submarine were exposed as for Shot Wahoo, i.e., the DD-593, DD-592, DD-474, the EC-2 and SSK-3. These ships were, respectively, located stern-on a[redacted] feet, broadside a[redacted] feet, stern-on at[redacted] feet, broadside a[redacted] feet and bow-on a[redacted] feet from surface zero as shown in Figure 3.3 (Umbrella array). In addition, the submarine-like Squaw-29 and its instrument barge, YFNB-12, were included, respectively located stern-on a[redacted] an[redacted] foot range.

The ships' machinery and equipment and the foundations thereof (including hull bottoms, hull frames, decks, and superstructures on the four surface target ships) were relatively highly instrumented with the same gages and gage-recording equipment as had been previously installed for Shot Wahoo. This included a total of 43 high-speed cameras installed in the four surface

[redacted]

TABLE 3.5 STRAINS ON SQUAW-29 FROM SHOT UMBRELLA

Position Number	Direction of Measurement of Strain	Frame Number	Degree from Crown	Strains in mils per inch	
				Maximum	Permanent Set
S1	*	33½	0	3.8	1.6
S2		—	60S	4.7	1.8
S3		—	120S	7.5	3.5
S4		—	180	8.3	4.6
S5		—	60P	5.6	3.0
S6		—	120P	5.5	2.6
S7	*	37½	0	6.9	4.0
S8		—	16P	9.9	6.0
S9		—	32P	10.0	6.6
S10		—	60P	8.7	5.4
S11		—	90P	10.8	7.4
S12		—	120P	11.0	9.0
S13		—	180	5.2	2.4
S14		—	60S	5.2	3.1
S15		—	120S	12.7	9.0
S16	*	34	0	8.1	4.1
S17		37	0	13.0	7.5
S18	†	37½	2P	−6.0	−4.0
S19		33½	32S	−1.7	−0.8
S20		33½	180	−0.9	−0.2
S21		38¼	180	2.0	0.0
S22	*	25½	Av	¶	¶
S23	‡	54	—	1.7	0.2
S24	§	—	—	0.0	0.0

* Circumferential (compression is positive strain).
† Axial (compression is positive strain).
‡ Two gages at right angles (compression is positive strain).
§ Dummy gage on unstrained block.
¶ Gage failed before shot.

TABLE 3.6 STRAINS ON THE USS BONITA (SSK-3) FROM SHOT UMBRELLA

Position Number	Location *	Maximum Strain	Equivalent Depth †
		μ in/in	ft
S1	Frame 27 at crown	600	500
S2	Frame 27, 90 deg port	1,160	640
S3	Frame 52½ at crown	360	280
S4	Frame 52½, 26 deg port	350	270
S5	Frame 52½, 45 deg port	390	310
S6	Frame 52½, 90 deg port	200	230
S7	Frame 52½, 90 deg stbd	310	180

* All gages measured circumferential strain. Compression is recorded as positive strain.

† Change in depth of submarine which would produce same static strain as the largest dynamic strain observed. Strain gages were calibrated during deep-dive trials.

[redacted]

ships, the SSK-3, and the Squaw, primarily for the purpose of recording shock damage to machinery and equipment. The same gages and recording equipment were also used on the submarine SSK-3 as had been previously installed for Shot Wahoo. The description of this instrumentation has been included in Section 2.4.3. In general, all shipboard machinery and equipment-response instrumentation installed for Shot Wahoo was also used for Shot Umbrella.

In addition, a total of 16 velocity-meter gages and 16 shock-spectrum-recorder gages were installed on the items of simulated major shipboard machinery and equipment in the Squaw. Seven of the high-speed cameras were installed in the Squaw to measure the shock motions of this equipment, as well as the hull motions thereof, for correlation with the shock velocity-time and shock-spectra data.

Results. On all seven ships in the Shot Umbrella array, records of the shock motion versus time were made successfully with all electronic-velocity meters. Timing-signal equipment and zero-time fiducial signals functioned satisfactorily. Good records were obtained on all except six of the 170 shock-spectrum recorders installed. All but one of the 43 high-speed cameras gave satisfactory results, with good quality films. In general, all instrumentation functioned in an excellent manner.

The records of shock versus time obtained from minus two to plus 20 seconds after detonation showed several excitations. However, in all cases, the maximum shock velocity was produced by the direct-shock wave. Minor motions produced by a sea-bottom-induced-pressure wave preceded those from the directly transmitted wave.

Figure 3.49 shows a typical oscillogram record from one of the targets, the response of the direct-shock wave on the EC-2. Tables 3.7 and 3.8 show a tabulation for the EC-2 and DD-474 of the velocities, rise time, and average acceleration for both the initial direct shock and the later motion which occurred after about $\frac{1}{4}$ second. The tabulations interestingly show the general range of response motions on various items of machinery and foundations. The maximum vertical velocity of about 12 ft/sec on the EC-2, 7 ft/sec on the DD-474, 3 ft/sec on the DD-592, and less than 1 ft/sec on the DD-593 compared reasonably well with similar measurements taken for the hull studies.

An example of the shock-spectrum recorder-data, which has been read and reduced, is shown in graphical form in Figure 3.50.

The ship's machinery and equipment of the EC-2, located broadside at 1,600 feet from surface zero, had been previously disabled by Shot Wahoo and this severe damage was increased by Shot Umbrella. This further disabling damage occurred when the casting over the low-pressure cylinder of the main engine broke off. Additional brickwork in the boiler crumpled. Structural damage in the propeller shaft alley was markedly increased.

On the DD-474, stern-on[redacted]eet from surface zero, the ship's machinery and equipment damage could probably be classified as light but closely approaching the moderate-damage range. The bolts attaching the flexure plate that supports the main propulsion turbines and condensers to the ship hull structure were further deformed in both shear and bending. The flexure plate itself began to buckle. Misalignment resulting from these deformations may have seriously damaged the propulsion plant; this will be determined later in a shipyard tear-down inspection. It will be recalled that complete failure of these flexure-plate bolts would drop the turbine into the bilge, and at normal turbine speeds this probably would result in severe damage to the ship. Figure 3.51 shows the vertical velocity records at the bulkhead, at the flexure plate and on the foundations for high-pressure and low-pressure turbine subbases in the forward engine room of the DD-474. The average accelerations were 27, 9 and 6 g, respectively. In addition, the DD-474 ship's master gyrocompass was made inoperable because of failure of support springs. Brick work in three of the four boilers was out of place. The sonar-head motor fell off its supports, preventing operation. Further gun damage, breakage of light bulbs, and shattering of several water closets also resulted.

The shock damage was negligible on the DD-592 and DD-593 a[redacted]and[redacted]feet, respectively.

The shock damage to equipment on the SSK-3 a[redacted]foot range, bow-on, consisted of minor items such as loosened bolts attaching some equipment, the flooding of No. 3 torpedo tube, and

[redacted]

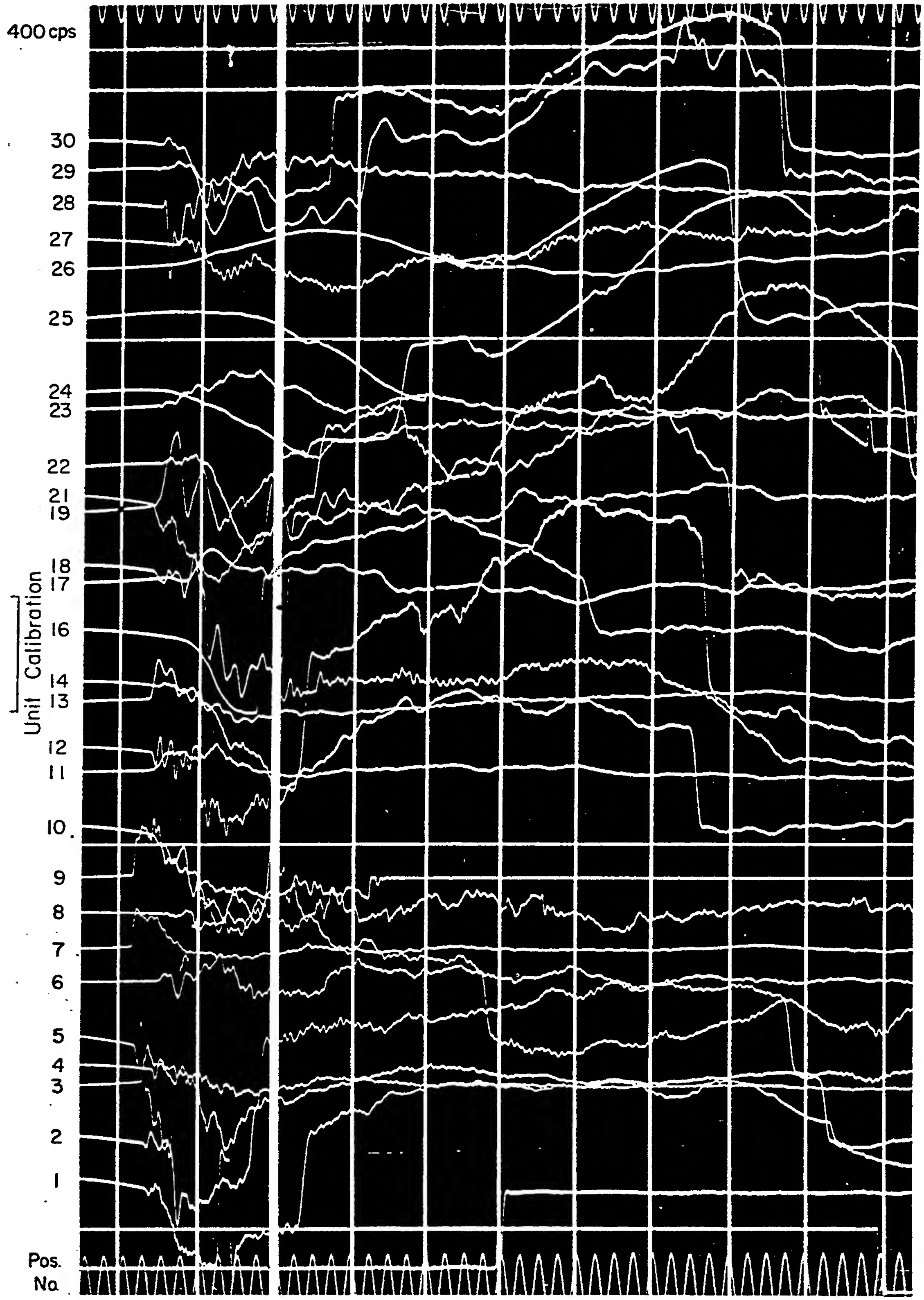


Figure 3.49 Oscillogram of direct shock wave on SS Michael Moran (EC-2) for Shot Umbrella.

[redacted]

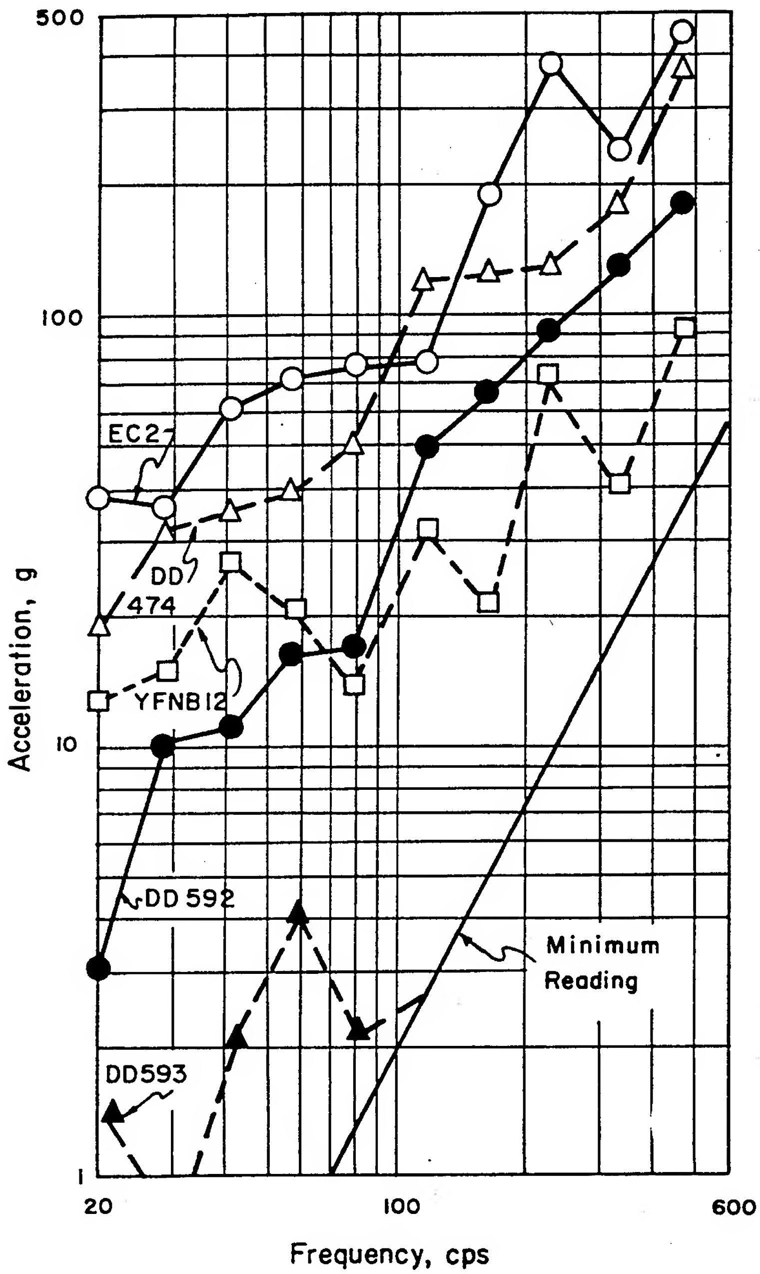


Figure 3.50 Shock spectra obtained near the bottom of a bulkhead on each of the surface targets, Shot Umbrella. Shock spectra are shown for Position 1 on EC-2, Position 17 on each of the three destroyers, and Position 2 on YFNB-12. On DD-593, deflections of the five highest-frequency reeds in the shock-spectrum recorder were all less than the minimum readable value.

[redacted]

some broken fluorescent light tubes. Since any of these items could be rectified within a few minutes, none was disabling.

The Squaw-29, submerged at 50-foot depth, at [redacted] feet from surface zero, stern towards the burst, sustained some simulated equipment damage. The steel weights simulating submarine main engines, generators, and motors had undergone severe response. One of the 24 bolts attaching the one simulated engine-generator failed in tension; the other 23 bolts were loose, many stretched as much as $\frac{1}{4}$ inch. In general, all mounting bolts for the simulated equipment on the

TABLE 3.7 VELOCITIES, RISE TIMES, AND AVERAGE ACCELERATIONS ON SS MICHAEL MORAN (EC-2) FROM SHOT UMBRELLA

Position Number	Orientation*	Location	Initial Shock			Later Motion †		
			Peak Velocity	Rise Time	Average Acceleration	Peak Velocity	Rise Time	Average Acceleration
			ft/sec	msec	g	ft/sec	msec	g
1	V	Bottom center Bulkhead 88	5.6	6	31	5.4	48	3
2	V	Bottom center Frame 97	8.6	1	210	4.9	40	4
3	A	Bottom center Frame 97	−6.3	1	−220	1.1	10	3
4	V	Bottom stbd Frame 97	10.7	4	79	5.3	12	13
5	V	Bottom port Frame 97	11.3 ‡	4 ‡	97	4.9	40	4
6	A	Low stbd Frame 97	−4.3	6	−25	−4.8	9	−17
7	A	Low port Frame 97	−24.9	1	−1,500	§	§	§
8	A	Higher stbd Frame 97	−8.4	11	−23	−4.8	7	−21
9	A	Higher port Frame 97	−35.3	3	−390	§	§	§
10	V	Subbase main engine	5.3	5	33	5.6	48	4
11	A	Subbase main engine	−2.4	8	−9	0.7	5	4
12	V	Foundation Caterpillar diesel	7.5	4	60	4.7	6	24
13	A	Foundation Caterpillar diesel	−6.7	1	−210	1.7	3	18
14	V	Foundation steam-generators	7.5 ‡	13 ‡	18	4.7	13	11
16	V	Top of main engine	7.5 ‡	7 ‡	33	4.0	9	14
17	A	Top of main engine	−3.1	3	−32	1.2	9	4
18	V	Caterpillar diesel	9.9	6	48	5.8	13	14
19	A	Caterpillar diesel	−5.0	3	−60	1.4	6	7
21	V	Platform deck Bulkhead 88	5.5	6	27	2.5	11	7
22	V	Platform deck Frame 83	5.5	8	22	5.1	27	6
23	A	Platform deck Frame 83	−3.5	13	−8	−2.7	37	−2
24	V	03 level Frame 89	4.5 ‡	18 ‡	8	7.1	46	5
25	V	Wheelhouse	8.1 ‡	25 ‡	10	9.7	57	5
26	A	Wheelhouse	−3.6	18	−6	§	§	§
27	V	Steering gear room	2.6	4	18	−1.1	25	−1
28	V	Shaft alley	9.7	1	600	§	§	§
29	V	Foundation operating diesel	5.9	3	61	5.5	37	5
30	V	Operating diesel	4.2	12	11	9.1	48	6

* Direction of measurement of motion: V, Vertical (motion upward is positive); A, Athwartship (motion to port is positive).

† Occurred about 0.24 second after initial shock motion.

‡ Meter bottomed at the limit of its displacement while velocity was still increasing.

§ Meter damaged after initial shock motion and gave no further record.

SSK-3 were loosened as a result of such stretching action. The YFNB-12, end-on at 2,350 feet, did not receive any equipment or structural damage.

Conclusions. The shipboard machinery and equipment shock damage on the target ships for Shot Umbrella occurred approximately as predicted. In the following conclusions of these studies, it should be understood that they apply to Shot Umbrella conditions:

1. The minimum safe range for delivery of an antisubmarine weapon by destroyers is [redacted] feet for Shot Umbrella conditions. Damage or malfunction of particularly delicate equipment (e.g., some types of electronic equipment) may occur at larger ranges.

2. The range for moderate damage for delivery of an antisubmarine weapon by destroyers is [redacted] feet for Shot Umbrella conditions.

3. The minimum safe range for a submarine is [redacted] for Shot Umbrella

[redacted]

conditions. Damage to particularly delicate equipment may occur at larger ranges.

4. The range for moderate damage to a submarine for Shot Umbrella conditions is from [redacted] feet.

5. Shock data defining the intensity and character of shock motions on merchant ships were obtained on an EC-2 at [redacted] feet from Shot Umbrella. At this range, complete disablement damage previously received was repeated and considerably increased.

6. Sets of shock motion data were obtained on all ships during Shot Umbrella.

7. Insufficient data still exist for correlating shock motion with damage to ship's equipment.

TABLE 3.8 VELOCITIES, RISE TIMES, AND AVERAGE ACCELERATIONS ON USS FULLAM (DD-474) FROM SHOT UMBRELLA

Position Number	Orientation *	Location	Peak Velocity †	Rise Time	Average Acceleration
			ft/sec	msec	g
1	V	Keel Frame 22	5.0	1	250
4	V	Foundation battery control	3.3	1	100
5	V	Battery control	3.5	1	110
6	V	Radio central Bulkhead 72	2.9	16	6
13	V	Keel Frame 99	5.7	1	230
17	V	Keel Bulkhead 110	3.4	3	32
18	L	Keel Frame 109	1.1	1	43
19	V	Flex plate Bulkhead 92½	2.4	1	120
20	V	Foundation reduction gear, fwd	3.1	2	61
21	V	Foundation reduction gear, aft	3.2	5	19
22	V	Foundation turbogenerator, fwd	4.1	12	11
23	A	Foundation turbogenerator, fwd	−1.9	21	−3
24	V	Foundation turbogenerator, aft	3.2	8	13
25	A	Foundation turbogenerator, aft	1.2	1	46
26	V	Reduction gear	4.6	5	30
27	V	Subbase HP turbine	5.6	18	9
28	V	Subbase LP turbine	5.6	27	6
29	V	Subbase turbogenerator	5.0	14	11
31	V	Main deck Bulkhead 110	4.5	12	11
33	V	Main deck Frame 107	3.8	16	8
34	V	Deckhouse top	6.6	18	8
46	V	Foundation 5-in. gun	5.5	3	60
48	V	Steering gear room	5.5	2	110
49	A	Steering gear room	2.0	1	45
50	L	Steering gear room	1.7	12	4
51	V	5-in. gun	7.5	12	19

* Direction of measurement of motion: V, Vertical (motion upward is positive); A, Athwartship (motion to port is positive); L, Longitudinal (motion forward is positive).

† Values shown are for the initial shock motion. An additional shock motion occurred about 0.19 second after the initial shock but values are not tabulated here. Peak velocities for the additional shock motion were somewhat smaller than for the initial shock and average accelerations were much lower.

The general lack of equipment damage, except on the EC-2, still leaves correlation of response data in the severe-damage range to be resolved.

8. The safe range and the damage for both submarines and surface ships is determined by shock damage to ship's machinery and equipment rather than hull damage, for both Shot Wahoo and Shot Umbrella conditions.

3.4.5 Summary. In summary, it is concluded that on Shot Umbrella, the results obtained from the projects in Program 3 were generally successful in achieving the main objectives of the program.

The responses and damages to hulls and to ships' machinery and equipment of the surface ships EC-2, DD-593, DD-592 and DD-474 were about as predicted. Response and damage to the submarine target, the SSK-3, was approximately as predicted. Response and damage to the Squaw-29 was somewhat less than predicted. The reason for the latter will be known only after

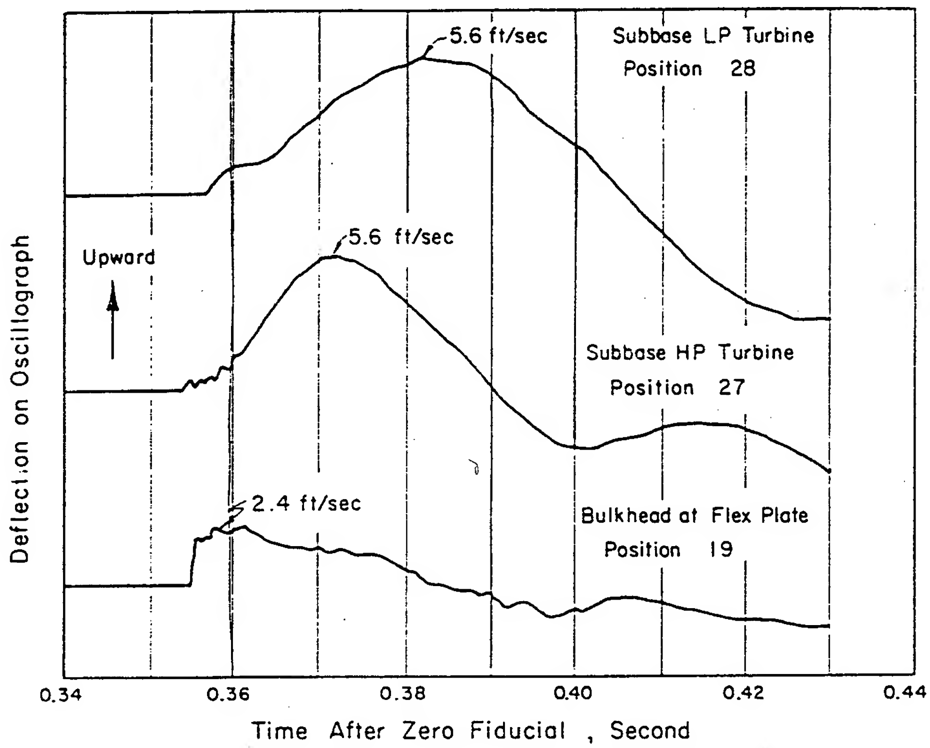


Figure 3.51 Vertical velocities of turbine foundation and subbases in USS Fullam (DD-474), for direct shock wave from Shot Umbrella.

detailed analysis of results. However, it may be due to a greater than estimated hull strength.

The EC-2 merchant ship located broadside (starboard) a[redacted]eet from surface zero sustained light hull damage similar to that previously received on Shot Wahoo, broadside (port). A maximum transient displacement of about four inches in the hull-side frames near the ship's center produced a maximum permanent hull-side-frame displacement of about 1 ½ inches. Maximum permanent hull-plate dishing between frames was about ¾ inch. Hair-line fracture cracks at various minor locations on the steel hull deck and superstructure were found. The propeller shaft alley tunnel was further seriously distorted, to a maximum of about 12 inches. As after Shot Wahoo, minor hull flooding, caused by leaks in the hull, was controllable by pumping. In contrast to the light hull damage, the severe disabling damage previously caused by Shot Wahoo to the ship's machinery and equipment of the EC-2 was further increased by Shot Umbrella.

As expected, there was no hull damage to the DD-474, the destroyer closest to surface zero and located stern-to a[redacted]oot range. However, a slight buckle in the after stack of the DD-474 bent bulwarks around the after gun tubs, and a slightly buckled mast was produced by a combination of shock and the surface water-wave passage over the stern. The ship's machinery and equipment damage on the DD-474 could probably be classified as light but closely approaching the moderate-damage range. The flexure-plate bolts which support the foundations to the main turbines were further deformed in both shear and bending. Misalignment between the turbine and propulsion shaft resulting from the bolt deformation was taken up in the coupling. Although the turbine still operated at the normal 400 rpm cruising propeller-shaft speed through and after the shot detonation, an increased machinery noise level indicated that the deformations may have

[redacted]

seriously damaged the propulsion plant. This will be determined later in a shipyard tear-down inspection. Other damage on the DD-474 consisted of ship's master gyrocompass made inoperable; brickwork in three out of four boilers knocked out of place; further five-inch gun damage occurred; and several water closets were shattered.

Hull and machinery shock damage on the other surface target ships on Shot Umbrella was considered negligible.

There was no hull damage of the SSK-3, submerged at a depth [redacted] and located bow-on at [redacted] foot range. Shock damage to equipment consisted of minor items, such as loosened bolts attached to some equipment and flooding of one torpedo tube. None of this shock damage was disabling, and it could have been rectified within a few minutes.

Hull damage to the Squaw-29 was less than expected; lethal damage and flooding of the pressure hull did not occur. However, four of the ten external ballast tanks ruptured. Maximum permanent plastic deformation of the $\frac{7}{8}$-inch pressure hull plating was about $\frac{1}{4}$ inch between frames. Some equipment damage occurred on the Squaw, including tension failure of one $\frac{7}{8}$-inch diameter equipment hold-down bolt and up to $\frac{1}{4}$-inch stretching of numerous other hold-down bolts, indicating all equipment had undergone severe response.

From the results obtained, there was confirmation that the safe range and damage range for submarine and surface ship targets, under Shot Umbrella conditions, is determined by shock damage to ships' machinery and equipment, rather than by hull damage.

The following other preliminary conclusions drawn from Shot Umbrella data with respect to both hull and shock damage to ships' machinery and equipment are considered significant. It should be understood that these apply to the shallow water Shot Umbrella conditions.

1. From the standpoint of hull deflection, the estimated lethal range for an EC-2 merchant ship [redacted] feet for Shot Umbrella conditions.

2. The severe or crippling shock-damage range for machinery and equipment of an EC-2 merchant ship [redacted] feet, under Shot Umbrella conditions.

3. The minimum safe range for repeated delivery of an antisubmarine weapon by destroyers [redacted] feet for Shot Umbrella conditions. Damage or malfunction of particularly delicate equipment, i.e., electronic equipment, may occur at larger ranges.

4. The minimum safe range for single delivery of an antisubmarine weapon by destroyers, with shipyard availability soon after, [redacted] feet for Shot Umbrella conditions.

5. The minimum safe range for delivery of an antisubmarine weapon from a submarine is [redacted] for Shot Umbrella conditions. Damage to particularly delicate equipment, i.e., electronic equipment, may occur at range [redacted]

6. Considerable basic information on hull response on surface ships as related to free-field pressures and loading measurements was obtained. This has provided check points for small-scale ship model experiments, which, upon further analysis, are expected to prove valuable in extrapolating results of Shot Umbrella to other geometries and ships.

7. From the standpoint of ship damage important to combat capability, the safe range for surface ships likely to delivery nuclear underwater weapons in the foreseeable future is determined by shock damage to equipment, rather than damage to the hull.

8. Further shock testing of both destroyer and submarine types is believed necessary at ranges where more severe damage will occur, in order to provide information required to more adequately shock harden the designs of these types of ships.

3.5 NAVAL MINE FIELD CLEARANCE BY ATOMIC UNDERWATER BURSTS

3.5.1 Objective. The objective of this experiment was to determine the ranges at which typical stockpile U. S. Naval bottom mines would be neutralized by a shallow water nuclear burst.

In general, Operation Hardtack offered realistic test parameters for providing field data on the feasibility of clearing bottom mine fields with nuclear weapons, since most bottom mines would normally be planted [redacted] The data obtained may be used in conjunction with other experimental data and theory to determine the probable effectiveness of nuclear weapons as a Naval mine countermeasure for all types of underwater mines.

[redacted]

3.5.2 Background. Mines that employ combination-influence mechanisms, delayed-arming devices, variable-ship counts, and anti-sweep devices may present a difficult problem to a mine-sweeping force. Explosive-clearance techniques could be used to destroy such a mine barrier in certain tactical situations, since any type of Naval mine may be neutralized by explosive means in several ways. Simple single-look mine mechanisms may be actuated by explosive shocks; acoustic mines may be actuated by explosions at ranges of several miles; single-and-combination-influence mechanisms may be damaged physically by explosive shock; and sensitive mine detonators may be initiated by near-contact explosions. However, all available data on response of mines to explosives indicate that case rupture is the proper criterion by which to consider a mine destroyed.

The mine characteristics of a typical mine such as the mine [redacted] are presented so as to provide a background for further details about this project. This stockpile mine is an aircraft-laid bottom mine that may be dropped without a parachute from altitudes [redacted] Specially designed shock mounts within a strong case prevent damage to components when the mine strikes the water. The mine is equipped with an induction-firing mechanism actuated by currents induced in a search coil by the magnetic field of a ship. The mine may be used against [redacted] This mine is one of the most difficult mines to render inoperative with explosives.

To provide additional background, a brief discussion is presented on the latest additions to the Navy mine arsenal. In the latest designs, there are influence-field detectors and associated firing mechanisms of three types (pressure, acoustic, and magnetic). The mine Mk 52 Mod 1 employs a magnetic-firing mechanism. The Mk 52 Mod 3 uses a combination of two firing mechanisms that respond individually to the magnetic and pressure-influence fields of a vessel. The Mk 52 Mod 6 uses a combination of three firing mechanisms, pressure, and acoustic.

The characteristics of each firing mechanism may be varied over a considerable range by choice of switch settings or plug-in circuits. All modifications of the Mk 52 mine have variable delay-arming times, sterilization times, ship counts, and inter-ship dead period. The total number of possible combinations of operational settings for the Mod 6 is 5,760. This mine is extremely difficult to sweep.

In situations where a nuclear detonation occurs underwater, the shock wave is of much longer duration than the shock wave from conventional mines and depth charges. Damage to mine cases corresponds in static manner to maximum pressure. This criterion is used in "Capabilities of Atomic Weapons," (Reference 15), to obtain curves of range versus yield for underwater mine-field neutralization. Consequently, the following criteria for mine damage were used in selecting mines at each range for Shot Umbrella:

[redacted]

3.5.3 Instrumentation. Two types of instrumentation were used: mechanical peak-pressure gages and mine-operation monitors. The mechanical-pressure gages provided the means by which the peak pressure of a shock wave of known time dependence could be computed from the deformation of a small copper sphere, compressed by a pressure-actuated piston.

[redacted]

The mine-operation monitoring system was designed to be mounted inside the mine in the space normally occupied by the booster and extender. The system was fitted in the booster compartment of the mine. Basically, it was a miniature tape transport that could transport 160 feet of ½-inch tape across a six-channel recording head for a period of 14 days. When the mines were planted, a hydrostatic switch was operated by the increase of water pressure with depth. In the case of the Mk 50, this switch simultaneously armed the mine and started the mine-operation monitoring system. All events recorded on the tape could then be related to the time of planting. In the case of mines Mk 39, 52, and 25, Mod 2, the hydrostatic pressure initiated a clock-delay mechanism, which delayed mine arming and recorder initiation for a preset period. The time of arrival could, therefore, be determined with respect to planting time. An indicator was installed in each mine to put a 10-second signal on one of the channels of the tape not used for mine actuations. The indicator was simply a one-shot multivibrator of 10-second period that would be triggered by the pulse emitted by a piezoelectric crystal when the shock wave impinged on the mine case.

The playback system consisted primarily of a tape transport, a time counter, and a readout device. This was installed on Site Elmer. As soon as the recorders were removed from the mines, the tape magazines were removed for processing.

In order to determine the effects of the nuclear detonation upon the mines as a function of distance, the mines were planted in rows at distances of between 1,500 and 8,000 feet from surface zero. The first three rows contained one or more mines of each type. The extent of damage to the mines at each range was determined by visual observation and measurements of deformation upon recovery. The distance of each mine from surface zero was computed from bearings and radar fixes made by means of the navigational equipment aboard the USS Takelma (ATF 113). The distance values are considered to be accurate to ± 20 yards.

The extent of mechanism damage incurred by each mine type at each range was determined by visual inspection.

After recovery, all mines were given operational tests with standard mine-test sets, in order to determine whether or not all components were functioning normally after the shot.

The operations of 23 mines of various types, planted at various distances, were monitored for a period of time, extending from the time at which the mines were armed to the time of recovery, by means of the system of internal recorders. The types and locations of these instrumented mines are indicated in Figure 3.52.

In order to extrapolate the mine-neutralization data to different weapons, a knowledge of the pressure-time histories at various ranges from Shot Umbrella was desired. In the final report (WT–1641), the pressure-time recordings and ball-crusher-gage data obtained by Project 1.1 will be correlated with that obtained by Project 6.7.

Water depths of all mines laid by the USS Takelma were measured with a fathometer. Data on the bottom characteristics of the Shot Umbrella target area was furnished by Project 1.13. This data will be useful in scaling mine-neutralization ranges for weapons of various nuclear yields in future studies of the mine-clearance problem.

All mines in the first row were completely demolished. The distances and mine types involved in the close-in area are given in Table 3.9. Damage sustained by a Mk 25 Mod 2 at 1,380 feet from surface zero is illustrated in Figure 3.53.

The effects produced by Shot Umbrella at distances greater than 1,600 feet are listed in Table 3.10. The type of damage suffered by Mk 25 Mod 2 mines at 1,980 feet is illustrated in Figure 3.54. These were the only mines in the second row that suffered case damage. [redacted]

[redacted]

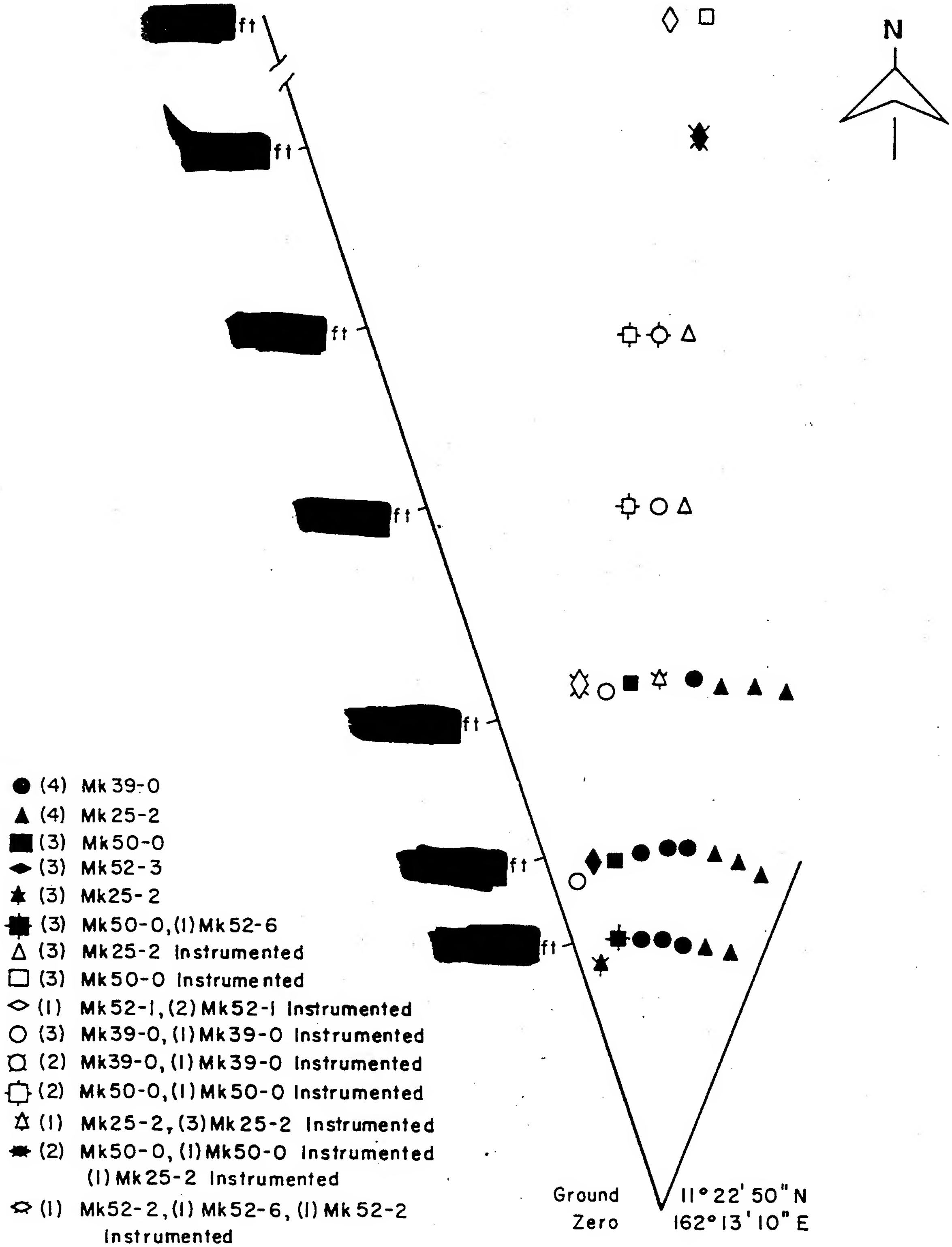


Figure 3.52 Layout of mine field.

[redacted]

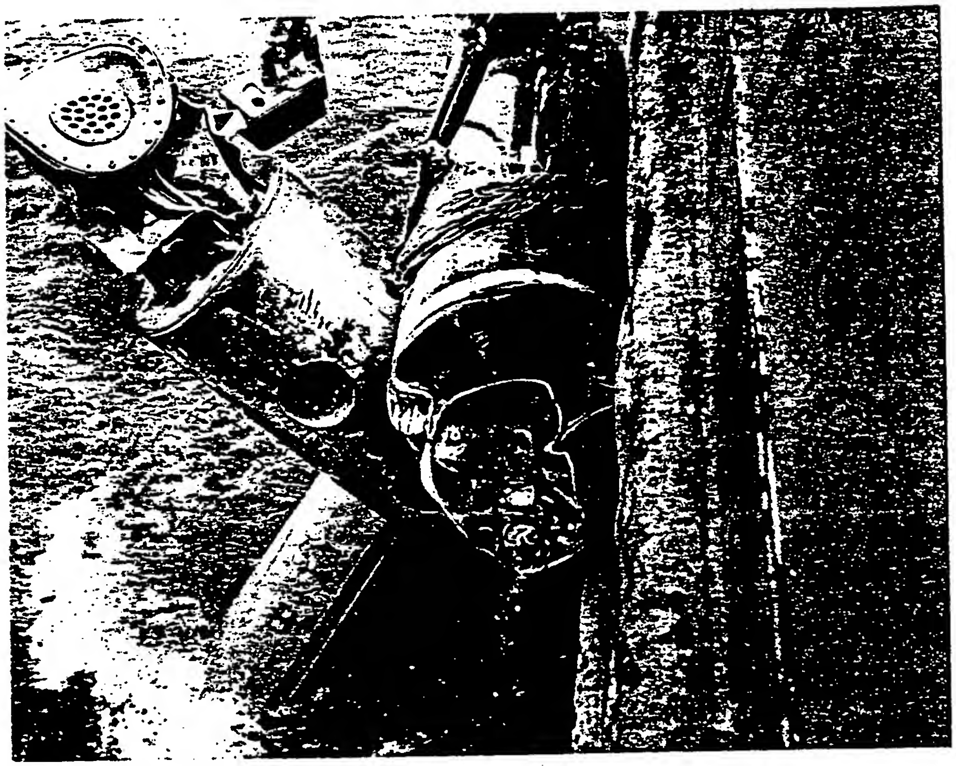


Figure 3.53 Damage to mines Mark 25-2 at [redacted]

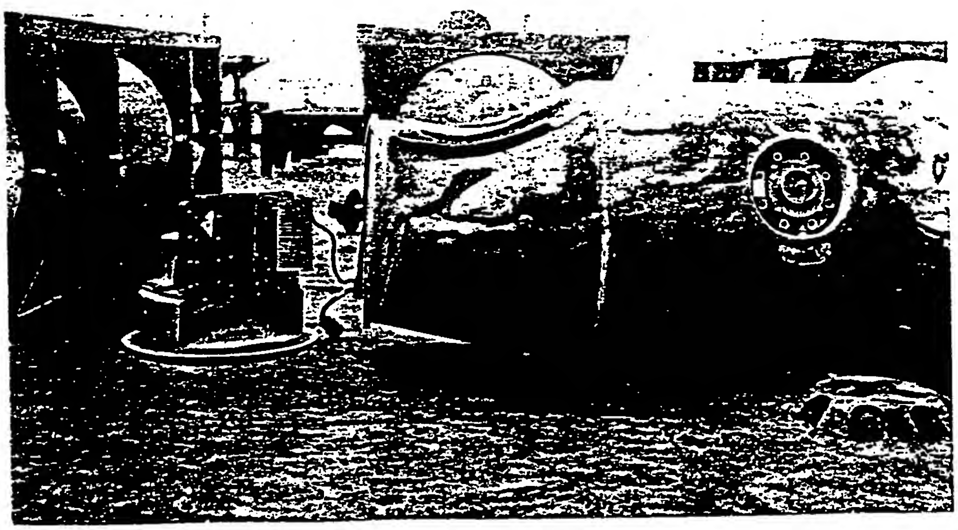


Figure 3.54 Damage to mines Mark 25-2 at [redacted]

Pages 182 through 185 are deleted.

[redacted]

the instrumented mines. The cause of the failure of the firing mechanisms M-11 of the two Mk 39 Mod 0 mines and the ACM circuits of the Mk 50 Mod 0 mines is not as yet known.

The mine actuations, by type, that occurred at time of Shot Umbrella are presented in Table 3.11 for mines located from 1,920 feet to 4,000 feet from surface zero. The type of actuations recorded are similar to those that have been recorded in counter-mine tests using high explosives. At the time of the shot, none of the mines fired. The pressure looks which occurred at the time of the shot are assumed to have been caused by closures of the sensitrol relay, SR-9, by shock.

All mechanical-pressure gages were recovered. Eight of the gages did not function. The deformations from the remaining 20 were measured, and the peak pressures were computed. Since the time dependence of the shock waves at various distances from surface zero will not be known until made available by Project 1.1, the peak pressures were computed on the assumption that the time dependence of the shock wave was a simple step function. These values, plotted as a function of distance from surface zero, are presented in Figure 3.55. Since the time constant of the shock wave is expected to be long, the step response approximation is warranted; however, the values in Figure 3.55 should be considered as preliminary.

[redacted]

3.5.4 Feasibility of Wide Area Clearance of Naval Influence Mines by Nuclear Weapons. The overall objective of the project was to determine the feasibility of employing nuclear weapons for wide-area mine clearance by influence means. To accomplish this, the specific objectives of the program were: (1) to measure and record the amplitude, duration, and extent of mine-actuating influences (pressure, acoustic, and magnetic) which may be generated at the sea bottom by the explosion of a low-yield (8 to 13 kt) nuclear weapon in shallow water (approximately 150-foot depth); (2) to determine the reaction of certain instrumented U. S. Naval mines to the influences generated; and (3) to evaluate the effect of influences generated in sweeping single-influence and combination mines.

Project 6.8 was planned on the basis of obtaining data from Shot Umbrella. Data for checkout and calibration purposes was obtained from Shots Wahoo, Yellowwood, and Tobacco. Three LCU instrumentation platforms were located at distances of 8,300, 20,150 and 44,750 feet from surface zero of Shot Umbrella. Figure 3.56 shows the locations of the instrumentation platforms, relative to surface zero, for each of the four shots. Figure 3.57 shows the location of underwater instrumentation with respect to one of the three platforms. Table 3.12 identifies the underwater units and provides code numbers by which results are identified with a specific underwater unit.

3.5.5 Data Requirements. Data was required in order to obtain information on the duration, extent, and characteristics of mine-actuating influences resulting from Shot Umbrella and to determine the reaction of certain instrumented U. S. Naval mines to the influences generated. Instrumentation to obtain the following data was provided:

1. Pressure Measurements: The time-pressure history resulting from the shot. Included were pressure changes due to waves, swells, and the shock wave.
2. Magnetic Measurement: The time history of the magnetic-field changes.
3. Acoustic Measurements: The time history of the sound-pressure level, 2 cps to 40 kc.

Page 187 is deleted.

[redacted]

TABLE 3.11 CONTINUED

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

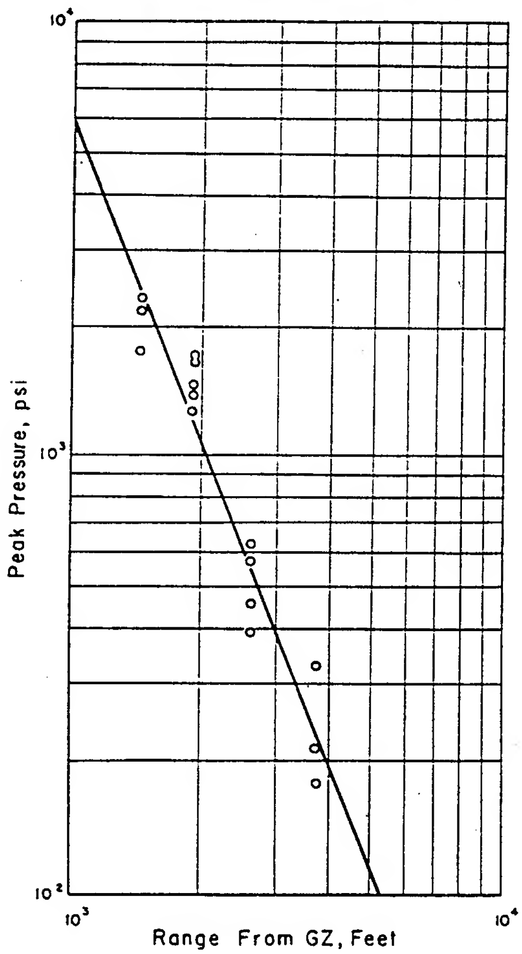


Figure 3.55 Peak pressures computed from mechanical-pressure-gage deformations, assuming step response.

[redacted]

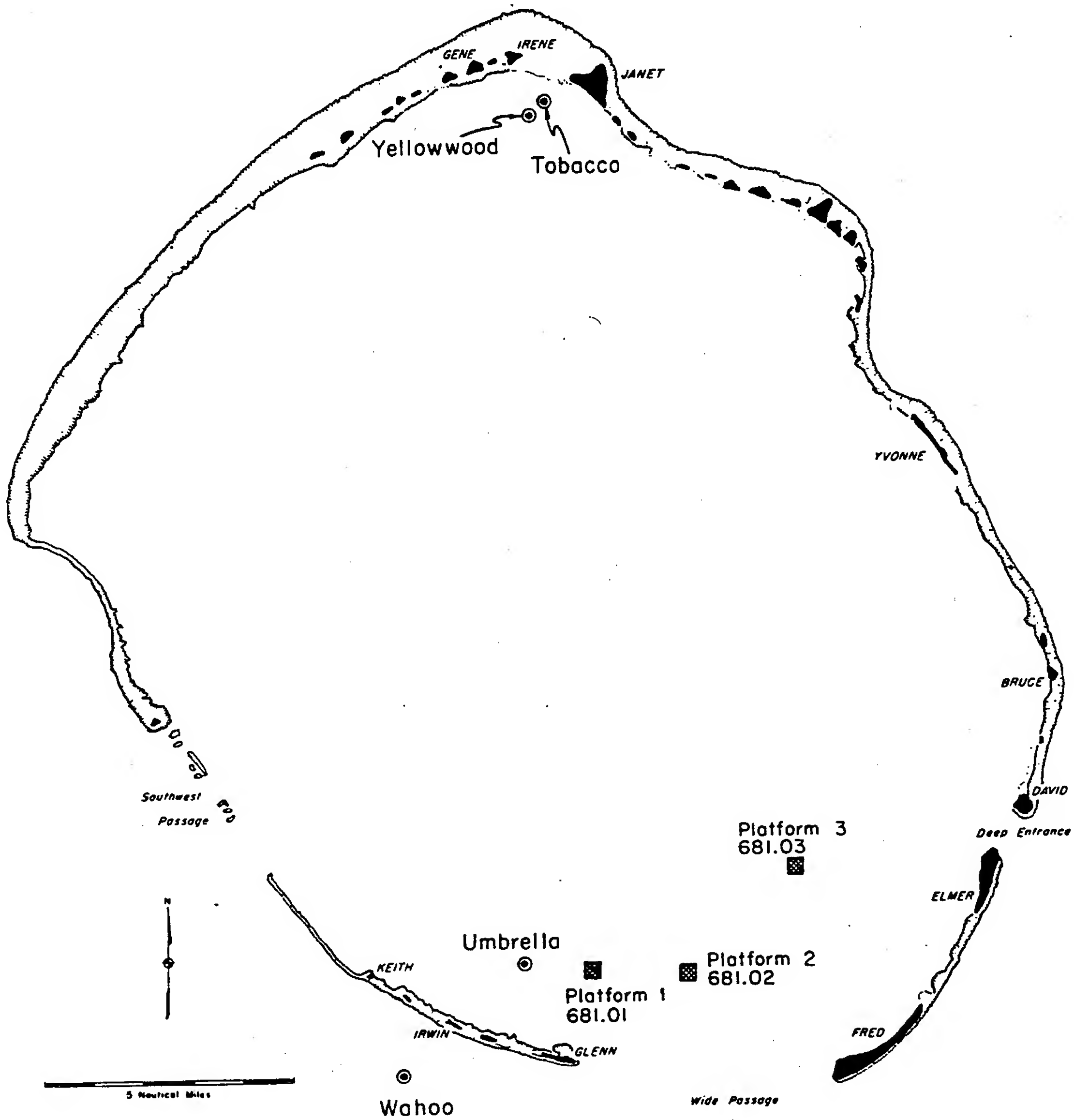


Figure 3.56 Location of instrument platforms relative to surface zero for Shots Umbrella, Wahoo, Yellowwood, and Tobacco.

[redacted]

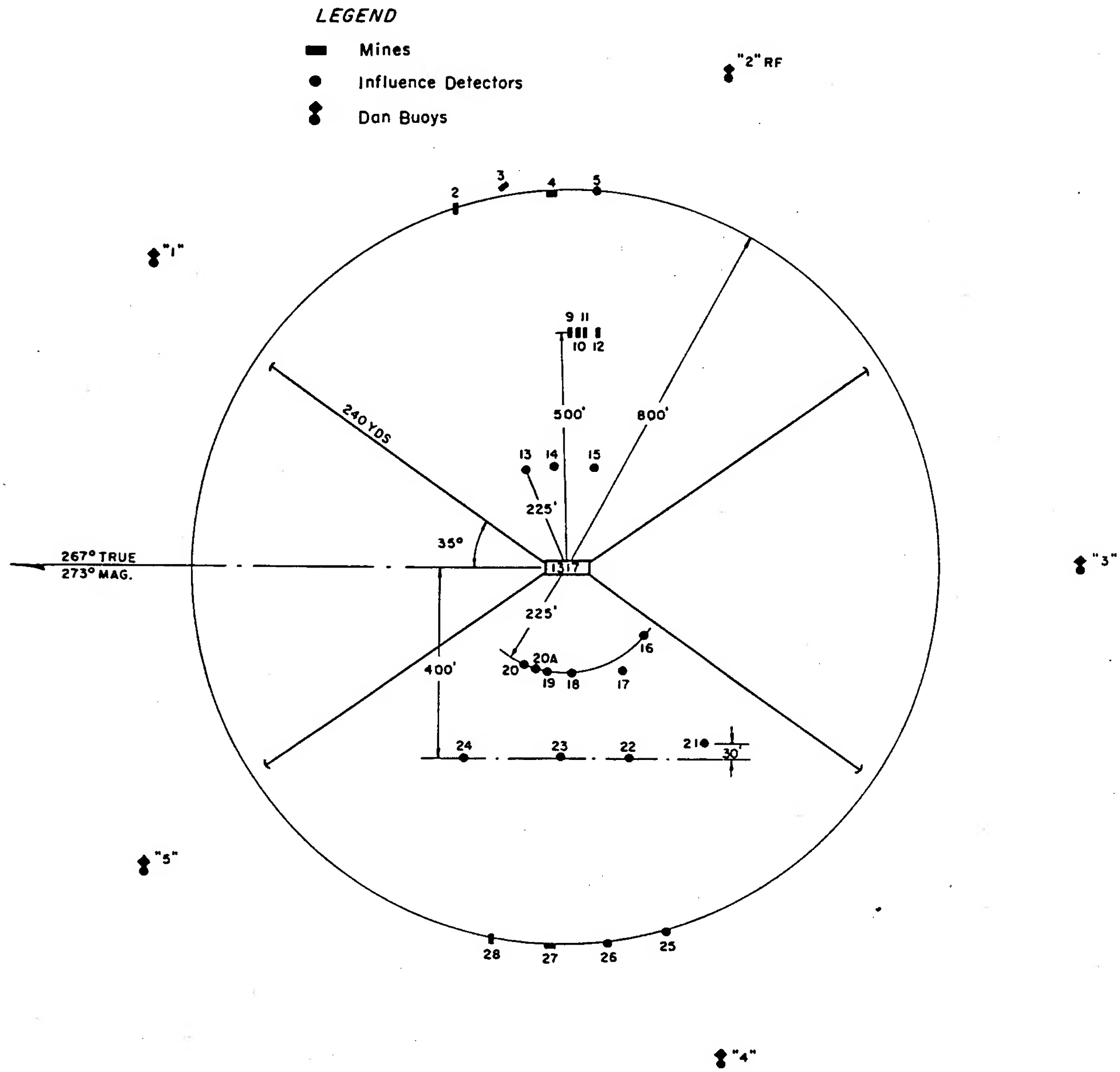


Figure 3.57 Schematic of underwater instrumentation and mines relative to Platform 1 (Station 681.01). For identification of code numbers of underwater units, see Table 3.12.

[redacted]

4. Seismic Measurements: The time history of displacement of the bottom (limited data).
5. Mine Reaction:

Mk 25 Mod 0: looks, fires, and search-coil output.
Mk 25 Mod 2: looks, pressure-switch opening, fires, and search-coil output.
Mk 36 Mod 2: ACM, fires, and plate-voltage rise.
Mk 50 Mod 0: ACM, fires, and plate-voltage rise.

6. Correlation of all influence measurements and mine reactions with respect to time.

As a typical example of the instrumentation utilized, there follows a detailed description of

TABLE 3.12 ARRAY SPECIFICATIONS FOR PLATFORM 1, STATION 681.01

Item Number *	Mine/Instrument Type	Serial Number	Depth of Water	Distance from Platform Center †	Bearing from Platform Center ‡	Orientation of Item §
			ft	ft	deg true	deg magnetic
1	LCU 1317	—	140	—	—	273
2	Mine Mark 25 Mod 0	1M1	145	800	339	000
3	Mine Mark 25 Mod 0	1M3	145	825	347	045
4	Mine Mark 25 Mod 0	1M2	145	790	354	090
5	Total Field Magnetometer	8	145	800	001	—
9	Mine Mark 36 Mod 2	1A1	140	500	357	176
10	Mine Mark 36 Mod 2	1A2	140	500	359	176
11	Mine Mark 50 Mod 0	1A3	140	500	001	176
12	Mine Mark 50 Mod 0	1A4	135	500	004	176
13	½-Inch Tourmaline Gage	130	140	225	334	—
14	½-Inch Tourmaline Gage	134	140	225	349	—
15	½-Inch Tourmaline Gage	128	140	225	010	—
16	Hydrophone BC-50	98	142	225	127	—
17	Hydrophone BC-50	102	142	250	147	—
18	Hydrophone BC-50	104	142	225	173	—
19	Geophone Vertical	453	142	225	—	—
20	Geophone 3-Component	422	142	225	—	273
20A	Geophone 3-Component	490	142	225	193	273
21	Pressure Pickup 0.2-Inch-100-Inch Range	30	140	475	138	273
22	Pressure Pickup 300 Pound	L8V	140	425	158	273
23	Pressure Pickup 0.2-Inch-100-Inch Range	32	140	400	178	273
24	Pressure Pickup 0.2-Inch-100-Inch Range	31	140	460	205	273
25	Total Field Magnetometer	3	143	800	161	000
26	Total Field Megnetometer	5	143	800	170	000
27	Mine Mark 25 Mod 2	1MP2	143	800	179	090
28	Mine Mark 25 Mod 2	1MP1	143	800	188	000
"1"	Dan Buoy Mark 5	—	—	1,100	303	—
"2"	Dan Buoy Mark 5	—	—	1,100	015	—
"3"	Dan Buoy Mark 5	—	—	1,100	087	—
"4"	Dan Buoy Mark 5	—	—	1,100	159	—
"5"	Dan Buoy Mark 5	—	—	1,100	231	—

* Items correspond to item numbers shown in Figure 3.57.
† Accuracy of distance from platform center is ± 20 feet.
‡ Accuracy of bearing from platform center is ± 1 degree.
§ Accuracy of orientation is ± 3 degrees.

the instrumentation for pressure measurements. (Comparable instrumentation was utilized to obtain acoustic, magnetic, and seismic measurements.) Pressures covering the range from 0.2 inch of water (0.0072 psi), peak to peak, to 2,768 inches of water (100 psi) were recorded in three channels of information. The first channel recorded peak-to-peak pressures from 0.2 to 20 inches of water, and the second channel recorded peak-to-peak pressure from 1 to 100 inches of water. The third channel recorded to 100 psi. The upper frequency cutoff of the high-pressure pickup (100 psi) was approximately 500 cps.

[redacted]

Pressures were recorded as a function of time prior to time zero and for a period of approximately 20 minutes thereafter. The 20-inch and 100-inch pressure signals were detected by an MDL pressure pickup, using a Wiancko ± 10-psi gage, Type 1404. The + 100-psi pressure signals were detected by an MDL pressure pickup using a Wiancko ± 100-psi gage, Type 1404. The pressure pickup containing the ± 10-psi gage had been modified by the addition of a low-pass hydraulic filter to prevent damage to the gage during fast rise-time high pressures.

3.5.6 Playback System. A block diagram of the pressure instrumentation is shown in Figure 3.58. This system, with the exception of the high-pressure pickup, was duplicated at each station. The MDL pressure-amplifier detector and the MDL pressure pickups were developed at the U. S. Navy Mine Defense Laboratory (formerly U. S. Navy Mine-Countermeasure Station), prior to this project. Information concerning this portion of the pressure system may be obtained from USNMCS Report No. 46 (Reference 16). The 7-channel tape recorder was Ampex Model FR-107. The buffer amplifier used to drive the high-pressure bridge was a push-pull triode circuit with transformer coupling and was identical to the buffer amplifier in the pressure-amplifier detector that drove the low-pressure bridge. The high-pressure bridge was similar to the low-pressure one in the pressure-amplifier detector, but it operated in a balanced condition and used an additional RC network to balance out the reactive component of the current in the bridge. The inputs to the 20-inch and 100-inch cathode followers were connected to the range-switch-voltage divider in the pressure-amplifier detector at the 2-inch and 20-inch points, respectively. The output of each of the cathode followers was fed into a resistive bridge, and the wiper output was fed to the tape recorder. The bucking voltage supply was also fed to this bridge, and, by adjustment of the potentiometer in the bridge circuit, the direct-current bias of each of the cathode followers could be balanced out. The bucking voltage power supplies were simple bridge rectifier types supplied with a floating output of 150 volts dc. By relay action, the pressure-calibration panel operated the calibrate power supply in the pressure-amplifier detector, which in turn produced the calibrate action in both the high-pressure and low-pressure pickups.

An example of a typical monitoring system is that which was used on the Mk 25 Mod 0 mines. A block diagram of the mine-monitoring system is shown in Figure 3.59. (Comparable systems were utilized to monitor Mk 25 Mod 2, Mk 36 Mod 2, and Mk 50 Mod 0 mines.) The mine-control panel remotely controlled power to the firing mechanism and dc amplifier in the mine by means of a relay in the mine. Magnetic signals detected by the search coil produced voltage changes which were fed to the firing mechanism and were also monitored by means of the amplifier. Information on the look and fire reactions of the firing mechanism were monitored by pen recorders. Search-coil voltage was monitored by a frequency-modulation (FM) channel of a tape recorder. A step change magnetic signal was fed from the trailer to the 10-turn coil placed around the search coil for use in calibration of the search-coil voltage monitor and to check operation of the overall system.

The mine-reaction data (looks and fires) were of the go-no-go type, causing a pen deflection for about one second. The search-coil-voltage data was essentially the output of the three pulse-per-second oscillator in the M-11 firing mechanism as seen by the search coil. In the ambient condition, the pulses appeared across the search coil at comparatively low magnitude; when a voltage appeared across the search coil, the pulses showed a change in amplitude. The relative direction of the pulse spikes, both in the ambient-field condition and with search-coil voltage applied, was an indication of direction of search-coil voltage and, hence, of magnetic-field change. The nature of this information is not particularly conducive to interpretation. For this reason, calibration signals of at least six levels from 0.02 milligauss to 5.0 milligauss in both directions were required immediately prior to the shot.

A representative mine idealization and checkout was that performed on the Mk 25 Mod 0 and Mk 25 Mod 2 mines. The preparation of the mines was accomplished with the background (earth's) field vector aligned in the same direction with respect to the mine as it was when planted. (Before idealization, the search coil was removed from the mine and placed at least 50 feet away from the idealizer.) Since mines were planted in each of three orientations, the

[redacted]

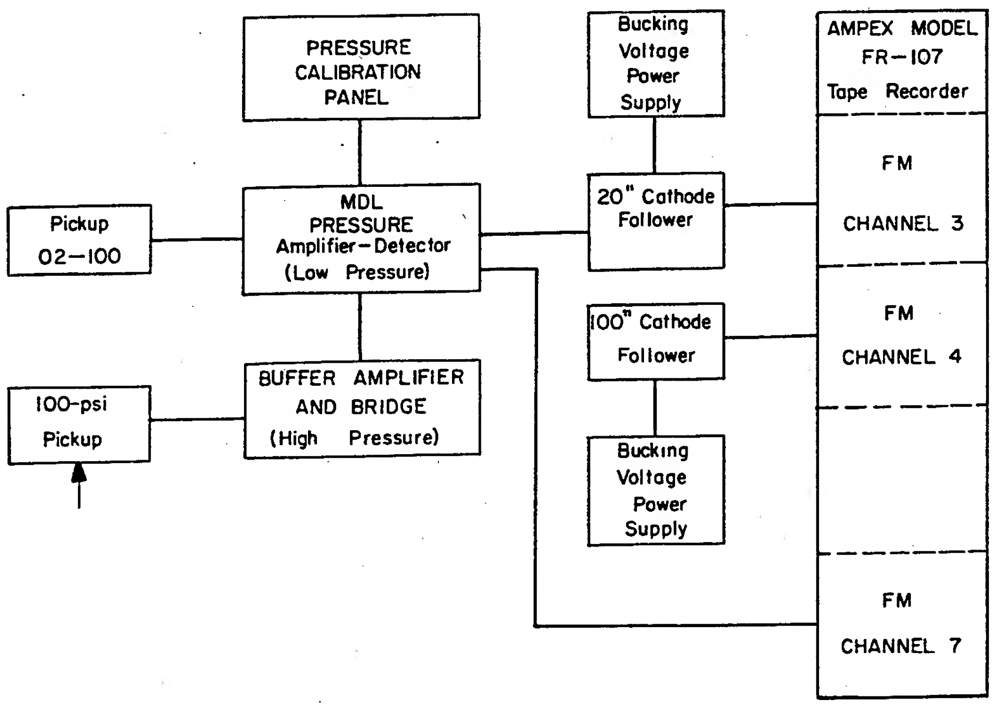


Figure 3.58 Block diagram of pressure measuring system.

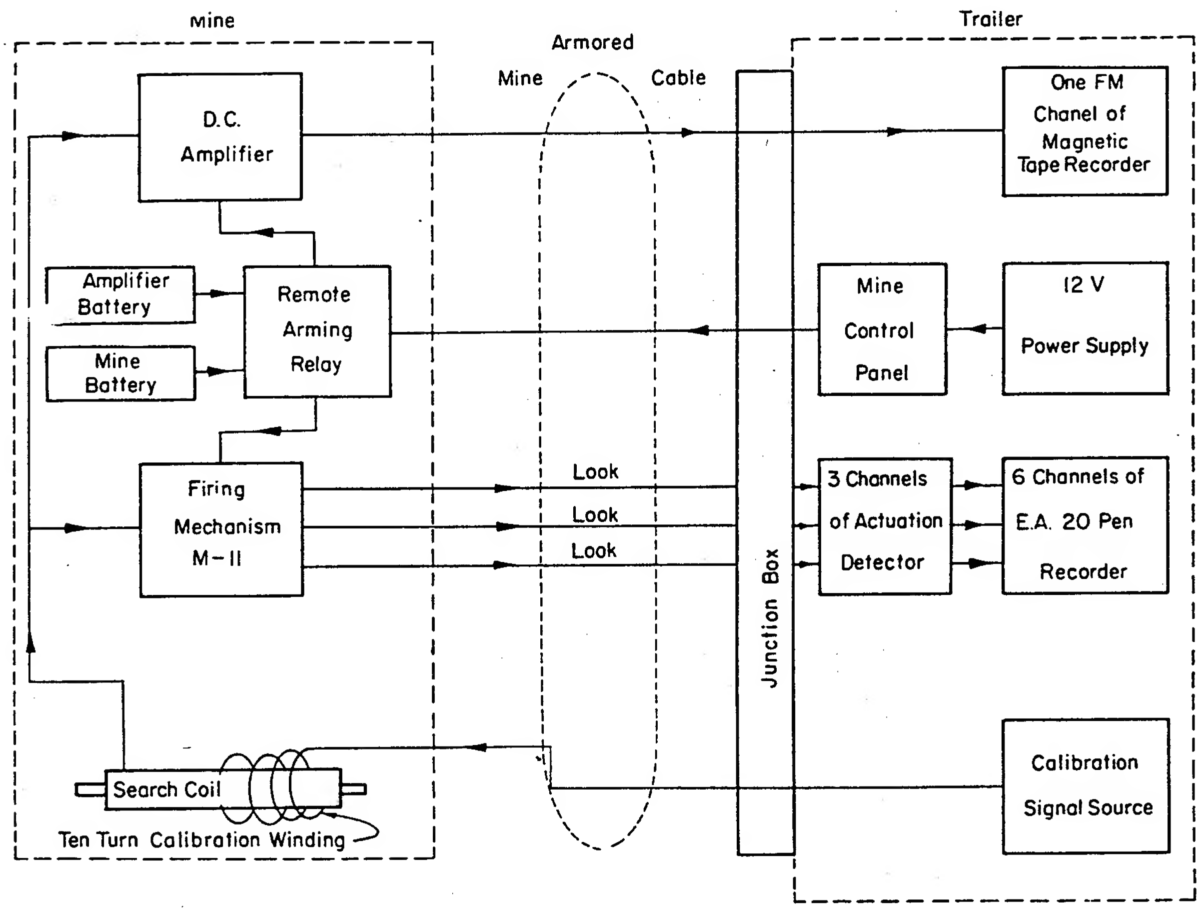


Figure 3.59 Block diagram of monitor system for mine Mark 25 Mod 0.

[redacted]

idealizer was oriented depending on the particular mine being idealized. Idealized mines were handled with care and were stored and repaired, while the specific orientation with respect to the earth's magnetic field was maintained. Preliminary checkout and calibration phases were accomplished with standard mine test sets and special test sets developed specifically for these monitored mines. Spurious magnetic-field changes were minimized during calibration.

The idealizer used (Figure 3.60) consisted of a coil system (with cart and track for moving the mine), a control unit, and a 100-foot cable connecting the two. The control unit operated on 230-volt, three-phase ac and distributed power to both coils of the coil system. The shaking field, a schedule of square pulses whose magnitude decayed with each pulse until the envelope reached essentially zero, was produced by one coil. The schedule was automatic after initiation and was cut off when the schedule was complete, approximately 40 minutes later. A second winding on the coil was available to correct the earth's field if a distorted background field, due to local anomalies, was encountered. Use of the second winding was not required.

The Mk 36 Mod 2 and Mk 50 Mod 0 mines were checked out by means of standard mine-test sets and special-test sets developed for these particular mines. Spurious acoustic background signals during calibration were minimized.

Control of the electronic equipment at each station was derived from a program-control unit actuated by the central-timing system at shot time minus five minutes. The program-control unit provided step-by-step control of the instrumentation, so the tape recorders were started and the influence measuring systems were calibrated prior to time zero. A backup system was provided to start the electronic system at H−5 seconds in the event of failure of the primary control system.

For Shot Umbrella, time zero was obtained by the use of a fiducial marker provided by Edgerton, Germeshausen and Grier (EG&G). On Shots Wahoo, Yellowwood, and Tobacco, the timing system was initiated by the minus-1-second radio signal provided by EG&G. To obtain time relative to time zero for all data, a one-kc signal, interrupted once each second, was superimposed on one channel of each magnetic-tape recorder. A pen deflection synchronized with the magnetic-tape signal was recorded at intervals of one second on each of the 20-pen operational recorders. The time-zero indication was impressed on both the one-kc signal and the pen recorders. The timing pulses were generated by an escapement mechanism that controlled the firing of a thyratron tube, which generated timing pulses that controlled both the magnetic-tape and paper-tape timing indications.

LCU hulls 634, 1123, and 1317 were employed as platforms to mount the trailers housing the monitoring instrumentation. All three installations were similar and had been standardized to the maximum practical extent. Figure 3.61 shows one installation (Platform 1). Padeyes were installed on the deck of each LCU for turnbuckle-pendant tiedown connections. As a further deterrent to movement from shock and for better stability, each set of trailer wheels was placed in steel chocks welded to the deck.

Power for instrumentation for each trailer was supplied by three 5-kw generators. Two were operated on load, with the third in a standby capacity. In case of failure of one of the operating generators, a transfer switch was provided to accomplish a changeover to the third generator. The generators were shock-mounted directly to the deck. Connections to the instrumentation were made through water-tight junction boxes on the outside of each trailer.

The fuel systems for each platform were prefabricated for rapid installation. The diesel oil was fed by gravity, and the gasoline was fed to a Thermo-King air-cooling unit by a separator pump. Each platform was equipped with fire fighting equipment, including P-500 fire pumps. The latter also served as emergency bilge pumps.

A schematic diagram of the underwater instrumentation array planted at Platform 1 is shown in Figure 3.57. Locations of all the arrays, with respect to shot locations, are given in Table 3.13. In order to locate an acceptable sea bottom for positioning the LCU platforms, a fathometer survey was conducted in the vicinity of the desired locations, and divers were employed to check the bottom conditions. Buoys to outline the arrays were planted to prevent craft from sweeping marker-recovery buoys and causing premature actuations of mines. Divers were used to properly position and orient equipment on the bottom. The USS Chanticleer (ASR-7) was

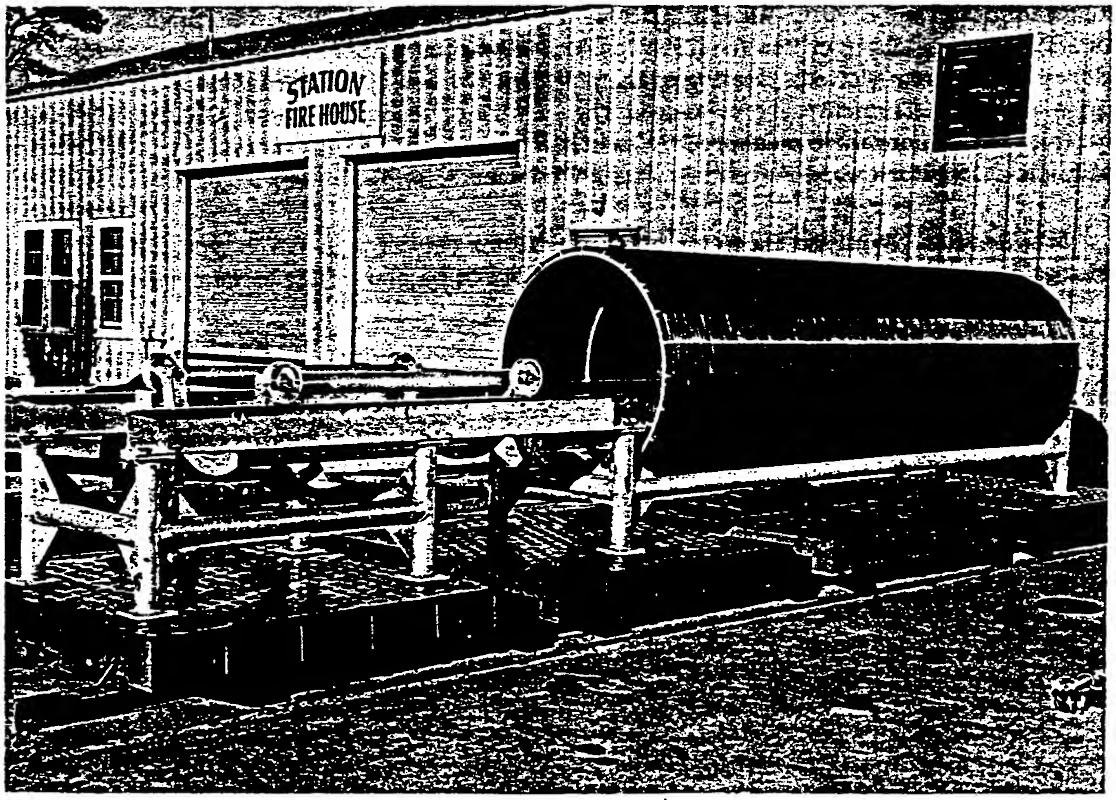


Figure 3.60 Idealizer for magnetic mines.

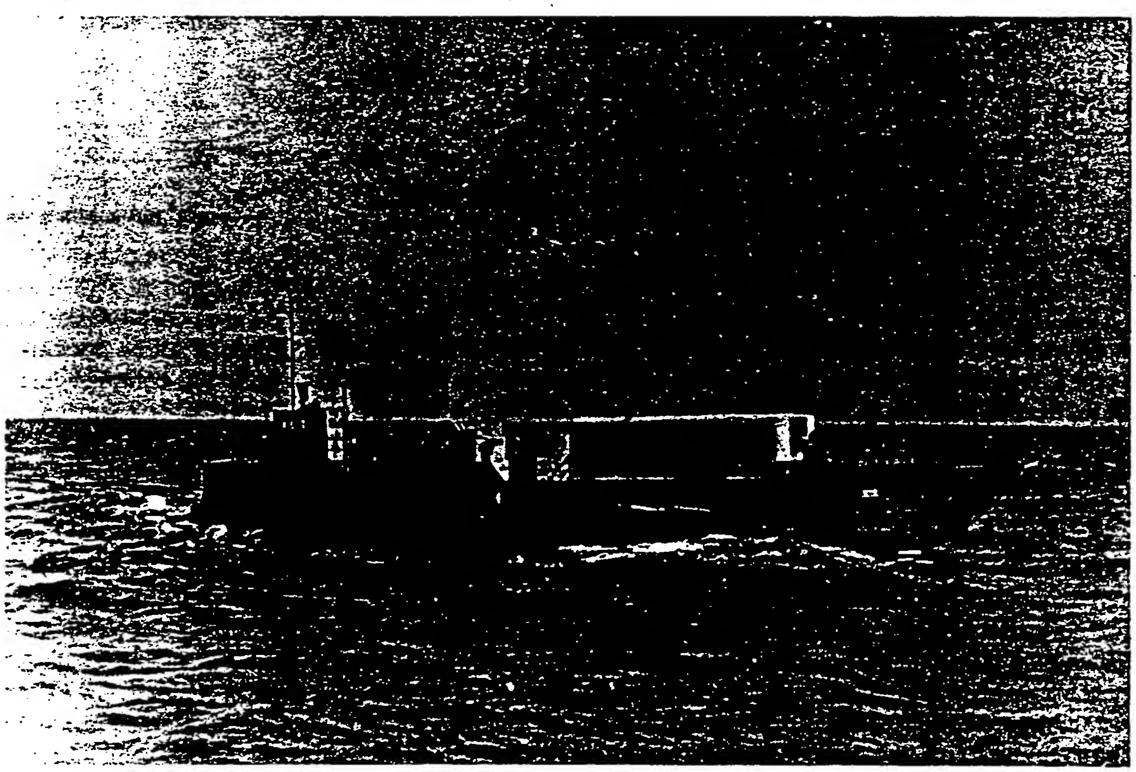


Figure 3.61 View of LCU 1317, Platform 1.

[redacted]

employed for the planting operation, because decompression chambers and diving support, plus lifting facilities, were within its capabilities. An LCM equipped with cable-handling facilities was employed for laying cables from the instruments to the platforms. The location of each underwater unit was plotted, relative to the platform, by use of a pelorus and measuring lines. Depths at each instrument were measured when divers oriented the units. Distances between objects on the bottom were measured by swimmers. Figure 3.62 illustrates a typical mine installation. Detectors were rigged in a similar manner.

3.5.7 Results. With the exception of mine reaction data of a go-no-go type, all data must undergo considerable reduction before it is in a form to be pictorially or numerically presented

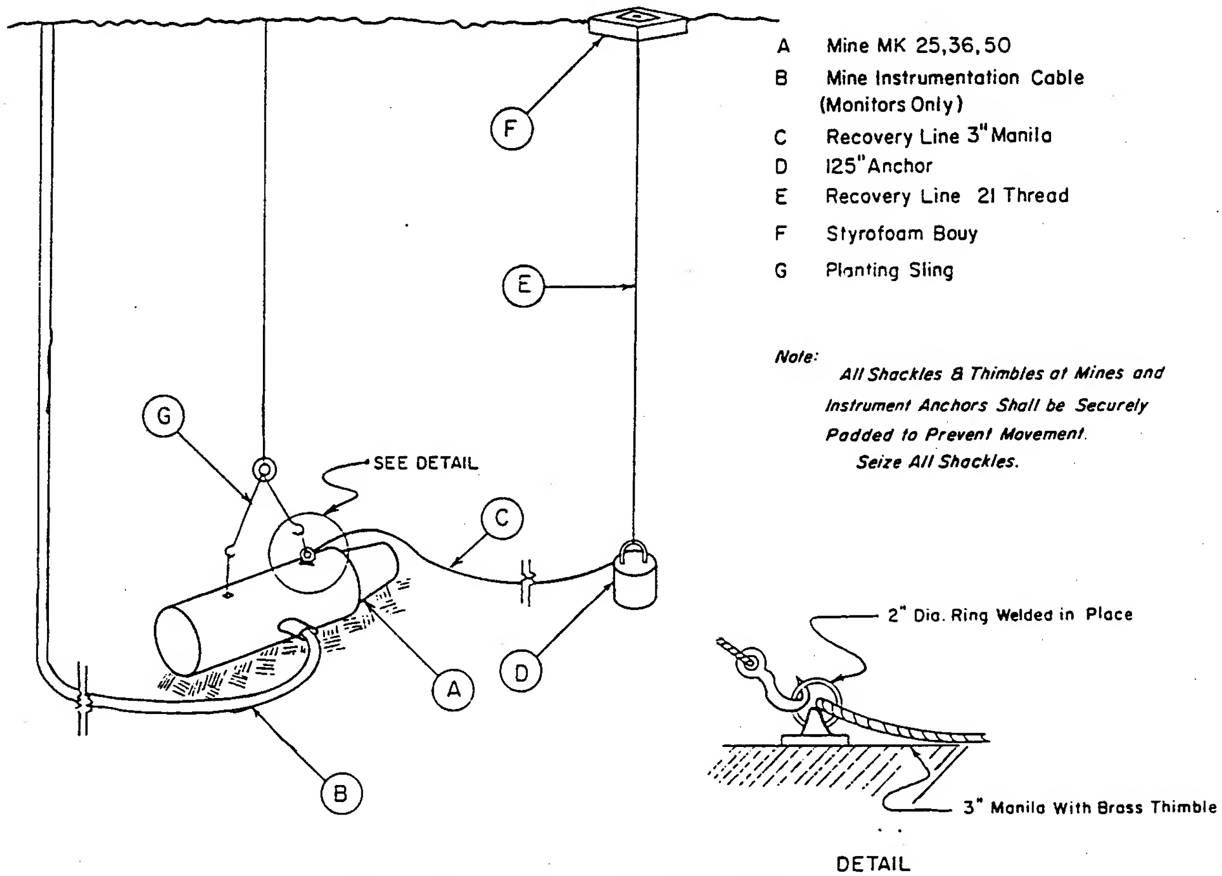


Figure 3.62 Typical mine installation.

or from which any conclusions can be drawn. Significant data reduction could not be accomplished in the field, owing to the lack of facilities and time; therefore, an early comprehensive evaluation of results, i. e., in the field, caused it not to be made, except for mine reaction.

The methods and objectives of the data reduction are, in general, peculiar to the field of mine countermeasures. A considerable portion of the reduction is of a manual nature. The following general methods will be used for reduction of the data:

Acoustic-Field Measurements. The data was obtained on magnetic tapes. Overlapping octave band analysis will be made [redacted] as a function of time. From this, appropriate plots may be made. The original recording will be played into appropriate simulation equipment to determine ACM's and fires of various types of acoustic mines, if the data shows that this type of analysis proves advantageous.

Magnetic-Field Measurements. The output of the total field detectors, as recorded on magnetic tape, will be reproduced for visual scanning on conventional playback equipment. The signal magnitude of any observed signals will be scaled. The time of occurrence of any significant signals will be obtained, and an attempt will be made to correlate these times with

[redacted]

events following the shot (bubble expansion, emergence of plume, shock wave, wave motion, and other effects). Analysis of wave form and probable effect on mines will be performed, as necessary.

P r e s s u r e - F i e l d   M e a s u r e m e n t s. Data was recorded on magnetic tapes and will be reproduced for analysis on paper tapes. The data will be reduced manually to determine amplitude and other characteristics of the underwater-pressure changes that affect mine countermeasures. Mine reactions will be correlated to determine the types of pressure change that caused the mines to fire.

TABLE 3.13 SHOT AND PLATFORM LOCATIONS

Code Name	Coordinates *	Holmes and Narver Coordinates	Distance of Shots to Platform P-1	Distance of Shots to Platform P-2	Distance of Shots to Platform P-3
			ft	ft	ft
Wahoo	11° 20′ 41″ 162° 10′ 45″	N 29,000 E 60,500	27,050	37,800	64,800
Yellowwood	11° 39′ 36.7″ 162° 13′ 30.6″	N 143,993 E 78,161	102,300	103,800	87,400
Tobacco	11° 39′ 48″ 162° 13′ 47″	N 145,140 E 79,799	103,300	104,700	87,700
Umbrella	11° 22′ 50″ 162° 13′ 09.6″	N 42,500 E 76,000	8,300	20,150	44,750
Platform Code Designation					
P-1 (Station 681.01)	11° 22′ 44″ 162° 14′ 32.2″	N 41,910 E 84,274			
P-2 (Station 681.02)	11° 22′ 42″ 162° 16′ 31.6″	N 41,708 E 96,147			
P-3 (Station 681.03)	11° 26′ 30″ 162° 19′ 40″	N 64,692 E 114,880			

* The first figure given is north latitude; the second is east longitude.

M o n i t o r e d   M i n e s. The monitored magnetic-mine mechanisms gave two channels of information: the go-no-go information obtainable from the record of looks and fires and the search-coil output. As in the case of the magnetometer measurements, an attempt will be made to correlate any looks, actuations, or significant search-coil output with events following the shot. The mine circuit will introduce marked distortion of signal form in the case of search-coil output. An attempt will be made to deduce the original wave shape of the signal (by circuit analysis and simulation techniques) of any significant search coil output recorded.

The acoustic mines will indicate fires and ACM's on a go-no-go basis. Data obtained from monitoring of the plate voltages will be correlated with acoustic measurements to determine the effect of sound-pressure level on the mine mechanism.

The pressure-magnetic mines will provide information on pressure looks obtained. This data will be correlated manually with pressure-field changes recorded.

Data was successfully obtained on about 80 percent of the recording channels. Mine reaction data of a go-no-go type were reduced. The time and facilities required to reduce and evaluate the remaining data in the form necessary for application to mine countermeasures precluded significant data reduction in the field. The following tentative conclusions summarizing results obtained on Shot Umbrella are based on the partial reduction of data:

1. [redacted]

2. A detailed study of the influence measurements and mine reaction data obtained from Shot Umbrella will be required to determine the degree of effectiveness of nuclear weapons for use in mine clearance by influence means.

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