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THE RESISTANCE OF HOLLOW GLASS MODELS TO UNDERWATER EXPLOSIONS AT GREAT DEPTHS
I. SPHERES

30 SEPTEMBER 1965

NOL

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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THE RESISTANCE OF HOLLOW GLASS MODELS TO UNDERWATER EXPLOSIONS AT GREAT DEPTHS

I. SPHERES

by

W. H. Faux

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ABSTRACT: Hollow glass spheres, 10 in. in diameter, were exposed to explosions of 1-lb charges at a series of depths in the ocean. At a depth of 300 ft, a sphere could not be placed closer than 19 ft from the charge without breaking. At 22,000 ft, the sphere could be as close as about 2.5 ft without damage. At this smaller range, the shock wave peak pressure was estimated to be an order of magnitude greater than at 19 ft, indicating a greatly increased strength of the spheres.

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UNDERWATER EXPLOSIONS DIVISION
EXPLOSIONS RESEARCH DEPARTMENT
U.S. NAVAL ORDNANCE LABORATORY
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THE RESISTANCE OF HOLLOW GLASS MODELS TO UNDERWATER EXPLOSIONS AT GREAT DEPTHS. I. SPHERES

The work described in this report is part of the U. S. Naval Ordnance Laboratory's program of development of glass submersibles. This investigation was carried out in FY 1964 under Task NOL-892/SP.

Mention of commercially available materials in this report does not constitute an endorsement or criticism by the Laboratory.

The authors gratefully acknowledge the helpful discussions and general guidance of H. A. Perry. They also wish to thank J. B. Dempsey, C. E. Hopkins, J. E. Morgan, E. G. Nacke, and R. B. Tussing, who carried out the field tests.

J. A. DARE
Captain, USN

C. J. ARONSON
By direction

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THE RESISTANCE OF HOLLOW GLASS MODELS TO UNDERWATER EXPLOSIONS AT GREAT DEPTHS

I. SPHERES

1 INTRODUCTION

In 1952 it was found (a)* that hollow glass spheres were more resistant to damage from impact by a solid object when deeply immersed. A theory developed by H. A. Perry of the Naval Ordnance Laboratory (b) explained this "depth-hardening effect" in terms of the properties of glass. It was not clear at that time whether the resistance of glass to the dynamic impact of a shock wave would be similarly increased. In March, 1964, therefore, sea tests were conducted to determine the behavior of deeply submerged glass structures under the dynamic load generated by an explosion. This report presents the results of those tests.

2 EXPERIMENTAL PROCEDURE

2.1 General Procedure: The procedure used was to find the critical damaging distance from a standard charge for a specified type of sphere at a series of depths. Two different standard models were used. Ninety-three shots were fired, using a new sphere for each shot in nearly every case. The firing location was in or just north of the Puerto Rico Trench, which offered water deep enough for a wide range of hydro-static pressures.

Table 1 gives the nominal conditions for each group of tests, and the number of shots fired at each depth. The shot depths shown were chosen arbitrarily to cover the range.

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* All such letters refer to the list of references on page 8.

TABLE 1

TEST CONDITIONS

Shot Depth (ft)	Approx Water Depth	No. of Shots CGW*	No. of Shots PPG**	Location
300	20,000	14	8	20° -- N 66° 30' W
7,200	18,000	20	14	20° 30' N 66° -- W
14,500	20,000	20	--	20° 20' N 66° -- W
22,000	26,500	17	--	19° 20' N 66° -- W

* Corning Glass Works Models

** Pittsburgh Plate Glass Models

2.2 Test Rig: Figure 1 illustrates the test rig; this was used to fix the distance between the charge and sphere. It was arranged so that it could be loosely fastened to a vertical wire and would slide down freely to the desired depth. Each model was contained in a nylon net and secured to a frame of iron rods. Each charge was secured to a similar frame. The charge and model frames were fastened to a steel pipe at predetermined distances apart, using hose clamps. This setup afforded a simple method of changing the charge-to-model stand-off.

All the test rigs on the 300 ft shots were lowered one at a time with the charge being electrically initiated. The test rig was recovered after each shot and the model was inspected for damage.

For each test at 7,000 ft or greater, a 1,000-lb weight was lowered on half-inch diameter wire cable by means of an oceanographic winch to a depth 1,500 to 2,000 ft beyond the nominal charge firing depth. Then the test rig, with the model and charge appropriately placed, was clamped to the wire and allowed to slide down freely. When the test rig reached the predetermined depth, the pressure actuator fired the charge; the rig continued to slide down the cable to the bottom end. Usually several test rigs were sent down the wire for each lowering of the weight.

Figure 2 illustrates the experimental arrangement. Recordings of the shock wave were made from pressure gages near the surface. These records were used to determine whether or not a model had broken (see Appendix A). At any given depth, if a model broke, the next model was placed farther from the charge; if the model was undamaged, the next model was placed closer. Increments of two feet for the charge-to-model stand-off were used at the 300-ft depth and one-foot increments were used at the greater depths. The charge-to-model stand-off was taken as the distance from the center of the charge to the center of the model.

2.3 Glass Models: Models used in these tests were limited to one size and shape, i.e., hollow spheres with a diameter of 10 inches and wall thickness sufficient to withstand a hydrostatic load of at least 10,000 psi. They were supplied by two manufacturers. The Corning Glass Works (CGW) fabricated hemispheres with a wall thickness of 0.36 ± 0.02 inches of Pyrex glass (Corning code 7740). These were annealed and fusion-sealed to form spheres. The spheres had an internal bead which formed around the joint during the sealing process. All the Corning models were abraded lightly within a five-inch diameter area about the pole inside each hemisphere prior to assembly. The Pittsburgh Plate Glass Company (PPG) pressed and ground Herculite II hemispheres of 0.5 ± 0.005 inch wall thickness. These hemispheres were surface compressed and assembled with an epoxy adhesive to form spheres.

The models were mounted in the test rig with the poles pointing toward and away from the charge; thus the equator (the joint) was oriented perpendicular to a line between the charge and the model.

After the first few shots it was decided to test each CGW model only once in order to reduce possible scatter in the results due to glass fatigue. Three CGW models had been used on two shots apiece. However, there were only 20 PPG models available, so some of these models were used on as many as three tests.

2.4 Charges: The charge used on all shots was a one pound (± 3 grams) cast pentolite cylinder with a 1:1 length to diameter ratio. Pentolite was selected for this investigation because it can be easily cast, does not have to be boostered, and is reliable even under extreme pressures. Only one of the ninety-three charges used in the series failed to detonate high order.

The 300-foot deep shots were fired electrically from the ship using standard U.S. Army Engineers' Special electric detonators. For the three greater depths a pressure-actuated firing device purchased from Weston Instruments, Inc., was used to initiate a special detonator* which was inserted in a hole in the charge. The firing device worked on a rupture disc principle.

* The detonators were designed and developed by the Explosion Dynamics Div. of NOL. The explosive load was equivalent to that in a U.S.Army Engineers' Special detonator.

3 MODEL DAMAGE

Several types of damage occurred to the models, as follows:

(a) The model was completely demolished. Only pieces of the model or none of the model were recovered.

(b) There was at least one hole in the model.

(c) The model was cracked as shown in Figure 3. In most cases the model had water inside. This damage occurred at the pole away from the charge in all cases.

(d) The model was chipped on the outside in an area five inches in diameter at the pole away from the charge.

(e) The internal bead around the joint flaked off. There was no leakage or evidence that cracks had propagated through the wall of the model.

(f) No damage. The model was recovered intact.

A summary of the model damage is shown in Figure 4 for each condition as a function of the charge-to-model stand-off (i.e., the distance from the center of the charge to the center of the model). It is apparent from this figure that the distance for critical damage decreased significantly as the depth of the test increased.

3.1 CORNING GLASS WORKS MODELS:

3.1.1 Results at 300 ft Depth. All of the fourteen CGW models tested at the 300 ft depth were recovered. Seven of the models were cracked at the pole away from the charge; seven were recovered intact. One model at 18 ft stand-off which was recovered intact had an outer plastic shipping jacket on for the test; this may have affected the result for that model. It appears that a reasonable critical range, where the model was just not cracked, was 19 feet.

3.1.2 Results at 7,200 ft Depth. Eight of the twenty CGW models tested at this depth were not recovered. These were all at stand-offs of 5 feet or less and were believed to have been demolished. Spheres showed no damage on shots with a charge-to-model stand-off of 6 feet or more. The critical stand-off was taken as 5.5 feet.

3.1.3 Results at 14,500 ft Depth. All six of the spheres at a stand-off of 3 ft or less were demolished while the balance of the twenty CGW models tested at this depth were not flooded at a stand-off of 4 ft or more. The inside weld on many of the models at a stand-off of 4 ft flaked off but no water was evident inside the glass. On two of these models 1/16-inch thick circular chips flaked off the outside of the model at the pole away from the charge. The critical stand-off is 3.5 ft at this depth.

3.1.4 Results at 22,000 ft Depth. Four of the 17 CGW spheres tested at this depth were demolished at a 2 ft stand-off; the balance of the models were not flooded when placed 3 ft or more from an explosion. The internal bead flaked off eleven of the models which were not flooded. The critical stand-off was taken as 2.5 feet.

3.2 PITTSBURGH PLATE GLASS MODELS:

3.2.1 Results at 300 ft Depth. All eight of the PPG models tested at 300 ft depth were recovered. Four were intact and four were damaged. The damaged spheres were cracked at the far pole in a manner similar to the CGW models, but there were many more cracks in the same area. The critical stand-off was taken as 15 feet.

3.2.2 Results at 6,500 ft Depth. Damage to the PPG models at 6,500 ft depth was somewhat different from the results with the CGW spheres at the corresponding depth. Of the fourteen PPG models tested no damage to eight models was observed at stand-offs of 5 ft or greater. The balance of the spheres tested at this depth were all damaged at 4 feet. Three models were not recovered and were presumed to be demolished. One model had a one-inch diameter hole at the far pole with severe cracking 1.5 inches around the opening; another sphere had a six inch diameter hole at the far pole while a third model had large holes at both poles. On the three models not recovered the bottom half of the net holding each sphere was cut.

4 ESTIMATED EXPLOSION PARAMETERS AT DEPTH

The effects of underwater explosions have been studied mainly for charges fired at shallow depths in the ocean. No broadband pressure-time measurements have been made near charges fired at depths as great as those of interest here. Pressure-time records obtained on these tests, as on several other tests (c-e), were from gages placed at a shallow depth; the depth of the explosion was varied. Reference (g) presents a summary of results obtained for these conditions. The information of reference (g) has been used to make some estimates of the parameters of the shock wave and bubble pulses that occurred for the conditions of interest herein; i.e., at the depths of the model tests. The estimated values are discussed in this section.

The relationships of reference (g) indicate that the shock wave peak pressure is independent of the depth of firing and is dependent only on the charge weight and propagation range for a given explosion. On this basis, the near-field similitude equations for pentolite (f) have been used to calculate the shock wave peak pressure (excess above the hydrostatic pressure) for the critical damage range for each condition (Table 2). The peak pressure of the first bubble pulse (above hydrostatic) is expected to be about 20 percent of the shock wave peak pressure; successive pulses are believed to have peak pressures that are about 20 percent of each preceding pulse. The bubble period is a function of the charge weight and the depth of explosion; this relationship has been well known for many years. The average first bubble period for each group of tests is listed in Table 2. Successive periods are about 70 percent of each preceding period.

TABLE 2

ESTIMATED SHOCK WAVE PEAK PRESSURES AND MEASURED FIRST BUBBLE PERIODS

Test Depth (ft)	Type of Model	Critical* Stand-off Distances (ft)	P_h** (psi)	P_m** (psi)	T** (msec)
300	PPG	15	148	1070	34.7
6,500	PPG	4.5	2900	4200	2.89
300	CGW	19	148	820	34.3
7,200	CGW	5.5	3200	3400	2.71
14,500	CGW	3.5	6450	5600	1.61
22,000	CGW	2.5	9800	8300	1.11

* Distance from the center of the charge to the center of the model.

** P_h is the total hydrostatic pressure = 0.445 (test depth + 33).

P_m is the excess shock wave peak pressure.

T is the time interval between the shock wave and first bubble peak pressures.

There is insufficient information to obtain good estimates for such parameters as the durations of the shock wave, bubble pulse, and negative phases because these appear to be dependent on both the explosion depth and transmission range. However, the bubble periods and the time at which the shock wave pressure returns to hydrostatic pressure decrease significantly as the burst depth increases. This will give a shock wave impulse $\left[\int p\,dt\right]$ that undoubtedly decreases, for the same range, as the burst depth increases. However, the shock wave energy flux density (which is proportional to $\int p^2 dt$) is not affected as much as the shock wave impulse. Measurements at depth are necessary before quantitative values of these parameters can be given. In conclusion, it is apparent from the values of Table 2 that the shock wave peak pressures were significantly higher at the critical damage ranges for the greater depths. The spheres have not been weakened by these much greater hydrostatic pressures; on the contrary, increased ambient pressure has made the spheres stronger.

5 SUMMARY

During the March 1964 sea tests, ninety-three pentolite charges were fired singly at ninety-three hollow glass spheres to test the resistance of glass to an explosive load at depths ranging from 300 ft to 22,000 feet. Two types of model were used: one made by Corning Glass Works (CGW) and one by Pittsburgh Plate Glass Company (PPG). It was shown that:

(a) The distance for critical damage to the CGW models changed from 19 ft at the 300 ft test depth to 2.5 ft at the 22,000 ft depth.

(b) The distance for critical damage to the PPG models was 15 ft at the 300 ft test depth and 4.5 ft at 6,500 feet.

(c) The surface compressed PPG spheres appear to be stronger than the annealed Pyrex CGW models. However, the wall of the PPG spheres was thicker, and the effect of the thickness of the glass is unknown.

(d) All damaged spheres that were recovered partially intact were broken on the side away from the charge.

(e) Because of the shorter ranges the shock wave peak pressure at the model was considerably higher for the deeper depths than for the shallow depth.

(f) Since both hydrostatic pressure and shock wave pressure were greater at the critical damage range, it is concluded that the spheres were significantly stronger for the deeper condition.

REFERENCES

(a) "The Ball Breaker, a Deep Water Bottom Signalling Device." J. D. Isaacs and A. E. Maxwell, Journal of Marine Research, XI, 1, 1952.

(b) "Feasibility of Transparent Hulls for Deep-Running Vehicles," H. A. Perry, ASME Paper, 63-WA-219, November 1963.

(c) "Underwater Explosions," R. H. Cole, Princeton University Press, 1948.

(d) "Studies of Explosions at Depths Greater than One Mile in the Ocean, III. Sonic Ranging of the Depth of Detonation," J. P. Slifko, NOLM 10828, 15 March 1950.

(e) "Studies of Explosions at Depths Greater than One Mile in the Ocean, VI. Bubble Period Measurements," J. P. Slifko, NAVORD Report 2276, 1 August 1954, Confidential.

(f) "Revised Similitude Equations for the Underwater Shock Wave Performance of Pentolite and HBX-1," M. A. Thiel, NAVWEPS Report 7380, 1 February 1961, Confidential.

(g) "Near Surface Measurements of Deep Explosions I. Pressure Pulses from Small Charges," Maurice Blaik and Ermine A. Christian, J. Acoust. Soc. Am., Vol. 38, No. 1, 50-56, July 1965.

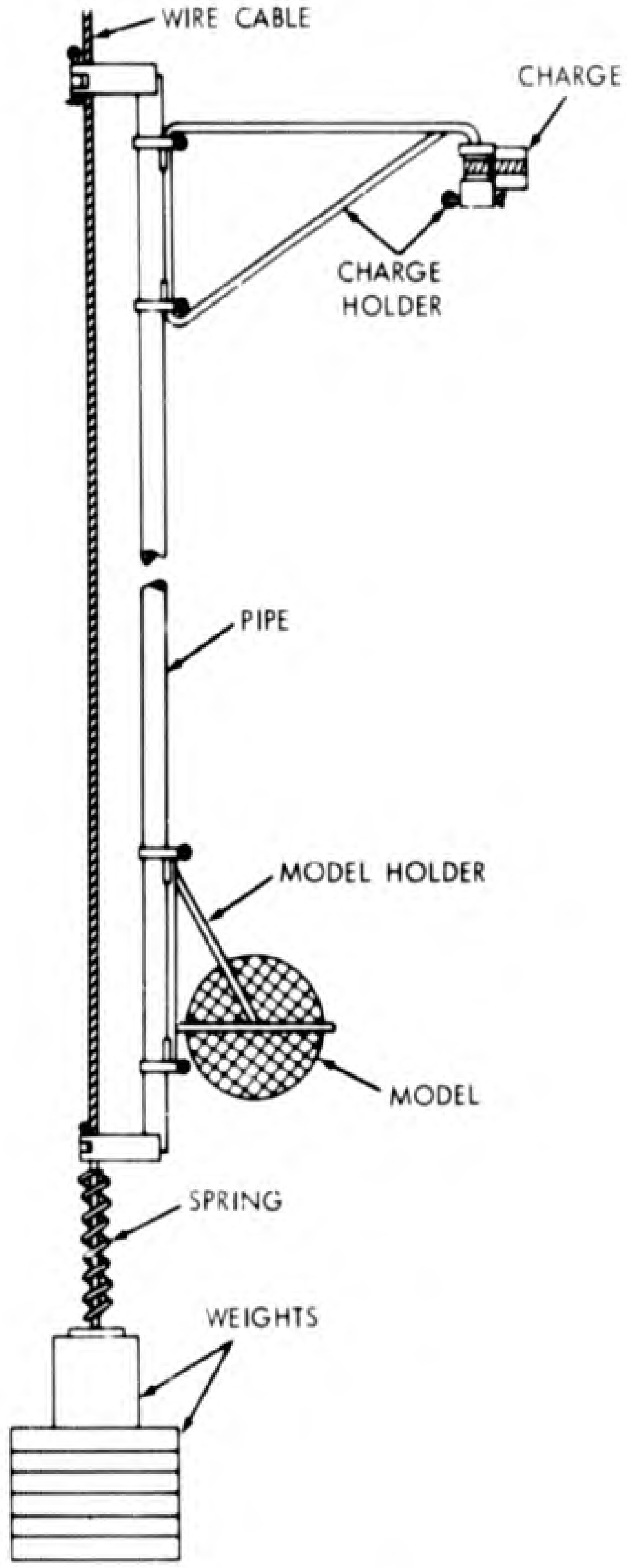


FIG. 1 TEST RIG

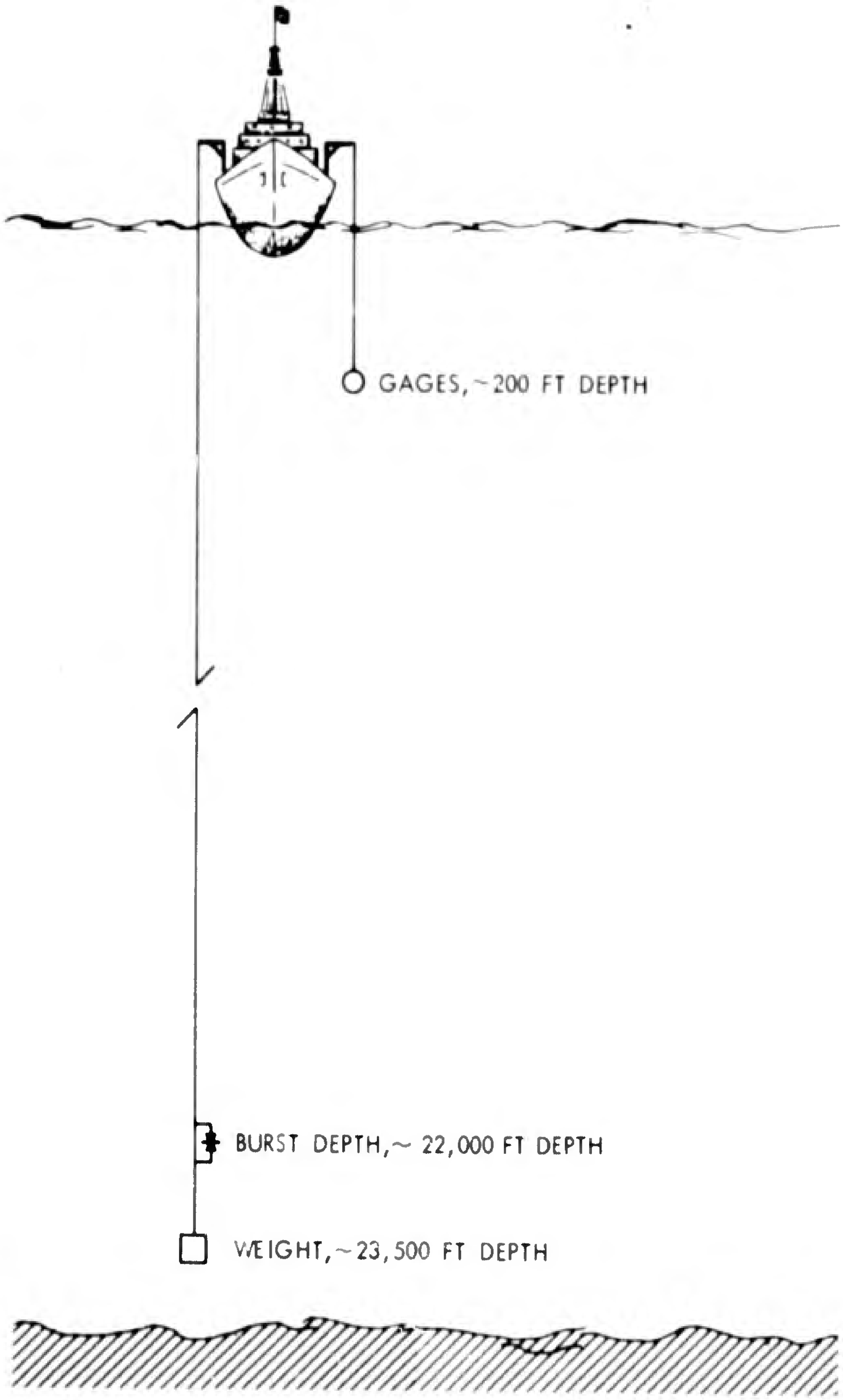


FIG. 2 UNDERSEA TEST CONFIGURATION, EXPLOSION AT 22,000 FT.

FIG. 3. TYPICAL CGW MODEL DAMAGE AT 300 FT.

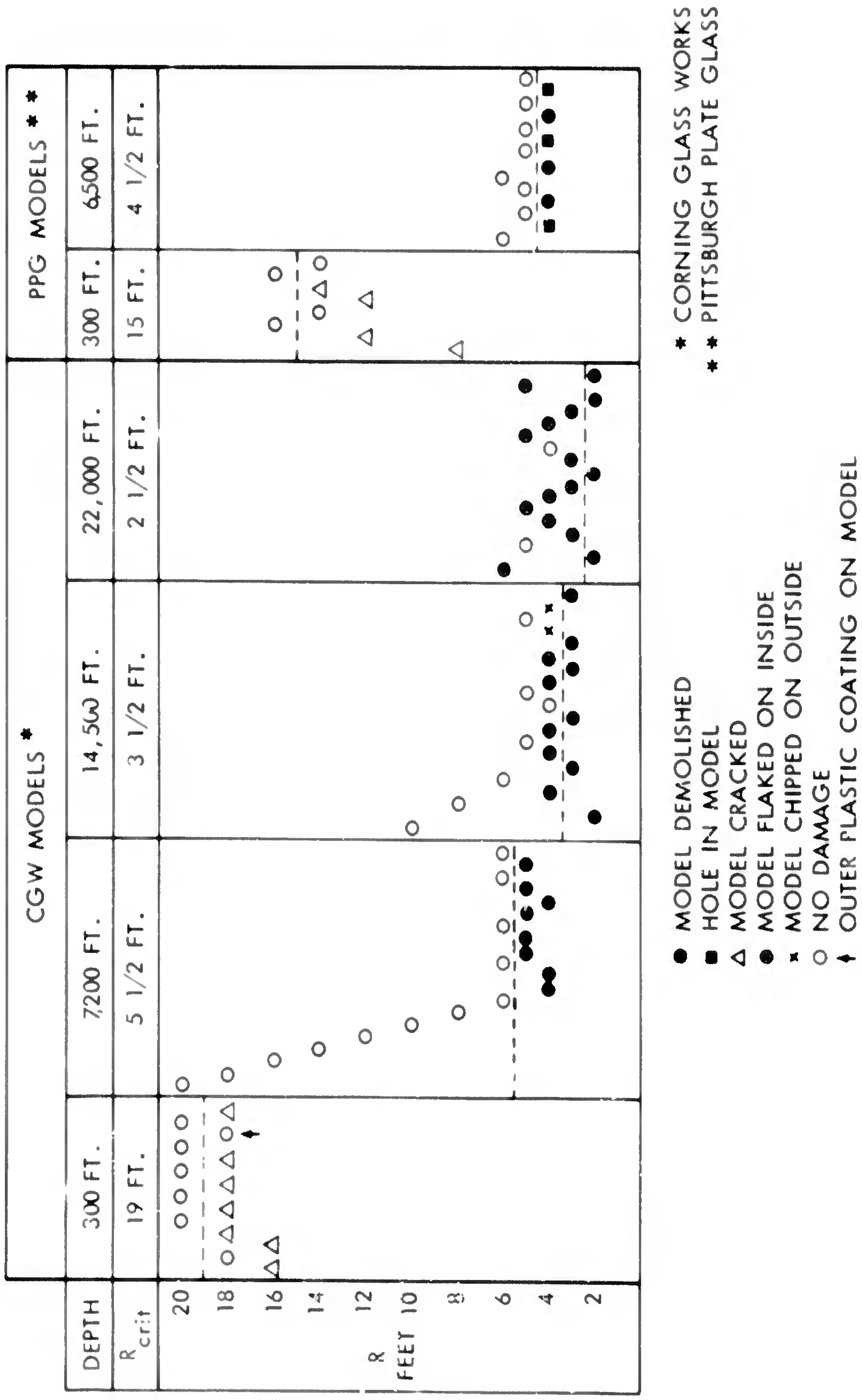


FIG. 4 MODEL DAMAGE

APPENDIX A

SHOCK WAVE MEASUREMENTS

Pressure-time measurements were recorded on each shot for a number of reasons: (1) to determine if possible from pressure-time recordings at the surface if the models were damaged without recovering the model after each shot, (2) to determine the depth of the charge burst, and (3) to supplement the limited deep explosion data available. Samples of these records are also given in Reference (g).

Instrumentation: Lead zirconate piezoelectric hydrophones*, suspended 200 ft below the water surface were used to record the explosion pressure signals. The signals were fed through 350 ft of low noise coaxial cable, cable terminations, and cathode follower circuits into cathode ray oscilloscopes where the spot deflections and sweeps were recorded by Polaroid Land cameras. Timing marks at some known interval and calibration steps resulting from the application of a known voltage were recorded frequently on separate pieces of photographic paper.

Three channels of cathode ray oscilloscope recording were used to record the shock wave and several bubble pulses. The sweep speeds were set for different recording times on the three channels on each shot; these recording times were changed for charges fired at different depths. The vertical settings were also changed.

An LC-50 hydrophone was used as a trigger gage. It was placed 5 ft below the recording hydrophones; a delay circuit was used between the trigger gage and the external scope sweep to insure proper recordings.

Pressure-time Records: Figures A1a, A2a, A3a, and A4a show typical pressure-time records obtained on two gages from tests at depths of 300 ft, 7200 ft, 14,500 ft and 22,000 ft respectively. The upper trace shows the pulses recorded on an LC-50 hydrophone while the lower trace shows the pulses recorded on an LC-32 hydrophone. Pressure and time scales are shown for each trace. The upper trace is inverted.

The records for the 300 ft shot show a shock wave followed by a single bubble pulse. The pressure between the two pulses remains positive, a condition which was probably caused by the response of the hydrophones; there should have been a negative phase between the pulses (c).

* Atlantic Research Corp. LC-32 and LC-50 types.

The records for the three deeper conditions show a shock wave followed by three bubble pulses. In these records, there are negative pressures between the pulses. However, these negative pressures may not be quantitatively correct because of hydrophone response.

Identification of Damaged Models: Figures A2b, A3b, and A4b show pressure-time traces on shots where the glass spheres were demolished. These records are for the three deepest depths. On each record there is an extra pulse which does not appear on the records for the OGW models where the model was not damaged. On A2b the extra pulse is 8.1 millisecs after the shock wave, on A3b at 3.8 millisecs and on A4b at 3.2 millisecs. These pulses were apparently caused by an implosion of the model.

On the PTG tests at 6500 ft there was no implosion pulse within the time recorded on the pressure-time records (Figure A1b). However, it was possible to determine from the pressure-time records whether or not a model was demolished. Each record had a small oscillation which is believed to be the reflection of the shock wave off the glass model. For models which broke there were additional oscillations on the trace following the reflected pulse.

Figures A2c, A3c, and A4c show the differences between the traces where no model implosion occurred and those where the model implosion did occur; i.e., the pressure changes caused by the model implosion.

Data Reduction: Five pressure values and three time values were read for each shot on as many channels as possible. The data reported herein were, in general, obtained from the LC-32 hydrophone; the LC-50 hydrophone gave overshoots at the peaks and more oscillations on the traces. Values of shock wave peak pressure (apparent), the first and second maximum negative pressures and the apparent peak pressures of the first and second bubble pulse were read. The shock wave duration; i.e., the time from the start of the rise of the shock wave pressure to the return to zero overpressure, and the first and second bubble periods were read. The first bubble period was taken as the time from the start of the rise of the shock wave to the peak of the first bubble pulse; the second bubble period as the time from the peak of the first pulse to the peak of the second pulse.

The data are shown in Table A-1 along with standard deviations of the individual values from the mean where:

p_s is the shock wave peak pressure.

p_{-1} is the maximum pressure of the first negative phase.

p_{b1} is the first bubble pulse peak pressure.

p_{-2} is the maximum pressure of the second negative phase.

P_{b2} is the second bubble pulse peak pressure.

Δt is the duration of the shock wave.

T_1 is the first bubble period.

T_2 is the second bubble period.

The depths listed in Table A-1 were calculated for a limited number of shots (g) using the arrival times of bottom and surface reflections. The values tabulated are in fair agreement with the nominal depth of explosion and the expected scatter caused by the hydrostatic firing devices.

As mentioned in the description of the pressure-time records, there was no negative phase on most of the records obtained for the 300 ft depth. For shots at this depth only the shock wave peak pressure and the two periods, T_1 and T_2 were read. The shock wave peak pressures are different for the shots fired early in the test and those fired later. In addition, a peak pressure of about 120 psi was expected for the underwater geometry used. No reason for these discrepancies is known.

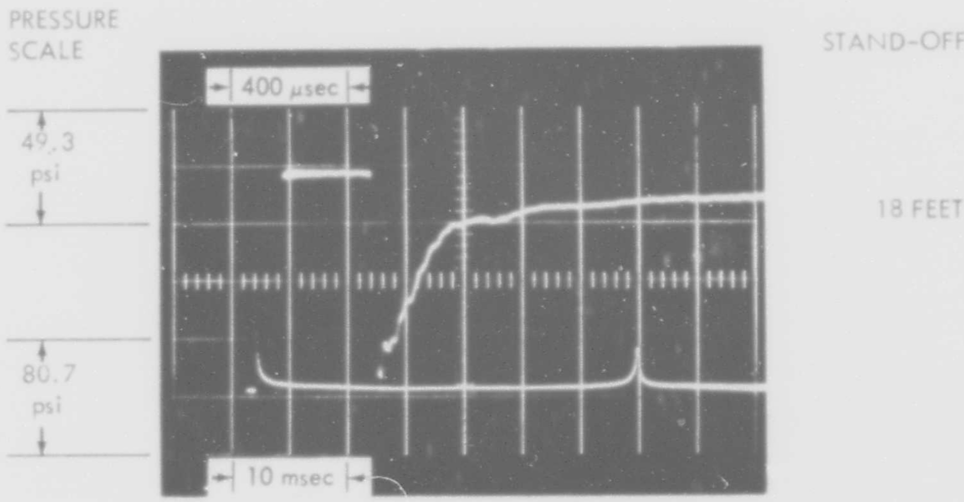
The values for the shots fired at the greater depths appear to be in reasonably good agreement with data obtained on other experiments (g) for similar conditions. However, some of the parameters have not been compared in detail. The results on these tests may have been affected somewhat by the presence of the model on each test.

TABLE A-1

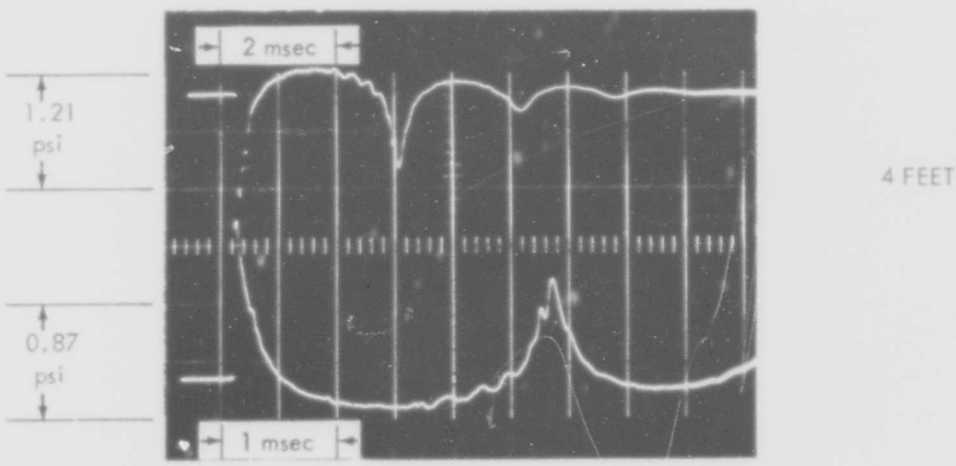
PRESSURES AND TIMES RECORDED AT A 200 FOOT DEPTH*

Charge Depth (ft)	Shot No.	P_s (psi)	P_{-1} (psi)	P_{b1} (psi)	P_{-2} (psi)	P_{b2} (psi)	ΔT (msec)	T_1 (msec)	T_2 (msec)
300	1-14	84.8 ±5.0%	---	---	---	---	----	34.7 ±1.4%	25.4 ±1.9%
300	86-93	70.2 ±2.1%	---	---	---	---	----	34.3 ±0.6%	25.8 ±1.2%
6,500	35-48	1.18 ±1.8%	0.227 ±2.3%	0.739 ±3.8%	0.101 ±11.9%	0.192 ±4.8%	0.430 ±2.9%	2.89 ±1.3%	2.15 ±1.3%
7,200	15-34	1.14 ±3.7%	0.236 ±3.3%	0.689 ±6.4%	0.113 ±11.8%	0.174 ±10.0%	0.410 ±3.5%	2.71 ±2.5%	2.06 ±3.0%
14,500	49-68	0.516 ±4.0%	0.174 ±2.2%	0.357 ±3.4%	0.088 ±7.5%	0.088 ±8.6%	0.320 ±4.4%	1.61 ±1.0%	1.24 ±3.0%
22,000	69-85	0.294 ±2.2%	0.140 ±2.9%	0.202 ±1.8%	0.056 ±4.0%	0.051 ±8.0%	0.295 ±1.8%	1.11 ±0.94%	0.91 ±1.1%

* The second entry (in percentage) in each column and row is the standard deviation of an individual value from the mean (σ). $\sigma = \pm\sqrt{\frac{\Sigma[x-\bar{x}]^2}{n-1}}$ where $\bar{x}$ is the average value, x is the individual value and n is the number of values.

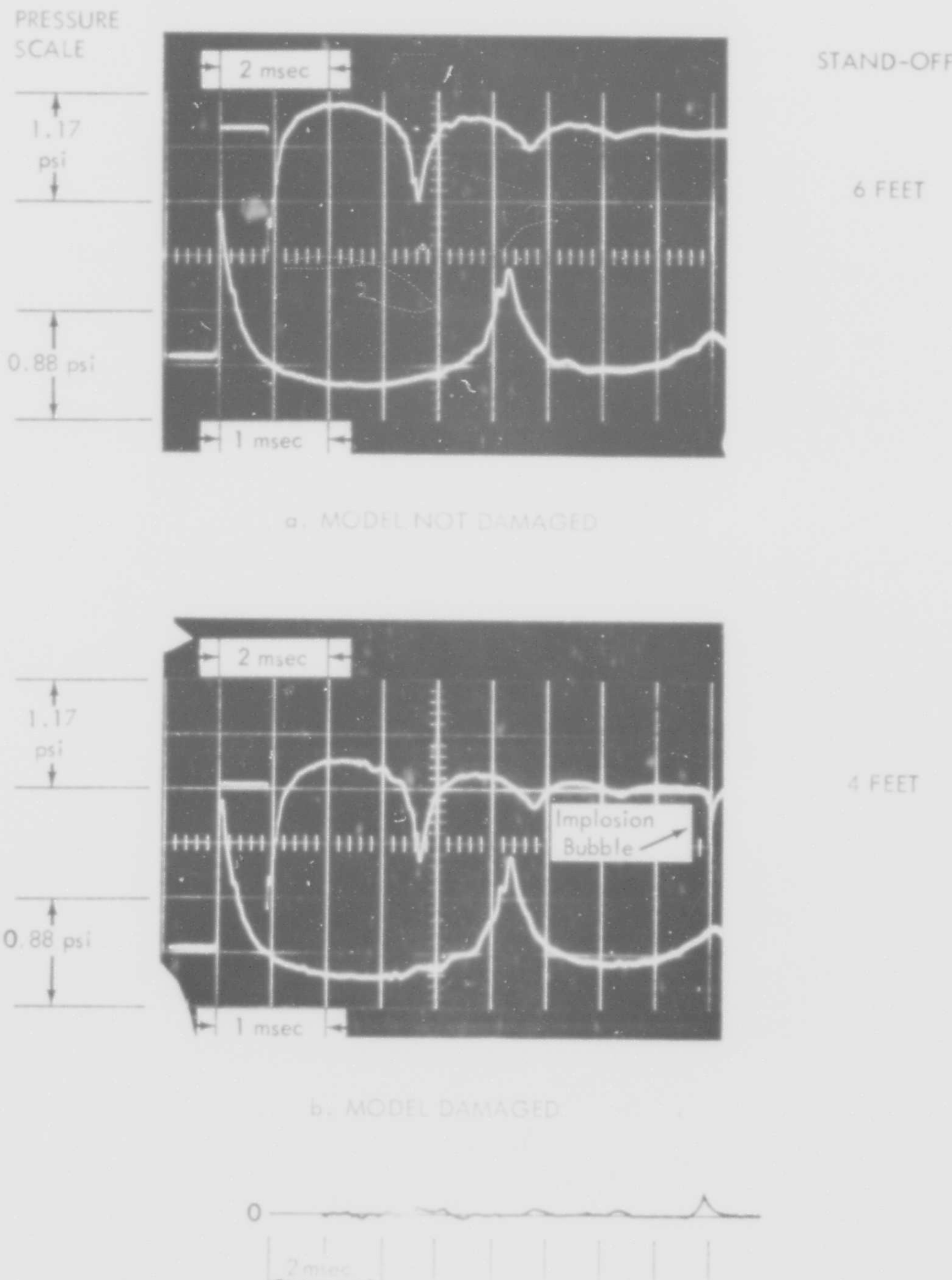


a. RECORD OF CGW TEST AT 300 FT (MODEL DAMAGED)



b. RECORD OF PPG TEST AT 6500 FT (MODEL DAMAGED)

FIG. A1 OSCILLOGRAMS OF CGW MODEL TEST AT 300 FT AND PPG MODEL TEST AT 6500 FT.

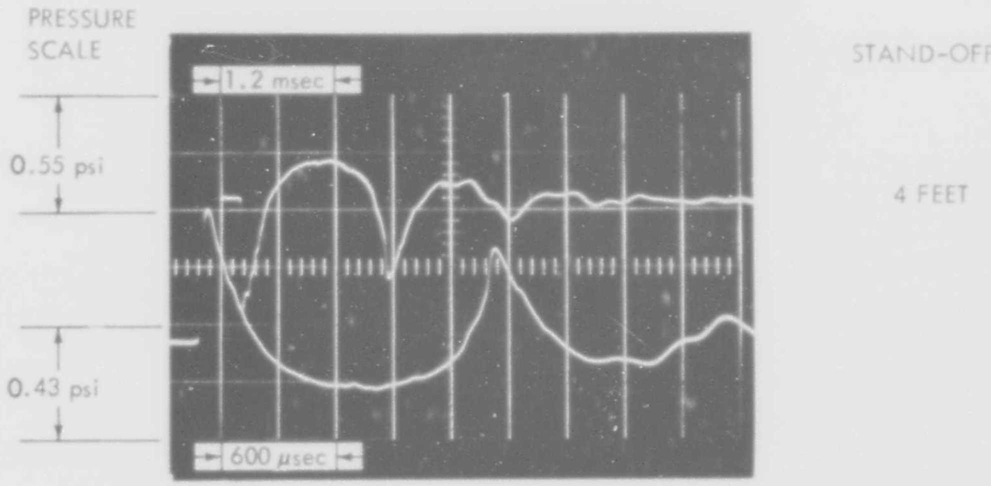


a. MODEL NOT DAMAGED

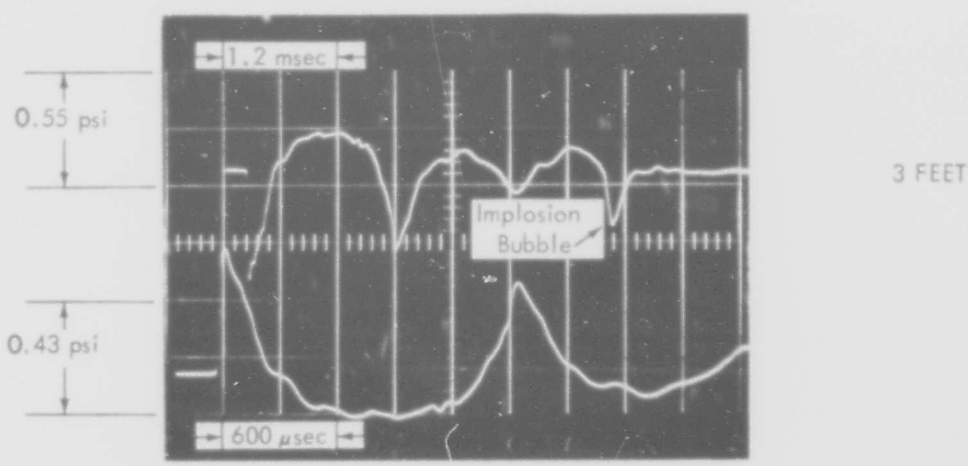
b. MODEL DAMAGED

c. DIFFERENCE BETWEEN UPPER TRACES OF a. AND b.

FIG. A2 OSCILLOGRAMS OF CGW MODEL TESTS AT 7200 FT.



a. MODEL NOT DAMAGED



b. MODEL DAMAGED

c. DIFFERENCE BETWEEN UPPER TRACES OF a. AND b.

FIG. A3 OSCILLOGRAMS OF CGW MODEL TESTS AT 14,500 FT.

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13. ABSTRACT

Hollow glass spheres, 10 in. in diameter, were exposed to explosions of 1-lb charges at a series of depths in the ocean. At a depth of 300 ft, a sphere could not be placed closer than 19 ft from the charge without breaking. At 22,000 ft, the sphere could be as close as about 2.5 ft without damage. At this smaller range, the shock wave peak pressure was estimated to be an order of magnitude greater than at 19 ft, indicating a greatly increased strength of the spheres.

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