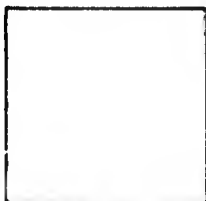


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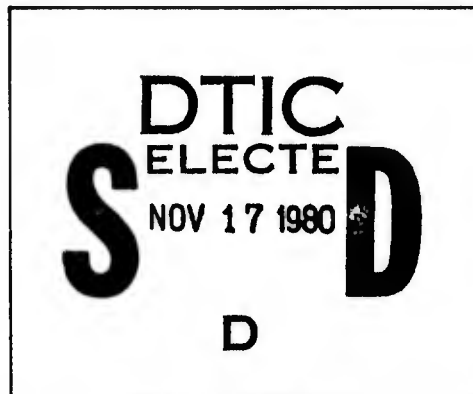
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REPORT TO THE SCIENTIFIC DIRECTOR

Operation Wigwam Preliminary Report

Project 3.1

APPLIED PRESSURES ON AND HULL RESPONSE OF
WIGWAM TARGETS

APPLIED PRESSURES ON AND HULL RESPONSE OF WIGWAM TARGETS

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ABSTRACT

The external pressures applied to the hull were measured with pressure gages and the deformation of the hull was measured with strain gages and displacement gages on the three SQUAW Targets. The results indicate that the SQUAW-12 was at a horizontal range of 5,200 feet, the shock pressure at the hull was about 845 psi, and the SQUAW was destroyed within 20 milliseconds. The SQUAW-13 was at a horizontal range of 7,200 feet, the shock pressure at the hull was about 540 psi, and the hull was near collapse but did not rupture. It is estimated that the lethal horizontal range of the SQUAW Target is about 7,000 feet.

* per telecon w/Betty Fox (USN Tech Libr, Chief), the classified references contained herein may remain.

de LaChance (DDA-2)
9-5-79

*Verified for Extracted Versions, 9 July '80,

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We are indebted to Commander R. C. Gooding, U.S. Navy, Mr. H. L. Rich and Dr. W. J. Sette of the Taylor Model Basin staff for their assistance in initiating the project and acquiring material during its early stages. Mr. J. N. Shellabarger and Mr. A. Cargyle of NEL have supervised the installation of our instrument trailers and other equipment into the barges, and have assisted in many ways during the operations at San Diego. Mr. C. T. Johnson of NEL and Mr. E. O. Arnold of NRF have also been of great help in the operations. We are indebted to Commander D. R. Saveker, U.S. Navy, for his efficient organization of the entire Program III and his continual advice and cooperation in making this project a success.

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APPLIED PRESSURES ON AND HULL RESPONSE OF WIGWAM TARGETS

1 INTRODUCTION

The objective of Project 3.1 was to measure the hull response of three submarine targets to an atomic depth charge, to determine from these measurements the critical range within which the submarine will be destroyed, and to formulate and verify an analysis of the response which might serve to predict the critical range of other submarines to such weapons.

The determination of the lethal range is the major objective of the entire WIGWAM Operation. Originally it had been hoped to do this after a detailed examination of the damage sustained by three submerged targets. However, now that both submerged targets have been lost, the measurements described here have become of greatly increased significance. The lethal radius data is of military importance because it is a guide to proper tactics in using atomic depth charges against enemy submarines and surface ships. Also it determines the optimum spacing and depth for submarines to minimize damage from such weapons.

This project has developed as the result of a long series of analytical and experimental studies, probably starting with a Manhattan Project Report which first discussed the effects of an underwater explosion of an atomic weapon.¹ More recently, the Pelican Committee has discussed the problem,² and elaborate model tests with conventional explosives have been conducted off Haiti by UERD³ and by DTMB.⁴

2 EXPERIMENTAL PROCEDURES

2.1 General Features

The three SQUAW Targets have been described in detail in another Program III report. They were instrumented by this project to measure the applied pressures and the resulting hull deformations. It was originally intended to position the targets all at the same depth, and at such ranges that the near target would almost surely be destroyed, the center target would be marginal, and the far target would almost surely be in the elastic response region. In this way it was hoped to obtain three complete sets of load and response measurements which would clearly show the elastic response, the plastic response and the conditions which are necessary to insure failure of the hull. As it turned out, because of conditions beyond our control, about 40 percent of all the instrument cables were broken, and the rigging was

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damaged so badly that the far SQUAW could not be submerged.

The same gage locations were used in all three SQUAWs. The external pressures acting on the hull were measured with diaphragm pressure gages and piezoelectric pressure gages. The deformations of the hull plating and of the null stiffeners were measured with strain gages and with displacement gages.

All of the gages, except the piezoelectric gages, were wired as complete resistance bridges at the gage site. Each of the gages was connected by a separate shielded 4-conductor cable to a terminal board in the forward compartment of the SQUAW and thence to an instrument trailer in the YFNB barge above. The gage circuits were automatically operated and calibrated, and the gage signals were amplified and recorded by instruments as outlined in the block diagram of Illustration 1. All of the diaphragm gage channels and about half of the strain gage channels were connected to two multi-channel carrier amplifiers which supplied power to the resistance bridges, amplified the signals, and recorded them through a multi-channel galvanometer oscillograph. The signals from the displacement gages were recorded directly without amplification. The remaining bridge channels and the piezoelectric channels were connected to a multi-channel recording cathode-ray-oscillograph. The strain gage resistance bridges (also the displacement gage circuits) were connected through a Bridge Control Unit which supplied battery power for each bridge circuit, balanced the bridges, and calibrated the channels. The piezoelectric channels were connected through a network which terminated the cable, and applied voltage steps for calibration purposes.

The carrier amplifiers, galvanometer oscillographs, and the recording CRO were all supplied with 110 volt, 60 cycles-per-second power from a battery driven motor-generator set. The entire system was operated and calibrated by a motor driven, cam type, sequence timer, operating from storage batteries, and triggered by timing signals from EG&G.

For each SQUAW there was a total of 50 gage stations, but only 43 recording channels were available in each trailer. It had been anticipated that some of the gages would fail prior to the test. As a result of the systematic failures in the main external cable bundle, it was possible to use all of the recording channels only on the YFNB-29. The gage stations which were recorded are described in Table 1 and the locations are shown in Illustration 2. On the SQUAW-29 the remaining stations were in operating condition, but on the SQUAW 12 and 13 the remaining gage stations were all inoperative because of breaks in the external cables.

2.2 Pressure Gages

There were 11 diaphragm pressure gages and three piezoelectric pressure gages installed outside the pressure hull of each SQUAW target.

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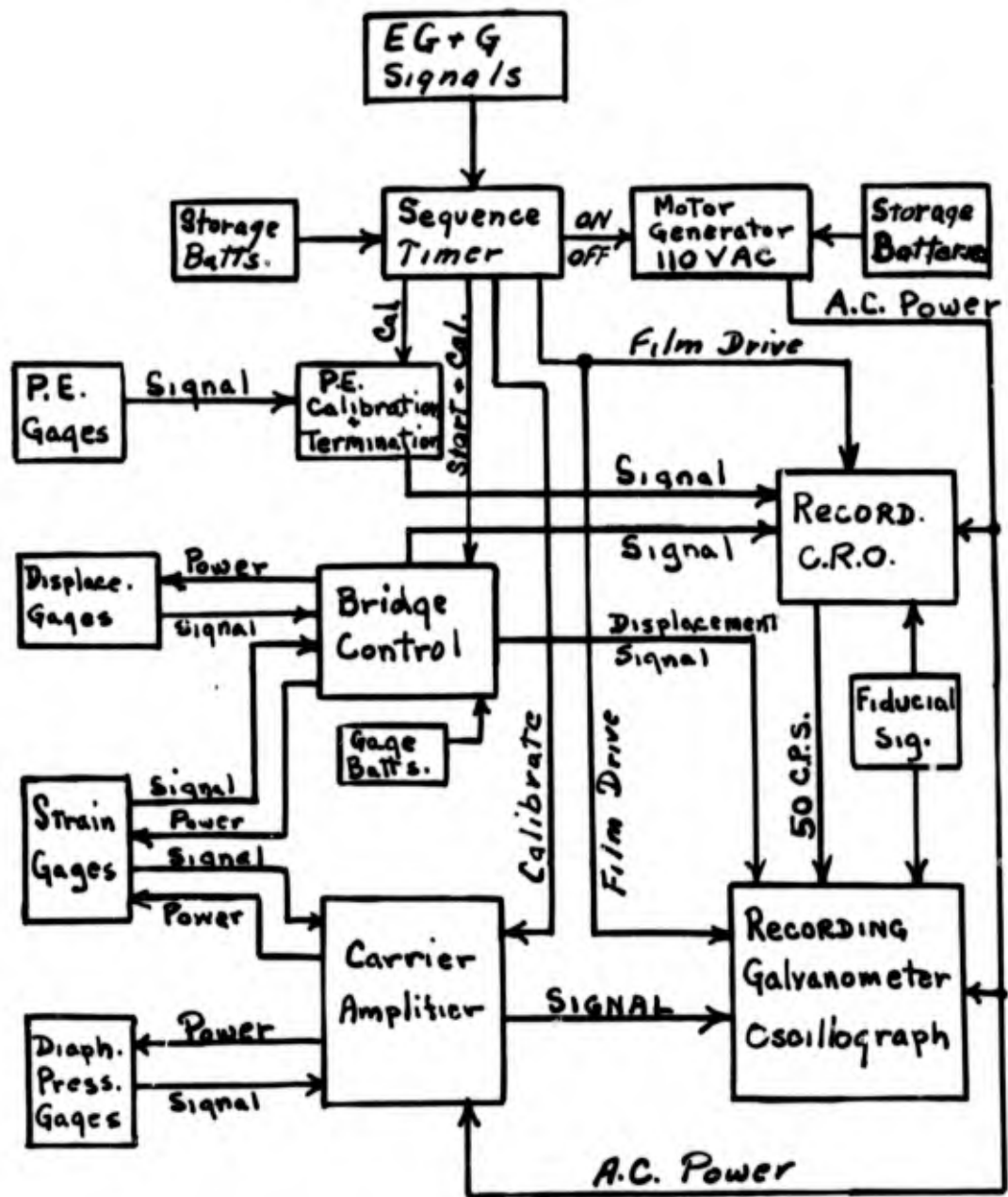


Illustration 1 - Block Diagram of Instrumentation

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TABLE 1 - GAGE STATIONS

No.	Description	Frame No.	Angular Position	Recorded			
				12	13	29	
Circumferential strain on inside							
01	hull plating	15½	0°	RC	RC	RC	
02	"	21½	0°	RG	RG	RG	
03	"	25½	0°	RG	RG	RG	
04	"	28½	0°	F	RC	RC	
05	"	33½	0°	RC	RC	RC	
06	"	33½	60°S	RC	RG	RG	
07	"	33½	120°S	RG	RG	RG	
08	"	33½	180°	RC	RC	RC	
09	"	33½	60°P	RC	RC	RC	
10	"	33½	120°P	F	F	RG	
11	"	37½	0°	F	RG	RG	
12	"	37½	16°P	RC	F	RG	
13	"	37½	32°P	F	RC	RC	
14	"	37½	60°P	F	RG	RG	
15	"	37½	90°P	F	F	RG	
16	"	37½	120°P	F	RG	RG	
17	"	37½	180°	F	F	RC	
18	"	37½	60°S	F	F	RG	
19	"	37½	120°S	F	F	RG	
20	Circumferential strain on flange of hull stiffener		22	0°	RG	RG	RG
21	"	"	25	0°	RG	RG	RG
22	"	"	34	0°	F	F	RG
23	"	"	37	0°	F	F	RG
24	Axial strain on hull plating		15½	0°	RC	RC	RC
25	"	"	25½	0°	F	RG	RG
26	"	"	37½	2°P	RC	RC	RC
27	"	"	33½	32°S	F	RG	RG
28	"	"	33½	180°	F	RC	RC
29	"	"	38½	180°	RC	RC	RC
30	Average circumferential strain on inside hull plating 8 active gages at $\pm 15^\circ, \pm 45^\circ, \pm 75^\circ, \pm 105^\circ$		25½	- -	RG	RG	RG
32	Strain on inside plating of hemispherical stern. 2 active gages at right angles		- -	- -	RC	RC	RC
33	Diaphragm pressure gage outside hull under walk at crown		15½	0°	F	F	N
34	"	"	20½	0°	F	F	N
35	"	"	26½	0°	F	F	N
36	"	"	33½	0°	F	RG	N
37	"	"	37½	0°	F	F	N

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TABLE 1 - GAGE STATIONS (Continued)

No.	Description	Frame No.	Angular Position	Recorded		
				12	13	29
38	Diaphragm pressure gage in ballast tanks	15	90°P	F	F	N
39	" "	15	90°P	F	F	RG
40	" "	15	180°S	F	F	RG
41	" "	37	90°P	F	RG	RG
42	" "	37	90°S	F	RG	N
43	" "	37	180°P	RG	RG	RG
46	Dummy bridge of 4 strain gages	45		F	RC	RC
47	Piezoelectric pressure gage outside hull under walk	15½	0°	F	RC	RC
48	" "	26½	0°	F	RC	RC
49	" "	37½	0°	F	RC	RC
50	Displacement gage between hull stiffener and stbd motor block	35	0°	F	F	RG
51	Displacement gage between hull plating and stbd motor block	35½	0°	RG	RG	RG
52	Displacement gage between hull stiffener and stbd motor block	35	90°	RG	RG	RG

NOTES:

- RC - means gage recorded on CRO.
- RG - means gage recorded with galvanometer oscillograph.
- F - means station failed probably because of cable break.
- N - means that gage was in good condition but not used.

All angles are measured relative to the center of the crown.

* Station 48 on SQUAW-29 was changed as described in text.

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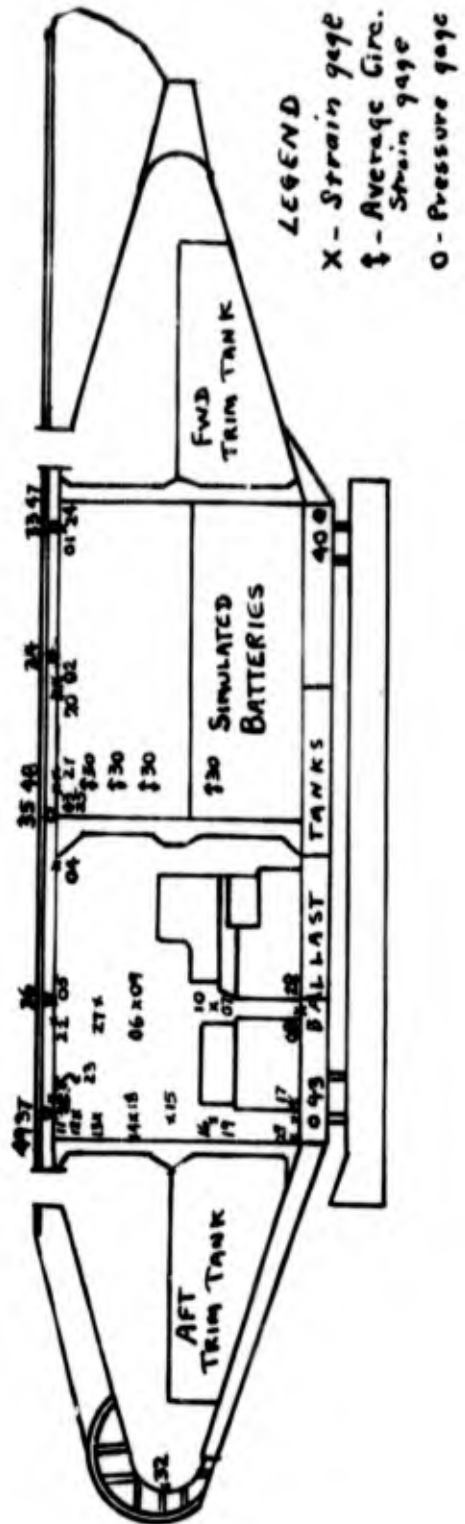
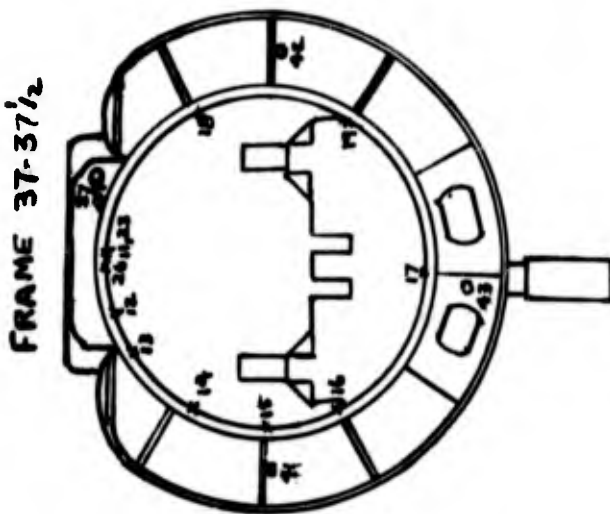
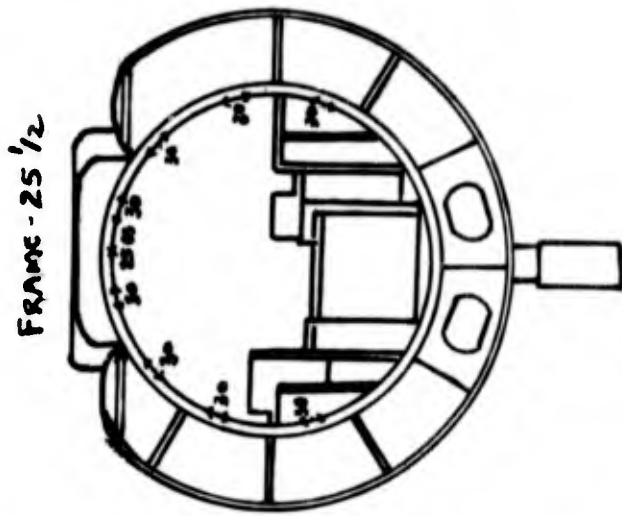


Illustration 2 - Location of Gage Stations

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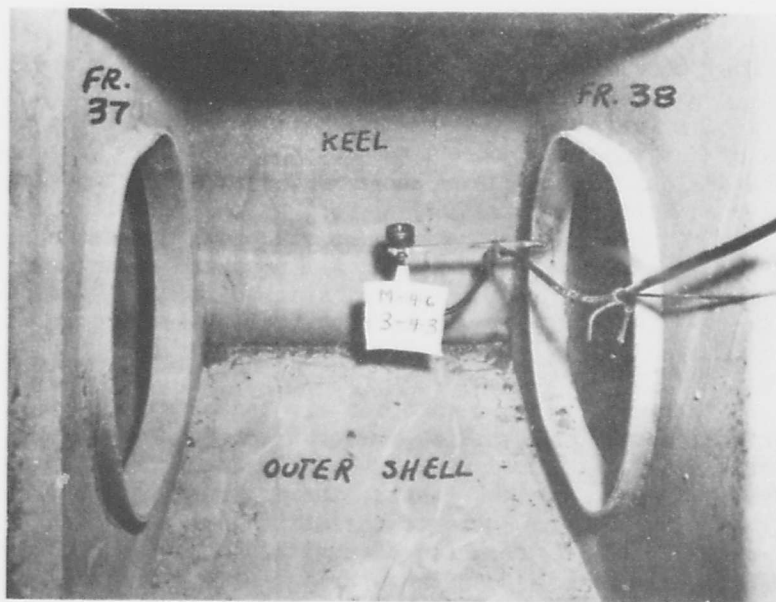
Six diaphragm gages were placed in two belts within the outer ballast tanks. They were midway between the hull and the outer shell. The remaining pressure gages were outside the pressure hull and under the walk in a position where they would be accessible from the ports on the side of the superstructure deck on the SQUAW-29. This meant that they were useless for measuring water pressure since the target was not submerged during the test. However, we had been fortunate in freeing one of these gages from its mount on D-1 day and suspending it about 25 feet below the water line. All pressure gages were connected through stuffing tubes in the access hatch to terminal boards inside the SQUAWs. Illustration 3a shows a typical pressure gage station in the tank at the keel.

In the diaphragm pressure gage, an air backed diaphragm 1 inch in diameter and about 30 mils thick, deforms under the water pressure. The deformation is measured with SK4 strain gages cemented to the inner face. As used in these tests, the pressure gage had one active strain gage, Type A8, cemented to the diaphragm, and three passive strain gages, Type A 8, cemented to the thick body. The four gages were connected to form a resistance bridge with a nominal resistance of 120 ohms. Each diaphragm gage was calibrated in a hydrostatic pressure chamber several times before installation. The sensitivities of these gages can best be expressed as a "bridge factor", which we define as the signal voltage from the bridge per unit applied voltage, per unit applied pressure. For the diaphragm pressure gages on the SQUAWs 12, 13 and 29, respectively, the average bridge factors were 0.50×10^{-6} , 0.70×10^{-6} , and 1.00×10^{-6} psi. The natural frequencies of the gage diaphragms in water were all in excess of 12 KC. However, because of the limitations of the recording systems used the diaphragm pressure gage systems were capable of recording pressure signals from DC to about 600 cps.

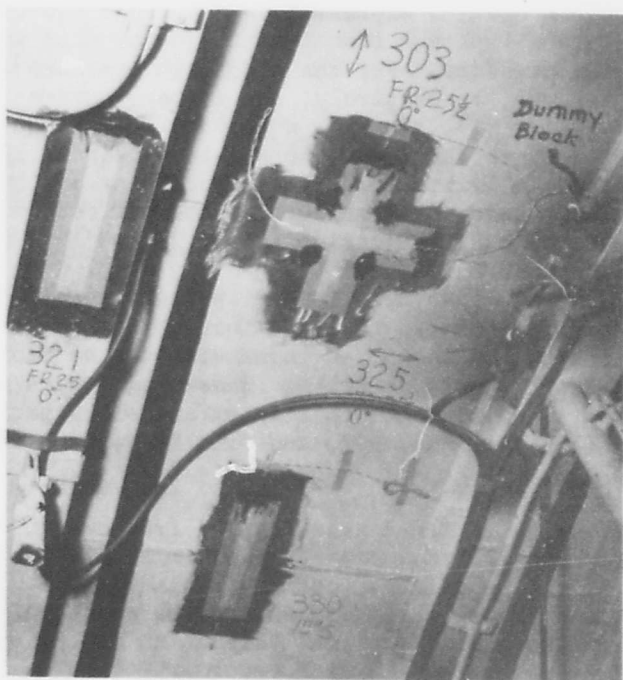
The piezoelectric gages used in this project were 4 or 8 ply tourmaline crystal gages, from 1/2 to 1 1/8 inches in diameter, supplied by Crystal Research Co. as assembled gages without the cable attached and without the waterproof covering. These gages were mounted on a special pipe fitting, attached to Simplex anti-microphonic cable, waterproofed with Bostik No. 292, and finally covered with a layer of rubber tape.

The sensitivities of these gages ranged from 8×10^{-12} to 81×10^{-12} coulombs per psi. The sensitivity was measured for each waterproofed gage, with the attached cable, by placing the complete assembled gage in a pressure pot, releasing the pressure with a bursting diaphragm, and recording the signal through an amplifier and high frequency galvanometer oscillograph recorder.

These gages were each connected to recording CRO's so that the time constants of the input circuits ranged from 0.76 to 2.2 sec prior to D-day.



(a)



(b)

Illustration 3 - (a) Diaphragm Pressure Gage in Tank at Keel
 (b) Several Strain Gage Stations and Dummy Blocks

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2.3 Strain Gages

All strains were measured with SR-4 type A9 gages. These are 300 ohm gages with a gage length of 6 inches. Each strain gage was connected as one arm of a complete resistance bridge at the gage station. The 3 passive arms of the bridge were type A, 300 ohm gages, which were attached to a 1" x 3" x 3" steel block. The steel block was elastically attached to a stud welded to the web of the stiffener adjacent to the gage station. It is believed that there was negligible probability of any signals resulting from the dummy gage block. The passive SR-4 elements on the gage block were all waterproofed with a hot-dip plastic "Barrier" coat. The active SR-4 strain gage was waterproofed by covering the gage with a 3" x 3" x 9" strip of plastic adhesive tape, scotch Electrical Tape #30. These waterproofing techniques in conjunction with the normally dry atmosphere at San Diego were sufficient to maintain the leakage resistance of all strain gages to more than 500 megohms, even after the gages had been applied for more than two months. Illustration 3b shows an installation of several strain gages together with the dummy gage blocks.

2.4 Displacement Gages

The displacement gage was a newly designed adaptation of the rubber band retraction gage described in reference 5. With this gage the displacement between two points is measured by attaching a length of nichrome wire to one of the points and measuring the electrical resistance between that point and a contact attached to the second point. The wire is kept taut by stretched rubber bands attached to the free end. The electrical contact is made by means of a small pool of mercury through which the nichrome wire passes. The mercury pool was contained in a hole drilled into a small plastic panel on which the remainder of the circuit was mounted. The circuit was a simple 200 ohm resistance bridge with the 5 ohm nichrome wire connected between two adjacent arms of the bridge. The bridge signals were recorded directly, without amplification, by means of a sensitive galvanometer with a flat frequency response to 125 cps.

Table 1 describes the three displacement gage channels. For all three positions the mercury contact fixture was attached to the motor block on the starboard side of the engine room compartment as shown in Illustration 4.

2.5 Carrier Amplifiers

There were two 12-channel Miller Type C3 carrier amplifiers in each trailer. These instruments use a 3 KC carrier frequency and have a flat frequency response from d.c. to about 500 cps. The bridge voltage can be adjusted independently on each channel in the range 0 to 10 volts r.m.s., and the nominal amplifier gain is such that a full scale output of 10 ma is obtained with an unattenuated input signal of 0.25 millivolts. All channels were specially engineered to be totally electrically independent, with no points in common on

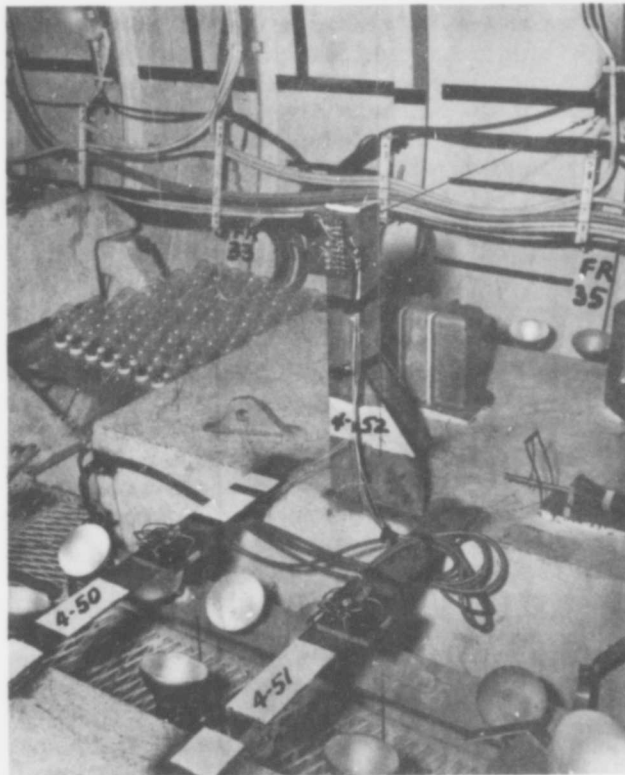


Illustration 4 - Displacement Gage Installations

either the input or output circuits. This instrument incorporates bridge balancing circuits and also a sequential relay-operated calibrating circuit which calibrates each channel in turn by shunting a high resistance across one arm of the external bridge circuit.

2.6 Galvanometer Oscillographs

There was one Consolidated Type 5-119 Oscillograph in the trailers of YFNB-12 and YFNB-13. This instrument was set to record up to 27 channels on 12-inch wide photographic paper moving at 40 in. per sec. The galvanometers used to record the signals from the carrier amplifiers were of types 316 or 216 (natural frequency 1600 cps, sensitivity 9.1 ma/in) and types 320 or 220 (natural frequency 1000 cps, sensitivity 2.3 ma/in). With the high frequency, low sensitivity galvanometers, the linear output of the carrier amplifiers was enough to give a linear deflection of the galvanometer trace of about 1.2 inches. Beyond this amount the galvanometer deflection begins to cut off rapidly as the input signal increases. With the low frequency, high sensitivity galvanometers, the galvanometer deflections were approximately linear with input signals for the whole width of the recording paper. The displacement gage signals were recorded with Type 338 galvanometers, 0.059 ma/in, flat frequency response to 125 cps.

On the YFNB-29 there were two Consolidated Type 5-114 Oscillographs which were used to record 15 and 12 gage stations respectively on 7-inch wide photographic paper moving at 29 in/sec. The same types of galvanometers were used as on the other two barges.

In addition, on each oscillograph, one galvanometer was used to record a precise 50 cps timing signal from a tuning fork-controlled oscillator in the CRO. Another galvanometer on each oscillograph was used to record the fiducial signal transmitted by EG&G.

2.7 Recording CRO

There was one Miller Type CR1 recording CRO in each YFNB. This instrument has 16 separate amplifiers recording through 8 dual-gun tubes on 8-inch wide photographic paper moving at 50 in/sec. The amplifiers are chopper-stabilized against drift and they have a nominal flat frequency response from d.c. to about 150 KC. However, in order to minimize noise, the upper frequency response limit was decreased to about 20 KC. At maximum gain, these instruments require a 5 mv signal to give a deflection of 1 inch on the tube face or 0.33 inches on the recording paper. One channel on each oscillograph was used to record the fiducial signal from EG&G.

2.8 Bridge Control Unit

There were two 8-channel units on each YFNB which were used to control the displacement gage bridges and those strain gage bridges

operating through the CRO recorder. This unit was used to apply battery power to the bridge, balance the bridge, and calibrate. These operations could be performed by individual switches and adjustments in each channel. At the time of the test the battery power was switched on and the channels were calibrated automatically by relays operated through the sequence timer. A voltmeter could be switched to any channel to measure the applied bridge voltage and a panel galvanometer could be similarly used to indicate bridge balance and to measure the calibration signals.

2.9 Sequence Timer

The sequence timer consisted of 12 microswitches which were operated through cams driven by a battery operated 12 volt motor. The timing motor was initially started by the -15 EG&G signal. This started the motor-generator which supplied power to the amplifiers and oscillographs. At -1 min. a second EG&G signal started the motor again and supplied battery power to the gages. At -15 sec. the final EG&G signal started the motor which continued to turn until it stopped in the reset position at +65 sec. In the interim, the film drive was turned on and off on the recorders, all channels were calibrated at -6 sec. and again at about +36 sec., and the motor-generator set was turned off at +60 sec. An auxiliary timing sequence, which was started by the -1 min. signal, would operate all the previously described functions if the other time signals failed.

3 OPERATIONS

At the end of April 1955, the project had completed all preparations for the test. The gages had been installed for about two months; they were all completely wired and checked through and appeared to be in excellent condition. The instruments on the barges were being continually checked and, except for minor difficulties which were corrected, were likewise in good condition. During the trip to the test site all circuits were continually monitored and breaks were discovered in seven of the instrument cables to the YFNB-13 and two of the instrument cables to the YFNB-12. These were apparently due to bends in the cable bundles where they had fouled with the tow lines. However, until D-1 day this was unimportant because there were enough spare channels for all of the recording circuits. After the SQUAWs 12 and 13 had been lowered into position on D-1 day the number of breaks rapidly increased until, on the morning of D day when the last check was made, only about 60 percent of the cables were intact. The SQUAW-29 was not submerged for the test, no cable breaks were noted, but extensive changes had to be made in the recording channels. Most of the pressure gages were disconnected from the recorders and strain gages were substituted. The sensitivities of the strain gage channels operating through the CRO were increased by increasing the bridge voltages. The sensitivities of those strain gage channels which operated through the carrier amplifiers were increased by increasing the bridge voltage and decreasing the input attenuation.

An effort was made to calibrate the sensitivity of all pressure and strain gage bridges by measuring the response of these channels to the static pressure difference of 110 psi between the surface and submerged positions of the SQUAWs. These measurements were made with an SR4 static strain indicator. However, it turned out that the bridge unbalance signals which were due to slow temperature effects were appreciable when compared with the signals due to the pressure difference. Hence, these calibration measurements were unsuccessful.

The records were recovered from the barges on D+1 day. It appears that all instruments had operated properly with one major exception. The recording paper in the CRO of the YFNB-13 had torn when the shock hit the barge, about 0.1 sec after the shock hit the SQUAW-13. At this time the significant signals had already recorded on the photographic paper. Unfortunately, when the jammed paper was later removed from the magazine, this portion of the record was badly fogged. Some of the initial signals were readable and we will try various techniques to read the remaining signals at the home laboratory.

This present report is being prepared in an effort to make the more significant test results quickly available. The results quoted here may be revised in the final report after more complete calibrations are made on the instruments and after a more complete analysis is made of our data, and the data are compared with the test results of other projects. The final report will also include a more detailed and critical description of the instrumentation.

4 TEST RESULTS

Illustration 5 shows a portion of the oscillogram obtained from the galvanometer oscillograph on the YFNB-13. The initial signals are due to the gages on the SQUAW. The violent signals and noise, which occur about 135 milliseconds later, are due to the shock acting on the instruments in the barge. Illustration 6 shows a similar portion of the oscillogram from the CRO on the YFNB-12. On this record each pair of traces comes from a separate tube face. The initial trace positions were on opposite sides of the tube usually near to the edge and the signal polarity was such that the expected signals were directed towards the center of the tube. Many of the signals disappear when they go off scale as early as 5 milliseconds after the shock. On this particular oscillogram all traces disappear completely from the tubes within 0.10 seconds after the shock.

Illustration 7 is a portion of an oscillogram obtained on the YFNB-29. Most of the signals are due to axial strains and it is presumed that the two center sections of the hull were not in contact with the water.

Table 2 is a summary of most of the significant data extracted from the oscillograms. The arrival times which are tabulated refer in most cases to the beginning of the first compression signal and are measured

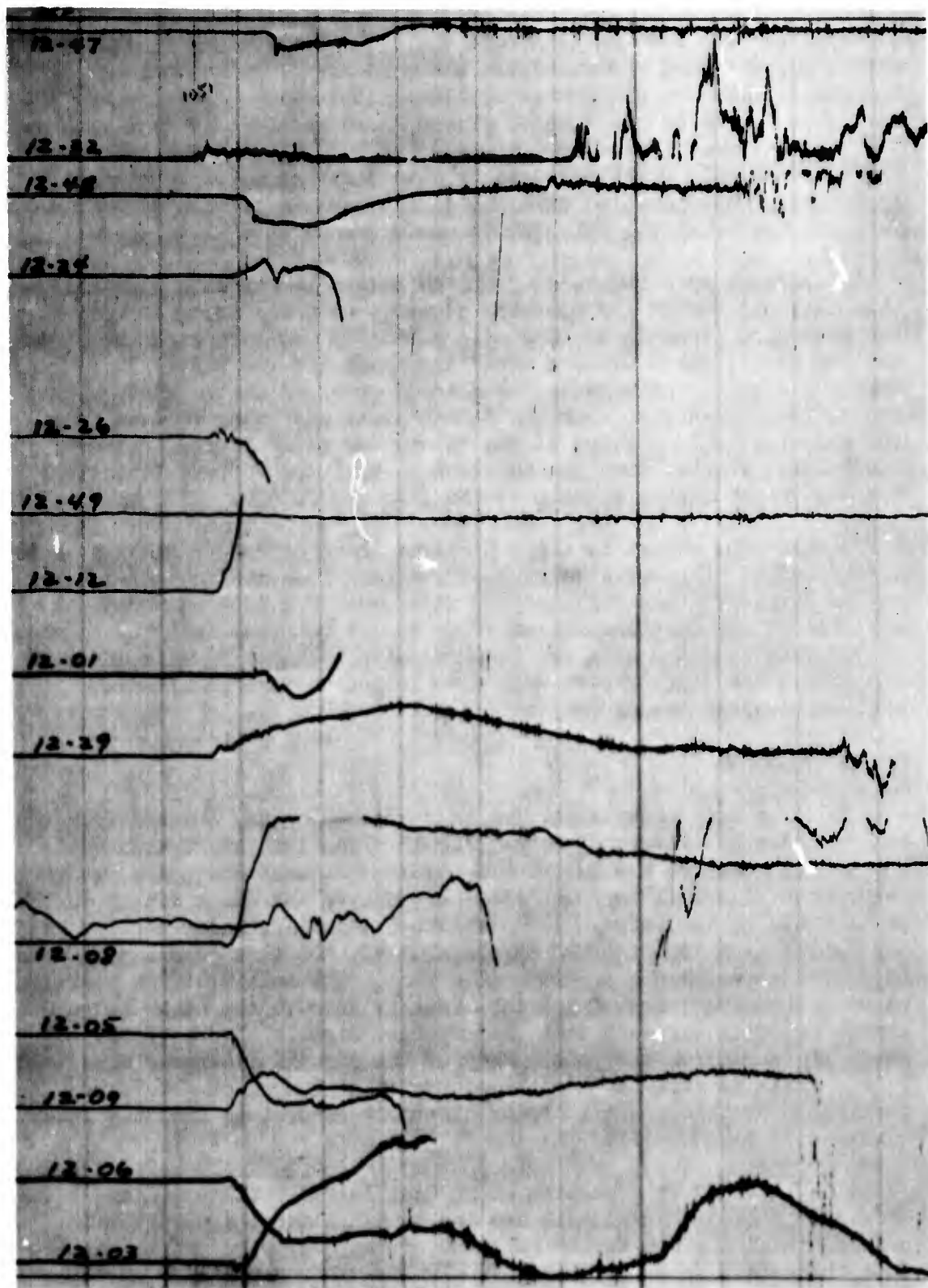
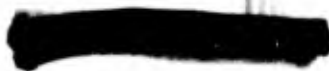


Illustration 5 - Oscillogram from SQUAW-12



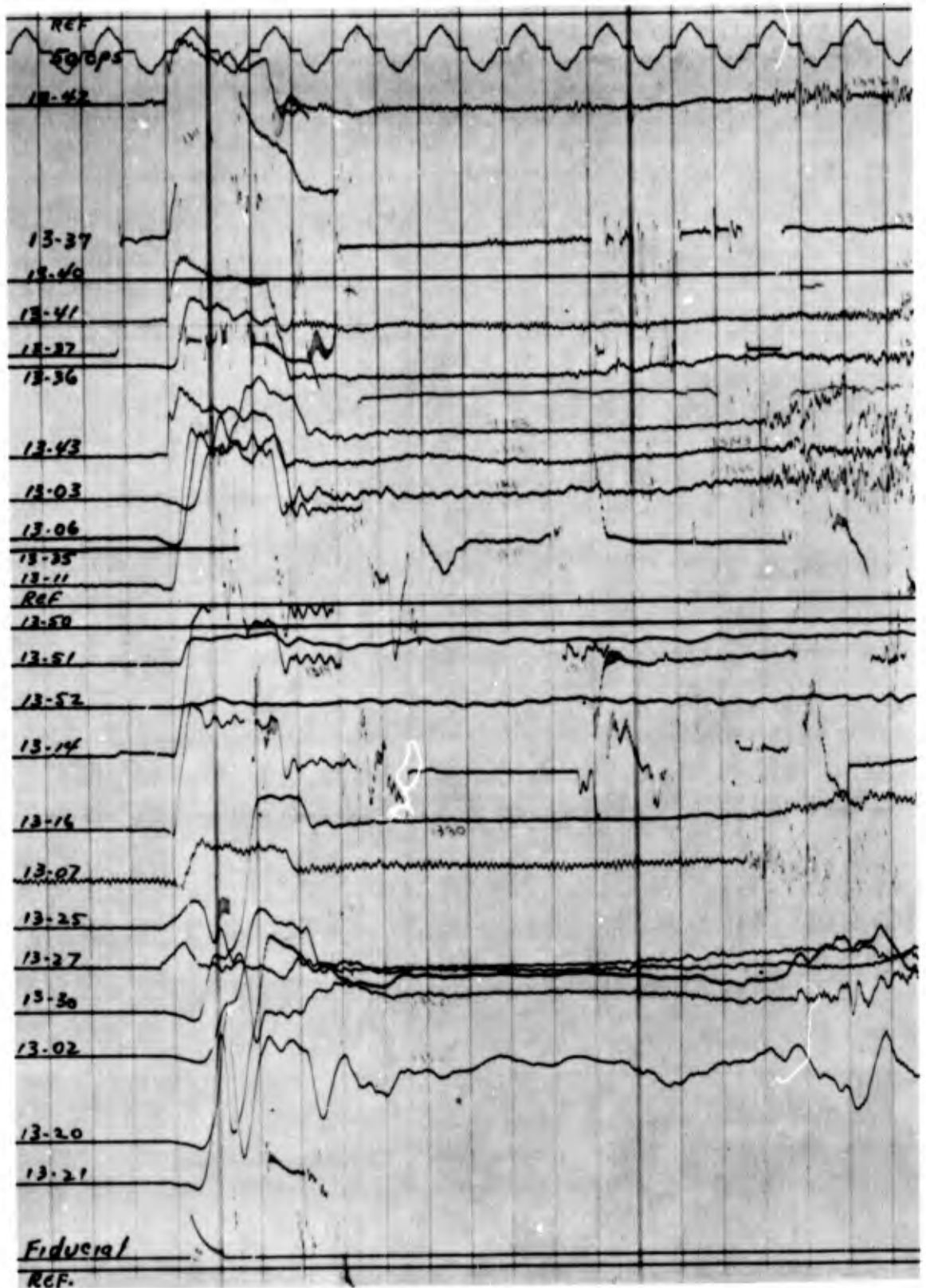


Illustration 6 - Oscillogram from SQUAW-13

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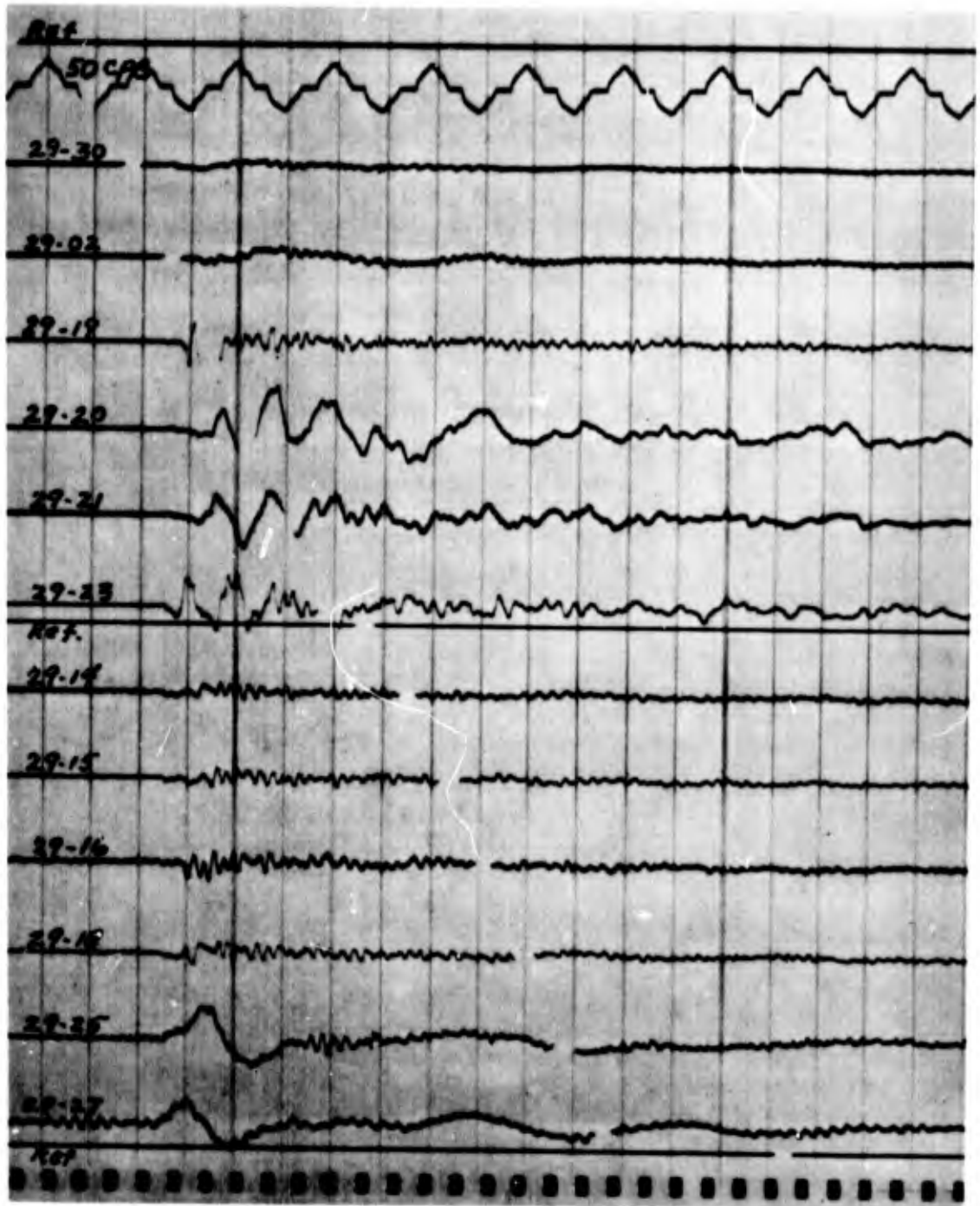


Illustration 7 - Oscillogram from SQUAW-29

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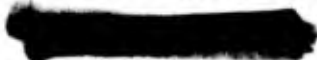


TABLE 2 - SUMMARY OF TEST RESULTS ON SQUAW-12

Station	Position		Time Compression Starts (sec)	Maximum Compression Strain (μ in/in)	Time of Maximum (sec)	Notes
	Frame	Angle				
12.01	15 $\frac{1}{2}$	0°	1.059	1350	1.064	
12.02	21 $\frac{1}{2}$	0°	1.057	30,000	1.098	
12.03	25 $\frac{1}{2}$	0°	1.056	>8300	1.089	(a)
12.05	33 $\frac{1}{2}$	0°	1.054	>6200	1.076	(a)
12.06	33 $\frac{1}{2}$	60°S	1.054	6500	1.095	
12.07	33 $\frac{1}{2}$	120°S	1.054	3440	1.068	
12.08	33 $\frac{1}{2}$	180°	1.054	>6900	1.064	(a)
12.09	33 $\frac{1}{2}$	60°P	1.054	2700	1.120	
12.12	37 $\frac{1}{2}$	16°P	1.053	>5840	1.056	(a)

CIRCUMFERENTIAL STRAIN ON HULL STIFFENERS

12.20	22	0°	1.057	>70,000	1.083	
12.21	25	0°	1.056	>45,000	1.076	

AVERAGE CIRCUMFERENTIAL STRAIN ON HULL PLATING

12.30	25 $\frac{1}{2}$	- -	1.056	6140	1.070	
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AXIAL STRAIN ON HULL PLATING

12.24	15 $\frac{1}{2}$	0°	1.055	-2530	1.077	(a)(b)
12.26	37 $\frac{1}{2}$	0°	1.052	-2490	1.060	(a) (b)
12.29	38 $\frac{1}{4}$	180°	1.052	3320	1.077	

STRAIN INSIDE STERN NOSE

12.32	0	- -	1.050	670	1.052	
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TABLE 2 - SUMMARY OF TEST RESULTS ON SQUAW-12
(Continued)

DISPLACEMENT OF HULL

Station	Position		Time of First Displ. (sec)	Maximum Displ. (in)	Time of Maximum Displ. (sec)	Set Displ. (in)
	Frame	Angle				
12.51	35½	0°	1.056	11.7	1.087	6.9
12.52	35	90°	1.056	11.2	1.101	- -

PRESSURE APPLIED TO HULL

Station	Position		Time of First Press. (sec)	Maximum Pressure (psi)	Time of Max. Press. (sec)	Cut-off Time (m sec)	Appar-ent Time Constant (msec)	Nega-tive Press-ure Level (psi)
	Frame	Angle						
12.43	37	180°P	1.054	845	1.059	42	48	-150

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TABLE 3 - SUMMARY OF TEST RESULTS ON SQUAW-13

Station	Position		Time Compression Starts (sec)	Maximum Compression Strain ($\mu\text{in/in}$)	Time of Maximum Strain (sec)	Compression Set Strain ($\mu\text{in/in}$)	Time of Set Strain Measurement	Notes
	Frame	Angle						
<u>CIRCUMFERENTIAL STRAIN ON HULL PLATING</u>								
13.01	15½	0°	--	--	--	1885	D+1	
13.02	21½	0°	1.475	5370	1.490	3400	5.2	day
13.03	25½	0°	1.475	3655	1.480	2020	5.2	sec
13.05	33½	0°	1.471	3570	1.476	1840	5.2	sec
13.06	33½	60°S	1.470	3470	1.481	1390	5.2	sec
13.07	33½	120°S	1.470	2650	1.475	860	5.2	sec
13.08	33½	180°	1.470	--	--	1190	5.2	sec
13.09	33½	60°P	1.470	3200	1.476	1415	5.2	sec
13.11	37½	0°	1.469	4890	1.476	2310	1.51	sec
13.14	37½	60°P	1.469	6220	1.476	3950	1.51	sec
13.16	37½	120°P	1.468	4520	1.473	2050	1.51	sec
<u>CIRCUMFERENTIAL STRAIN ON HULL STIFFENERS</u>								
13.20	22	0°	1.475	3190	1.480	1600	5.2	sec
13.21	25	0°	1.474	10,000	1.491	7800	5.2	sec
<u>AVERAGE CIRCUMFERENTIAL STRAIN ON HULL PLATING</u>								
13.30	25½	--	1.474	6550	1.492	5900	5.2	sec

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TABLE 3 - SUMMARY OF TEST RESULTS ON SQUAW-13
(Continued)

Station	Position		Time Com- pression Starts (sec)	Maximum Compression Strain (μ in/in)	Time of Max- imum Strain (sec)	Compression Set Strain (μ in/in)	Time of Set Strain Mea- surement	Notes
	Frame	Angle						

AXIAL STRAIN ON HULL PLATING

13.24	15½	0°	1.466	430	1.472	-775	D+1 day	(b)(c)
13.25	25½	0°	1.465	-3680	1.488	-2210	5.2 sec	(b)
13.26	37½	0°	1.463	-760	1.467	-1255	D+1 day	(b)(c)
13.27	33½	32°P	1.465	948	1.471	-152	5.2 sec	(b)
13.28	33½	180°	1.464	630	1.470	- -	- -	
13.29	38¼	180°	1.463	610	1.467	- -	- -	

STRAIN INSIDE STERN NOSE

13.32	0	- -	1.461	460	1.462	00	D+1 day	
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DISPLACEMENT

Station	Position		Time of First Displ. (sec)	Max. Displ. (in)	Time of Max. Displ. (sec)	Set Displ. (in)
	Frame	Angle				
13.51	35½	0°	1.470	2.64	1.482	2.01
13.52	35	90°	1.471	.50	1.480	.25

PRESSURE

Station	Position		Time of First Press- ure (sec)	Maximum Pressure (psi)	Time of Maximum Pressure (sec)	Cut-off Time (msec)	Apparent Time Con- stant (msec)	Negative Pressure Level (psi)
	Frame	Angle						
13.42	37	90°S	1.468	538	1.471	1.495	51	-139
13.41	37	90°P	1.467	523	1.470	1.494	47	-84
13.36	33½	0°P	1.470	534	1.476	1.496	45	-119
13.43	37	180°P	1.467	568	1.470	1.494	51	-99

TABLE 4 - SUMMARY OF TEST RESULTS FROM SQUAW-29

Station.	Position		Time Compres- sion Starts (sec)	Maximum Compres- sion Strain (μ in/in)	Time of Maximum Strain (sec)	Compres- sion Set Strain (μ in/in)	Notes
	Frame	Angle					

CIRCUMFERENTIAL STRAIN ON HULL PLATING

29.01 to 29.19	---	---	---	<75	---	00	(d)
----------------------	-----	-----	-----	-----	-----	----	-----

CIRCUMFERENTIAL STRAIN ON HULL STIFFENERS

29.20	22	0°	2.042	90		00
29.21	25	0°	2.040	90		00
29.22	34	0°	2.038	125		00
29.23	37	0°	2.038	110		00

AVERAGE CIRCUMFERENTIAL STRAIN ON HULL PLATING

29.30	25½	---	2.039	<20		
-------	-----	-----	-------	-----	--	--

AXIAL STRAIN ON HULL PLATING

29.24	15½	0°	2.048	105		00
29.25	25½	0°	2.038	140		00
29.26	37½	0°	2.037	140		00
29.27	33½	32°P	2.037	110		00
29.28	33½	180°	2.040	90		00
29.29	38¼	180°	2.037	70		00

STRAIN INSIDE STERN NOSE

29.32	0	---	2.035	150		00
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DISPLACEMENTS

No significant records.

TABLE 4 - SUMMARY OF TEST RESULTS FROM SQUAW-29
(Continued)

PRESSURE

Station	Position	Time of First Pressure (sec)	Maximum Pressure (psi)	Time of Maximum Pressure (sec)	Cut-off Time (msec)	Apparent Time Constant (msec)	Notes
29.48	See Note TABLE 1	2.039	430	2.039	2.0	50	(e)

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TABLE 5: RANGE AND ATTITUDE OF SQUAW TARGETS

Target	Arrival time at Sta 32 Sec.	Slant Range ft.	Horiz. Range ft.	Angle Between SQUAW and Shock Wave.	Horizontal bearing of SQUAW relative to weapon
12	1.050	5300	5100	61°	69°
13	1.460	7400	7200	0°	--
29	2.034	10300	10100	--	--



from the time of detonation, which is assumed to occur at 29 milliseconds after the first fiducial radio signal received from EG&G. The peak strains and pressures which are tabulated are the peak values which occur on the oscillograms. In many cases much higher strains occurred, but they were off scale. In some cases the signals can not be read at present with any confidence because the oscillogram is fogged. The "set" strains which are tabulated were read, in most cases, on the oscillograms after the barge shock had ceased. For the CRO channels on the YFNB-13 the set strains were measured with an SR4 indicator on D+1 day.

5 DISCUSSION OF TEST RESULTS

5.1 Target Range and Attitude

The slant range of each target, at the stern, has been calculated from the measured time of arrival data and some arrival time vs range calculations of Program I and Program IV. The calculated values are given in Table 5.

The horizontal ranges, which are also tabulated, were calculated on the assumption that the weapon depth was 2000 feet and that the sterns of the SQUAWs 12, 13, and 29 were at depths of 300 feet, 250 feet, and 0 feet, respectively.

Table 5 also lists the angles which the longitudinal axes of the SQUAWs 12 and 13 made with the direction of the incident shock wave. These angles were estimated from Illustration 8, which are graphs of the arrival time at various stations plotted against the longitudinal distance of the station from the stern. The calculation is somewhat ambiguous because it is not certain how to take account of diffracted pressures and precursor strains.

Finally, we have calculated (from the previous angle data) the horizontal bearings of the SQUAWs 12 and 13 relative to the weapon ship. This assumes that the SQUAW-12 was pitching with the stern down 35° at H-hour and that the SQUAW-13 was level, as reported by Project 3.6. The calculated angle of 61° for the SQUAW-12 means that the shock was far from being end-on as had originally been hoped. We can not determine from the time of arrival data with any certainty whether the port or starboard side was facing the weapon. On the SQUAW-13 the computed value of 0° for the angle between the SQUAW and the incident wave is inconsistent with the presumably level attitude of the SQUAW, but the difference is at most only 15° which is probably within the combined experimental errors.

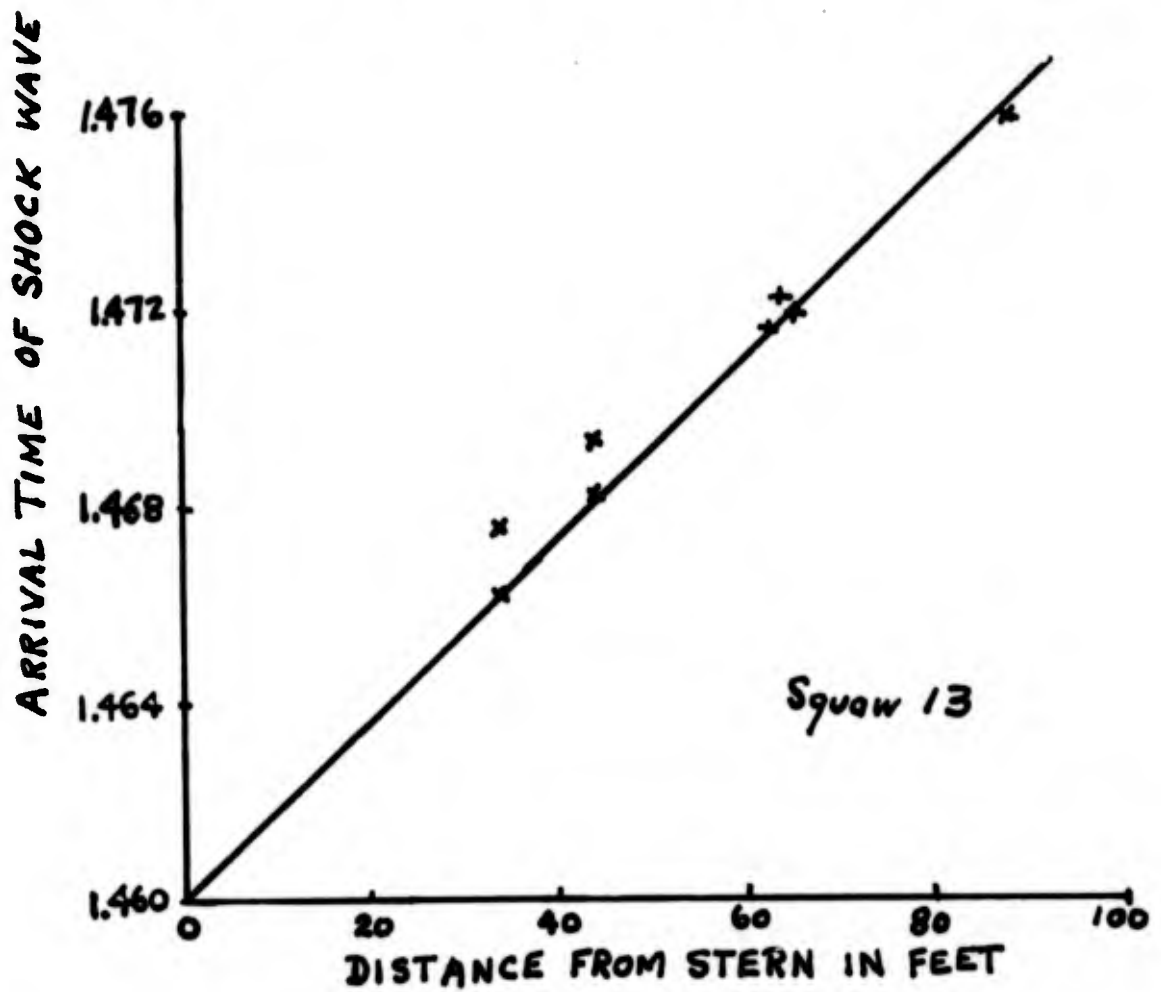
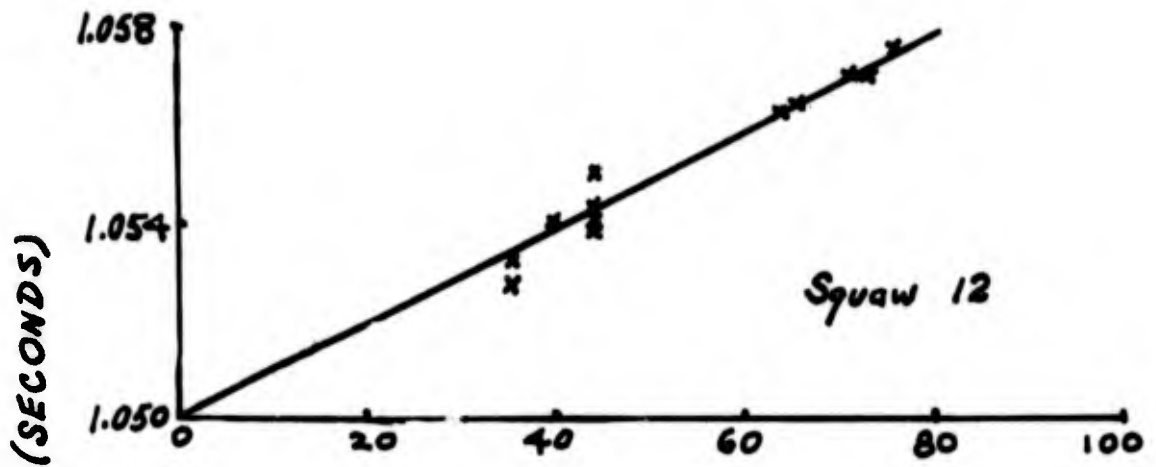


Illustration 8 - Graphs of Shock-wave Arrival Times



5.2 Applied Pressures

The pressure oscillograms are replotted in Illustration 9. In addition to these, there are three oscillograms, obtained from the piezoelectric gages on SQUAW-13 which have not yet been retraced because they are badly fogged.

The one reliable pressure gage on the SQUAW-12 indicates a peak pressure of 845 psi. This gage was partially protected from the direct shock wave by the SQUAW hull and also by the keel structures. This accounts for the initial rise time of about 4 msec, and for perturbations on the record. The measured cut-off time of 42 msec gives a depth of 285 feet at this gage, in good agreement with the expected value.

The peak pressures measured with the diaphragm gages on the SQUAW-13 average 541 psi with a scatter of ± 28 psi. The scatter is within the experimental error at present, but it may possibly be real and be due to differing contributions of reflected and diffracted pressures. The pressures which were measured in the tanks all show an initial pressure spike which may be due to the pressures being transmitted through the outer tank shell and to the motion of that shell. The pressure record obtained at Station 13.36 (under the deck) shows a more gradual rise in pressure perhaps due to the longer diffraction time. The measured cut-off time of 25 msec indicates a depth of 230 feet which is in fair agreement with the nominal value of 250 feet.

The single pressure gage which recorded a large pressure on the SQUAW-29 was a piezoelectric gage which was exposed to free field pressure about 25 feet below the surface. The depth checks with the recorded cut-off time of 2.0 msec. The peak incident pressure of 430 psi is provisionally believed to be accurate within 10 percent. The three other pressure gages which were operating indicate no signal in excess of the noise level of about 5 psi. It is therefore believed that these gages were in the air.

All of the pressure gages on the 12 and 13 indicate irregular perturbations which are due to the presence of the target and which are superimposed on a smooth incident pressure wave. From the average rate of decay of these pressure oscillograms we estimate that the decay time of the incident pressure wave is about 50 ± 10 msec.

5.3 Hull Response of SQUAW-12

The maximum recorded strains appear to be in the battery compartment. In this compartment, Stations 20 and 21 on the stiffeners at the crown and Stations 02 and 03 on the plating at the crown, all show enormous strains which reach 0.004 to 0.008 within 8 msec and reach 0.01 to 0.03 within 25 msec. We believe that such large deformations were most probably accompanied by rupture and that this compartment began to collapse within 10 to 20 msec. After 30 msec there is a

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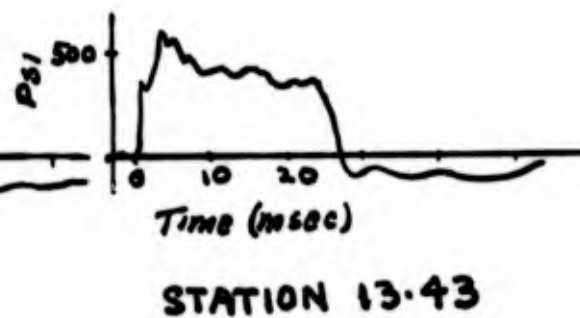
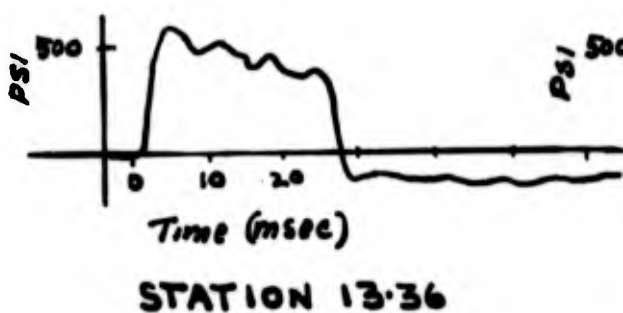
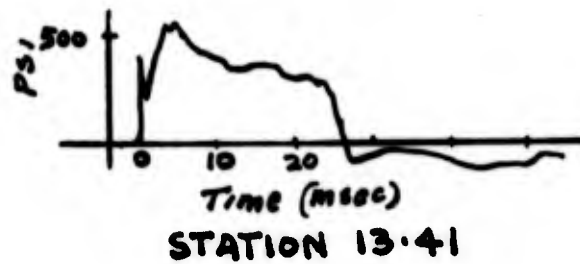
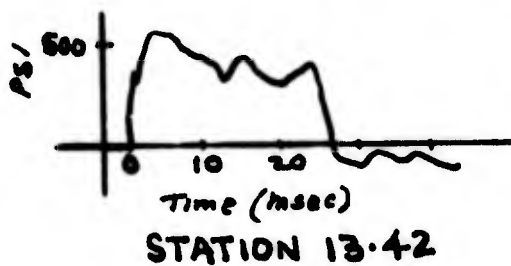
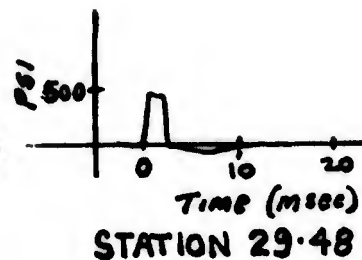
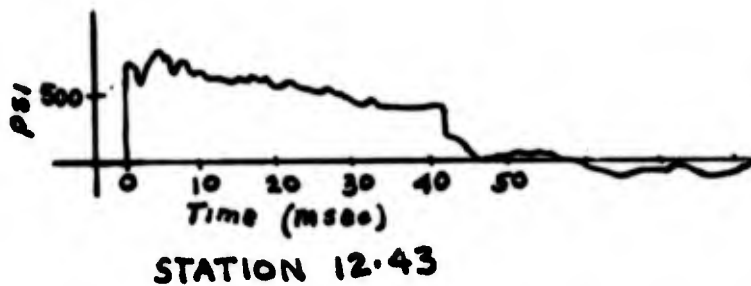


Illustration 9 - Pressure Oscillograms

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major failure in the gages at Station 30. At 1 sec after the shock hits the target none of the gages are recording properly and after about 30 sec all gages fail to calibrate, which might indicate that by that time the entire target was lost.

In the Engine Room compartment the maximum indicated strain is greater than 0.0069 when Station 12.08 goes off scale. Other stations 12.05 and 12.06 go off scale on the CRO tubes when the strains exceed 0.0065. However, from the rates at which the strains are increasing at these stations, it does not appear that the peak values will be as high as in the battery compartment. The strains measured at Stations 12.06 and 12.09 are of special interest because these gages are at similar locations on port and starboard side at Frame 33½. The strains on the starboard gage are always larger than those at the port gage, despite the fact that it is presumed from other evidence that the port side of the target faced the shock wave.

The displacement gage stations in this compartment all show very large deformations of the hull. Station 12.52 indicates that the stiffener on the port side at Frame 35 deflected inboard with a steady motion until the meter limit of 11.2 inches was reached after 45 msec. The initial velocity was about 30 feet per second while the average velocity was about 20 feet per second. This is in excellent agreement with the velocity reported at an adjacent frame by Project 3.2. The motion starts about 1 millisecond before the inboard motion at the crown and these facts make it most plausible that the port side of the target faced the shock. The two displacement gages at the crown likewise indicate inboard displacements of the stiffener and plating of at least one foot in about 25 milliseconds. These deflections are so large, up to 12 shell thicknesses, that it must be considered that the hull also failed in the Engine Room Compartment within 20 milliseconds.

The indicated failures in both compartments occurred so soon that it is believed that the SQUAW-12 was well within the lethal range; the shock was overwhelming, not marginal. Even if the applied pressure had cut off after 20 milliseconds instead of about 40 milliseconds, the target would have been destroyed.

5.4 Hull Response of the SQUAW-13

There is a significant difference in the strains recorded in the Engine Room and in the Battery Room. The strains measured on the hull plating, in the Engine Room, at Stations 06, 07, 11, 14, and 16 all vary in time almost in the same way as the applied pressures, see Illustration 10. The peak strain is obtained at the same time as the peak pressure at the nearest pressure gage; the strains decrease slightly as the applied pressure decays and when the pressure is cut off, the strain likewise drops abruptly. However, the strains all remain at a set of about 60 percent of their peak values. The displacement gage on the plating at the crown indicates that a displacement of about 2 inches is reached at the time of the peak pressure,

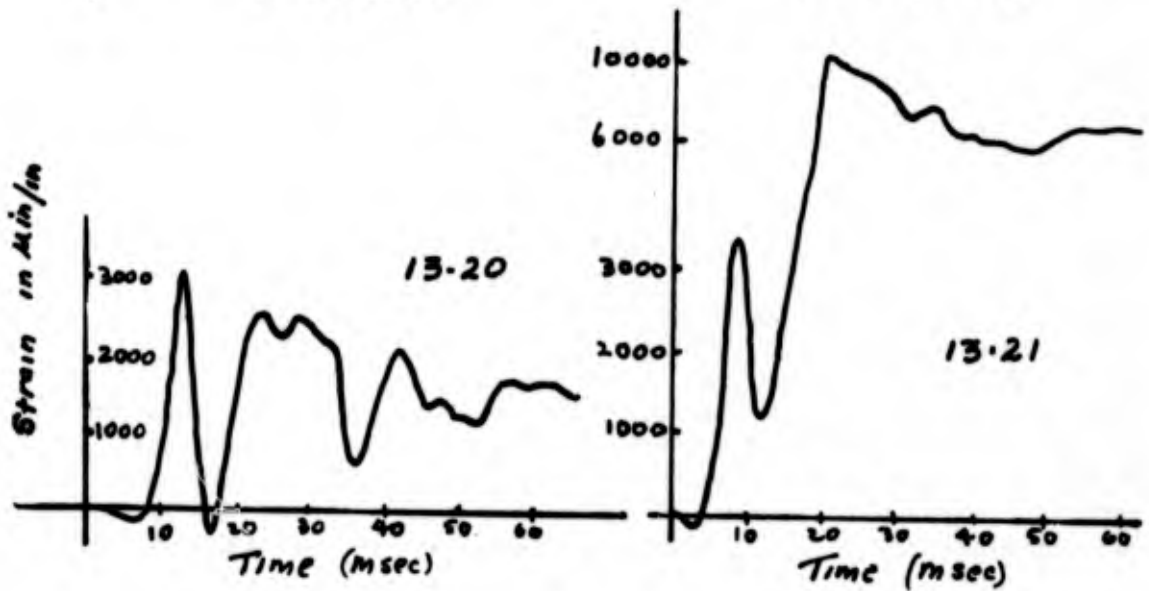
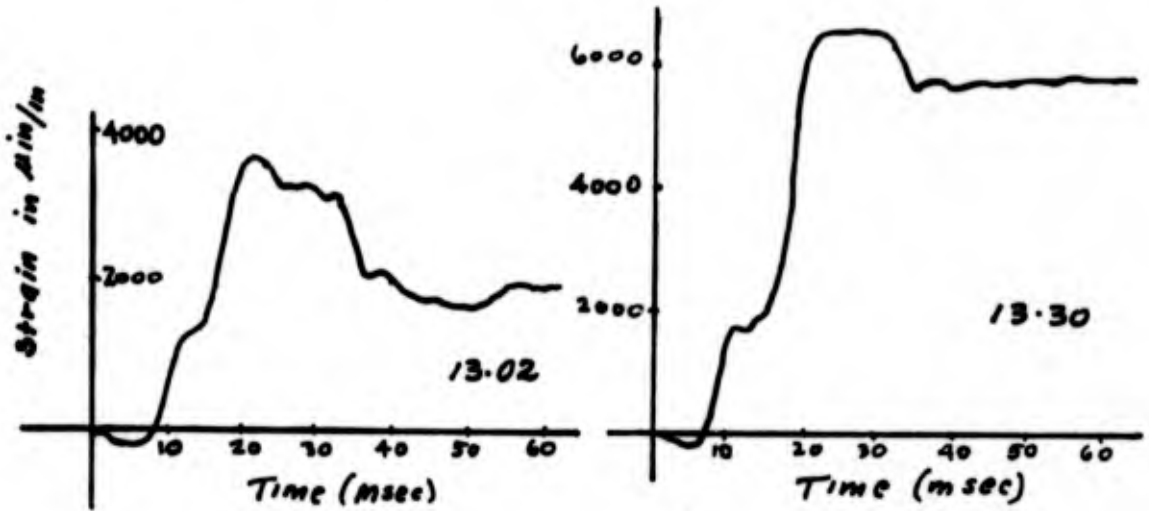
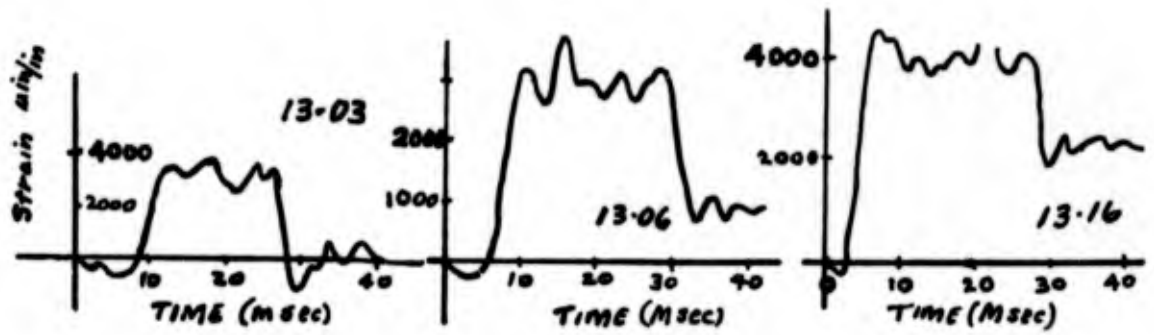


Illustration 10 - Strain Oscillograms for SQUAW-13

and this displacement likewise tends to decrease slightly when the pressure is cut off. It appears as though the hull in this compartment has yielded elastically and plastically without any buckling or rupture until the deformed structure is in equilibrium with the external applied pressures. This apparent equilibrium is reached very quickly, within a millisecond or so, and persists as long as the pressure is applied.

However, the strains measured in the battery compartment do not vary in a similar manner with the applied pressures. At the two stations on stiffeners, 13.20 and 13.21, the strains oscillate rapidly to high peak values of 0.0032 and more than 0.010 after about 20 milliseconds. At the gage stations on plating, 13.02, 13.03, 13.30, the strains attain an initial level of about 0.0015 after about 5 milliseconds, and then rise again to maximum values of from 0.0035 to 0.0045 after another 10 milliseconds. These strains are all very high and can normally be associated with failure of the hull. However, it is clear that failure did not occur. Furthermore, since the peak strains were reached before the pressure was cut off, it is clear that failure did not occur, not because there was insufficient time but because the applied pressures were slightly too low. That is, the residual strength of the deformed hull in its stressed condition was in excess of about 500 psi + 110 psi static.

When the SQUAW-13 was being towed back to the base after the WIGWAM test, there were a few occasions when it dropped to a depth of 600 feet and hung from the instrument cable. The fact that it did not collapse is evidence that the residual strength of the damaged SQUAW was certainly in excess of 260 psi.

5.5 Estimate of the Lethal Range

It seems certain from the discussion of the damage on the SQUAW-13 that the SQUAW would begin to collapse as soon as the external applied pressure on the hull reaches the static collapse pressure. Apparently, as shown by the strain oscillograms in the engine room compartment, inertial effects and strain rate effects are of negligible importance. These same oscillograms also indicate that "response" times of the hull structure are very small compared to the cut off time for the pressure wave. This is shown by the rapidity with which the strain decays to its set value after the pressure is cut off. Hence, it seems that once collapse starts, there is negligible chance of it stopping short because of pressure cut-off.

The static collapse pressure as theoretically calculated from the plans, using the measured values for the yield strength of the plating, has been reported as 650 psi. This pressure is the same as the average value for the total pressure (excess pressure plus hydrostatic pressure) which was measured at the SQUAW-13, yet the 13 did not collapse. However, there is an uncertainty of at least 3 percent in the pressure

measurement, and an uncertainty of more than this in the theoretical calculation of the static collapse pressure. It is estimated therefore that, under the WIGWAM test conditions, the critical horizontal range for a SQUAW target is slightly less than the range of the SQUAW-13, or about 7000 feet. This estimate is tentative, subject to further checks on the target standoffs, the incident pressure field, and the static collapse pressure.

6 CONCLUSIONS

It is tentatively concluded that the lethal horizontal range of the SQUAW target is 7000 feet when the target depth is 250 feet and weapon depth is 2000 feet. The corresponding slant range is about 7200 feet. The total applied pressure which is necessary for collapse is about 700 psi according to our measurements, but this figure will be modified as other pressure data becomes available.

For any other submarine the experimental evidence indicates that the critical pressure is identical with the static collapse pressure.

7 RECOMMENDATIONS

We believe that the preliminary estimates of the pressure field of the weapon and of the lethal range of the submarine targets were fairly successful. They have probably been confirmed with as much precision as is possible at this time. Accordingly, we recommend that no further major test of this sort should be conducted unless there is a major change in the weapon, or until there is a more precise and quantitative understanding of the damage mechanism in submarines.

The SQUAW-29 remains after the WIGWAM test as an extraordinary unique and useful test vehicle. We recommend that it be used for underwater explosion tests with conventional chemical charges in the elastic range; such tests to be conducted by personnel of this project. We anticipate that we could obtain from these tests a large amount of information on the structural characteristics of the SQUAW which could be of considerable value in interpreting the measurements made during WIGWAM. The elastic range tests could also be of tremendous value in verifying present theories on the flexural response of submarines to underwater explosions. These underwater explosion tests are completely compatible with other proposed non-destructive uses for the SQUAW-29.

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Tech. Library
- 52 Commanding Officer, Transportation R&D Station, Ft.
Eustis, Va.
- 53 Director, Technical Documents Center, Evans Signal
Laboratory, Belmar, N.J.
- 54 Director, Waterways Experiment Station, PO Box 631,
Vicksburg, Miss. ATTN: Library
- 55 Director, Armed Forces Institute of Pathology, 7th and
Independence Avenue, S.W., Washington 25, D.C.
- 56 Director, Operations Research Office, Johns Hopkins
University, 7100 Connecticut Ave., Chevy Chase, Md.,
Washington 15, D.C. ATTN: Library
- 57- 63 Technical Information Service, Oak Ridge, Tenn.
(Surplus)

NAVY ACTIVITIES

- 64- 65 Chief of Naval Operations, D/N, Washington 25, D.C.
ATTN: OP-36
- 66 Chief of Naval Operations, D/N, Washington 25, D.C.
ATTN: OP-03EG
- 67 Director of Naval Intelligence, D/N, Washington 25,
D.C. ATTN: OP-92ZV
- 68 Chief, Bureau of Medicine and Surgery, D/N, Washington
25, D.C. ATTN: Special Weapons Defense Div.
- 69 Chief, Bureau of Ordnance, D/N, Washington 25, D.C.
- 70 Chief, Bureau of Ships, D/N, Washington 25, D.C. ATTN:
Code 348
- 71 Chief, Bureau of Yards and Docks, D/N, Washington 25,
D.C. ATTN: D-440
- 72 Chief, Bureau of Supplies and Accounts, D/N, Washing-
ton 25, D.C.
- 73- 74 Chief, Bureau of Aeronautics, D/N, Washington 25, D.C.
- 75 Chief of Naval Research, Department of the Navy,
Washington 25, D.C. ATTN: LI(jg) F. McKee, USN
- 76 Commander-in-Chief, U.S. Pacific Fleet, Fleet Post
Office, San Francisco, Calif.
- 77 Commander-in-Chief, U.S. Atlantic Fleet, U.S. Naval
Base, Norfolk 11, Va.
- 78- 81 Commandant, U.S. Marine Corps, Washington 25, D.C.
ATTN: Code A03E
- 82 President, U.S. Naval War College, Newport, R.I.
- 83 Superintendent, U.S. Naval Postgraduate School,
Monterey, Calif.
- 84 Commanding Officer, U.S. Naval Schools Command, U.S.
Naval Station, Treasure Island, San Francisco,
Calif.
- 85 Commanding Officer, U.S. Fleet Training Center, Naval
Base, Norfolk 11, Va. ATTN: Special Weapons School
- 86- 87 Commanding Officer, U.S. Fleet Training Center, Naval
Station, San Diego 36, Calif. ATTN: (SPWP Control)
- 88 Commanding Officer, U.S. Naval Damage Control Training
Center, Naval Base, Philadelphia 12, Pa. ATTN: ABC
Defense Course
- 89 Commanding Officer, U.S. Naval Unit, Chemical Corps
School, Army Chemical Training Center, Ft. McClellan,
Ala.
- 90 Commander, U.S. Naval Ordnance Laboratory, Silver
Spring 19, Md. ATTN: EE
- 91 Commander, U.S. Naval Ordnance Laboratory, Silver
Spring 19, Md. ATTN: ER
- 92 Commander, U.S. Naval Ordnance Laboratory, Silver
Spring 19, Md. ATTN: R

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- 93 Commander, U.S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.
- 94 Officer-in-Charge, U.S. Naval Civil Engineering Res. and Evaluation Lab., U.S. Naval Construction Battalion Center, Port Hueneme, Calif. ATTN: Code 753
- 95 Commanding Officer, U.S. Naval Medical Research Inst., National Naval Medical Center, Bethesda 14, Md.
- 96 Director, U.S. Naval Research Laboratory, Washington 25, D.C. ATTN: Code 2029
- 97 Commanding Officer and Director, U.S. Navy Electronics Laboratory, San Diego 52, Calif. ATTN: Code 4223
- 98-99 Commanding Officer, U.S. Naval Radiological Defense Laboratory, San Francisco 24, Calif. ATTN: Technical Information Division
- 100 Director, Naval Air Experimental Station, Air Material Center, U.S. Naval Base, Philadelphia, Penn.
- 101 Commanding Officer and Director, David W. Taylor Model Basin, Washington 7, D.C. ATTN: Library
- 102 Commander, U.S. Naval Air Development Center, Johnsville, Pa.
- 103 Director, Office of Naval Research Branch Office, 1000 Geary St., San Francisco, Calif.
- 104 Commanding Officer and Director, U.S. Naval Engineering Experiment Station, Annapolis, Md. ATTN: Code 705
- 105-111 Technical Information Service, Oak Ridge, Tenn. (Surplus)
- 141 Commander, Crew Training Air Force, Randolph Field, Tex. ATTN: 2978, DCS/O
- 142 Commander, Headquarters, Technical Training Air Force, Gulfport, Miss. ATTN: TA&D
- 143-144 Commandant, Air Force School of Aviation Medicine, Randolph AFB, Tex.
- 145-150 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCOSI
- 151-152 Commander, Air Force Cambridge Research Center, 230 Albany Street, Cambridge 39, Mass. ATTN: CRQST-2
- 153-155 Commander, Air Force Special Weapons Center, Kirtland AFB, N. Mex. ATTN: Library
- 156 Commandant, USAF Institute of Technology, Wright-Patterson AFB, Dayton, O. ATTN: Resident College
- 157 Commander, Lowry AFB, Denver, Colo. ATTN: Department of Armament Training
- 158 Commander, 1009th Special Weapons Squadron, Headquarters, USAF, Washington 25, D.C.
- 159-160 The RAND Corporation, 1700 Main Street, Santa Monica, Calif. ATTN: Nuclear Energy Division
- 161 Commander, Second Air Force, Barksdale AFB, Louisiana. ATTN: Operations Anal. Office
- 162 Commander, Eighth Air Force, Westover AFB, Mass. ATTN: Operations Anal. Office
- 163 Commander, Fifteenth Air Force, March AFB, Calif. ATTN: Operations Anal. Office
- 164-170 Technical Information Service, Oak Ridge, Tenn. (Surplus)

AIR FORCE ACTIVITIES

- 112 Asst. for Atomic Energy, Headquarters, USAF, Washington 25, D.C. ATTN: DCS/O
- 113 Director of Operations, Headquarters, USAF, Washington 25, D.C. ATTN: Operations Analysis
- 114 Director of Plans, Headquarters, USAF, Washington 25, D.C. ATTN: War Plans Div.
- 115 Director of Research and Development, Headquarters, USAF, Washington 25, D.C. ATTN: Combat Components Div.
- 116-117 Director of Intelligence, Headquarters, USAF, Washington 25, D.C. ATTN: AFOIN-IB2
- 118 The Surgeon General, Headquarters, USAF, Washington 25, D.C. ATTN: Bio. Def. Br., Pre. Med. Div.
- 119 Deputy Chief of Staff, Intelligence, Headquarters, U.S. Air Forces Europe, APO 633, c/o PM, New York, N.Y. ATTN: Directorate of Air Targets
- 120 Commander, 497th Reconnaissance Technical Squadron (Augmented), APO 633, c/o PM, New York, N.Y.
- 121 Commander, Far East Air Forces, APO 925, c/o PM, San Francisco, Calif.
- 122 Commander-in-Chief, Strategic Air Command, Offutt Air Force Base, Omaha, Nebraska. ATTN: Special Weapons Branch, Inspection Div., Inspector General
- 123 Commander, Tactical Air Command, Langley AFB, Va. ATTN: Documents Security Branch
- 124 Commander, Air Defense Command, Ent AFB, Colo.
- 125-126 Commander, Wright Air Development Center, Wright-Patterson AFB, Dayton, O. ATTN: WCRWN, Blast Effects Research
- 127 Commander, Air Training Command, Scott AFB, Belleville, Ill. ATTN: DCS/O GTP
- 128 Assistant Chief of Staff, Installations, Headquarters, USAF, Washington 25, D.C. ATTN: AFCEI-E
- 129 Commander, Air Research and Development Command, PO Box 1395, Baltimore, Md. ATTN: RDDN
- 130 Commander, Air Proving Ground Command, Eglin AFB, Fla. ATTN: AG/TRB
- 131-132 Director, Air University Library, Maxwell AFB, Ala.
- 133-140 Commander, Flying Training Air Force, Waco, Tex. ATTN: Director of Observer Training

OTHER DEPARTMENT OF DEFENSE ACTIVITIES

- 171 Asst. Secretary of Defense, Research and Development, D/D, Washington 25, D.C. ATTN: Tech. Library
- 172 U.S. Documents Officer, Office of the U.S. National Military Representative - SHAPE, APO 55, New York, New York
- 173 Director, Weapons Systems Evaluation Group, OSD, Rm 2E1006, Pentagon, Washington 25, D.C.
- 174 Armed Services Explosives Safety Board, D/D, Building T-7, Gravelly Point, Washington 25, D.C.
- 175 Commandant, Armed Forces Staff College, Norfolk 11, Va. ATTN: Secretary
- 176-181 Commanding General, Field Command, Armed Forces Special Weapons Project, PO Box 5100, Albuquerque, N. Mex.
- 182-183 Commanding General, Field Command, Armed Forces, Special Weapons Project, PO Box 5100, Albuquerque, N. Mex. ATTN: Technical Training Group
- 184-192 Chief, Armed Forces Special Weapons Project, Washington 25, D.C. ATTN: Document Library Branch
- 193-199 Technical Information Service, Oak Ridge, Tenn. (Surplus)

ATOMIC ENERGY COMMISSION ACTIVITIES

- 200-202 U.S. Atomic Energy Commission, Classified Technical Library, 1901 Constitution Ave., Washington 25, D.C. ATTN: Mrs. J. M. O'Leary (For DMA)
- 203-205 Los Alamos Scientific Laboratory, Report Library, PO Box 1663, Los Alamos, N. Mex. ATTN: Helen Redman
- 206-210 Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: Martin Lucero
- 211-213 University of California Radiation Laboratory, PO Box 808, Livermore, Calif. ATTN: Margaret Edlund
- 214 Weapon Data Section, Technical Information Service, Oak Ridge, Tenn.
- 215-260 Technical Information Service, Oak Ridge, Tenn. (Surplus)

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