AFTAC Project No. VELA T/6708
ARPA Order No. 624
ARPA Program Code No. 6F10

EXPLOSION PROGRAM
KURILE ISLANDS EXPERIMENT

Special Report No. 2
OCEAN-BOTTOM SEISMOGRAPHIC EXPERIMENTS

Prepared by
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TEXAS INSTRUMENTS INCORPORATED
Science Services Division
P.O. Box 5621
Dallas, Texas 75222

28 April 1967

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AIR FORCE TECHNICAL APPLICATIONS CENTER,
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SECTION I
INTRODUCTION

During October, November and December 1966, an Ocean-Bottom Seismograph experiment was conducted near the Kurile Islands to evaluate the seismicity of the area and to confirm the operational worthiness of the instrument. In addition to the recording of earthquakes, calibration charges were fired to provide additional data for evaluation of travel times for this region. The objective of this report is to detail the procedures developed for the explosion program and to give the reliability of the calibration data.

The explosive used was 120,000 lb of high-energy composition B packed in 50-lb cubical cans (9-1/2 in. side), which was shot in ten 5.2-ton, six 1-ton and one 1.5-ton packages. These charges were exploded in a network designed to provide optimum recording on the ocean-bottom instrumentation and minimum damage to marine life. The shots were restricted to the following conditions: daylight hours, 2 mi or more from any approaching vessel, a minimum of 1300 fm of water depth, and/or more than 100 km from land.

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SECTION II

METHOD

Ship Rigging — Figure 1 shows the 165-ft M/V Campeche Seal and the special rigging necessary to accomplish the calibration program.

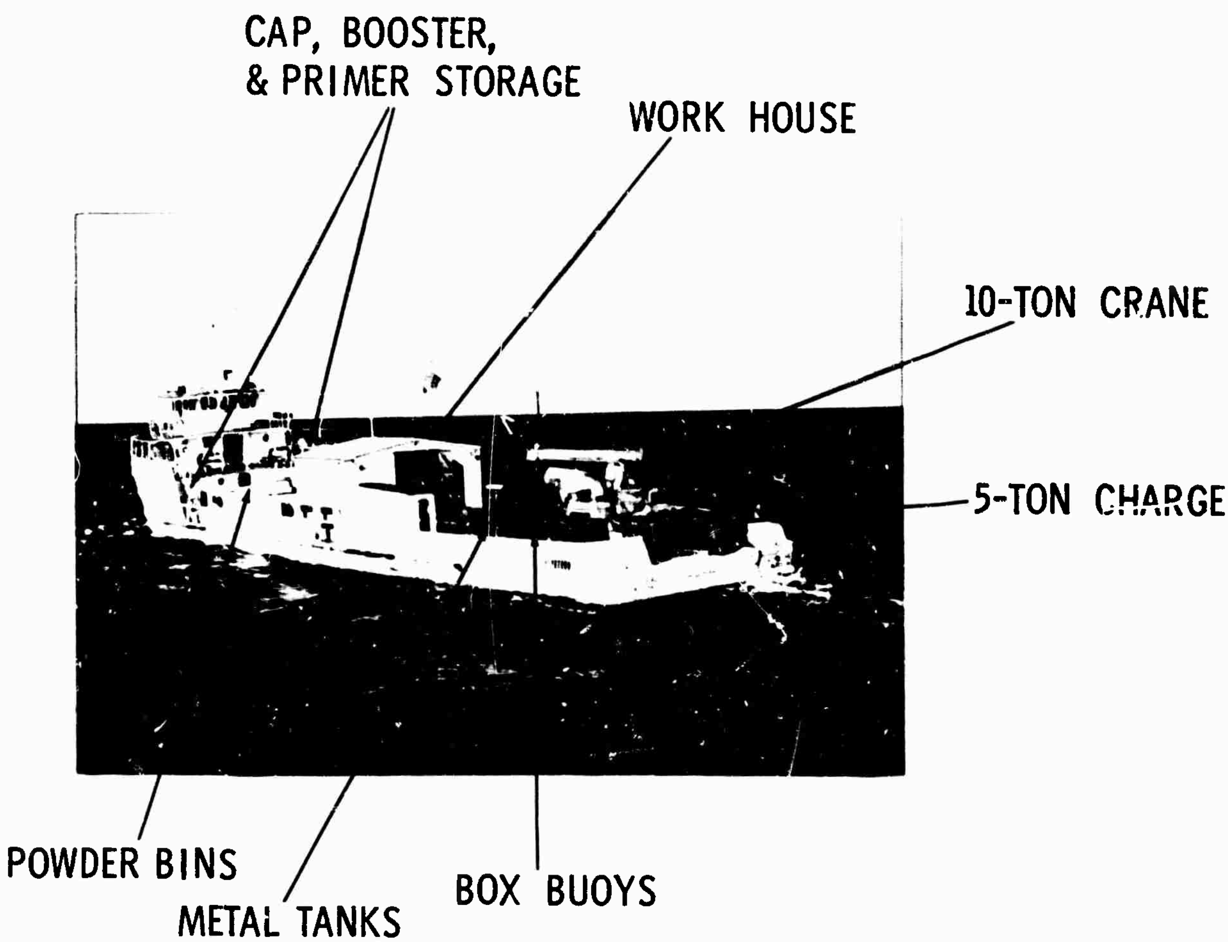


Figure 1. M/V Campeche Seal

For powder storage, two 210-x-135-x-38-in. wood-lined powder bins were constructed, each providing a 61,600-lb or 1232-can capacity. Caps, boosters and primers were stored in two wood-lined metal boxes behind the ship's superstructure. Roller conveyers were used to move the powder 75 to 100 ft to the loading area.

Each charge was launched from the stern of the M/V Campeche Seal by lifting an A-frame with a 10-ton hydraulic crane (Figure 2). The charges were placed on two 2-x-6-x-84-in. wooden skids. When the A-frame was inclined, the charge slid into the water.

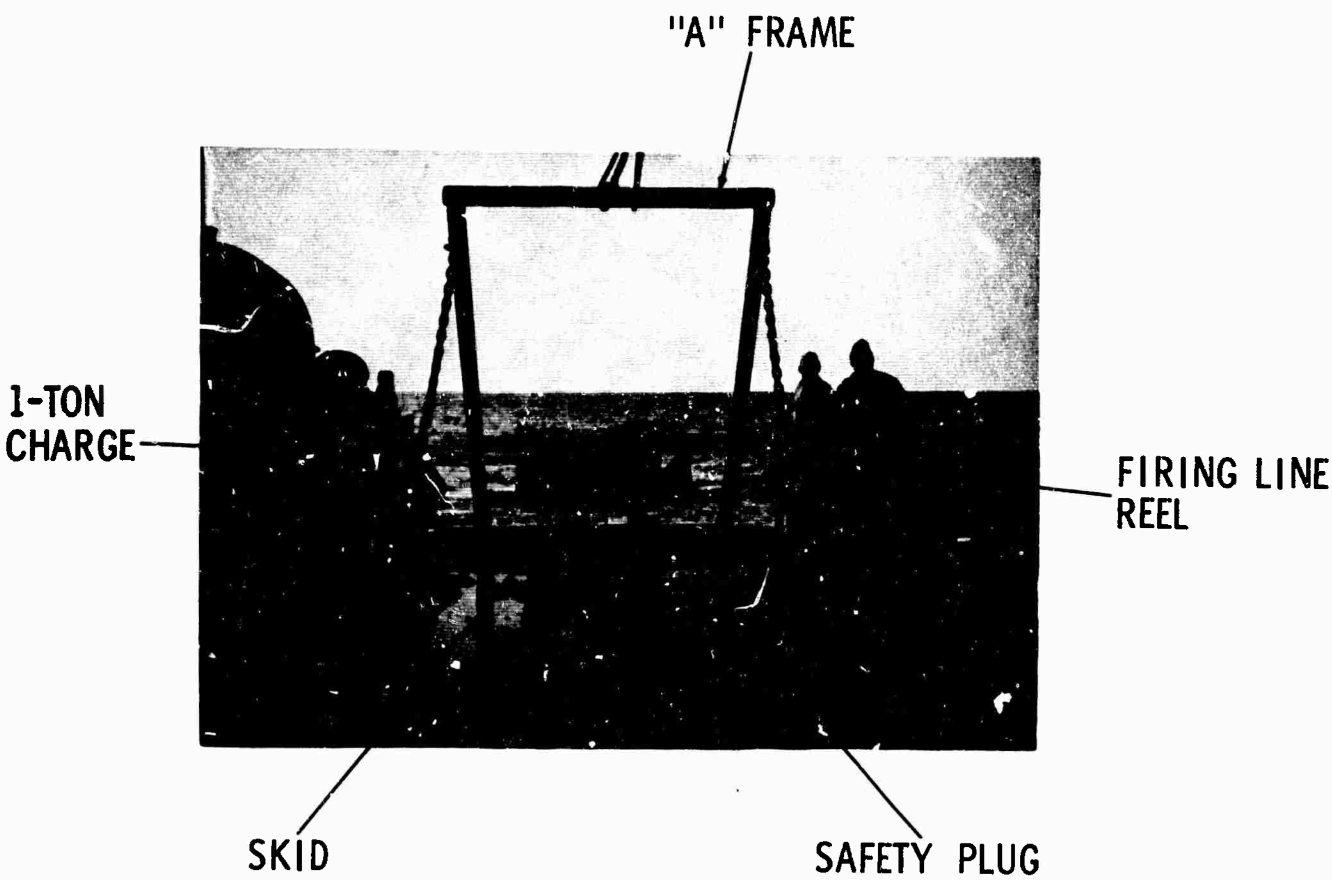


Figure 2. A-Frame Assembly

Material — Explosives used were government-furnished property stored at the U.S. Naval Ordnance Depot in Bangor, Washington, and delivered to the Naval Ordnance Depot in Seal Beach, California. Primers, boosters and caps were obtained from the Washington state supply center of E. I. duPont de Nemours and Co., Inc.

The material list for the calibration shots included:

- Firing equipment — firing line, blaster, blasting-cap safety plug, marine geophone, WWV receiver, 6-channel galvoamplifier, and Visicorder
- Packaging material — metal banding, nylon line, manila rope, jet engine tanks, and lumber
- Flotation material — nylon line, polyurethane inflatable buoys, styrofoam blocks, and wooden box buoys filled with styrofoam

The appendix presents a complete inventory containing specific material requirements.

1-Ton Charge — Each 1-ton charge was constructed of two layers of 20 cans banded to a 38-x-48-in. wooden pallet with 115 ft of 1-in. banding (Figure 3). To allow space for primers, two 5-x-9-in. spacers were placed in the top and side of each charge. Two primers, two boosters and two caps were used to fire each of these charges.

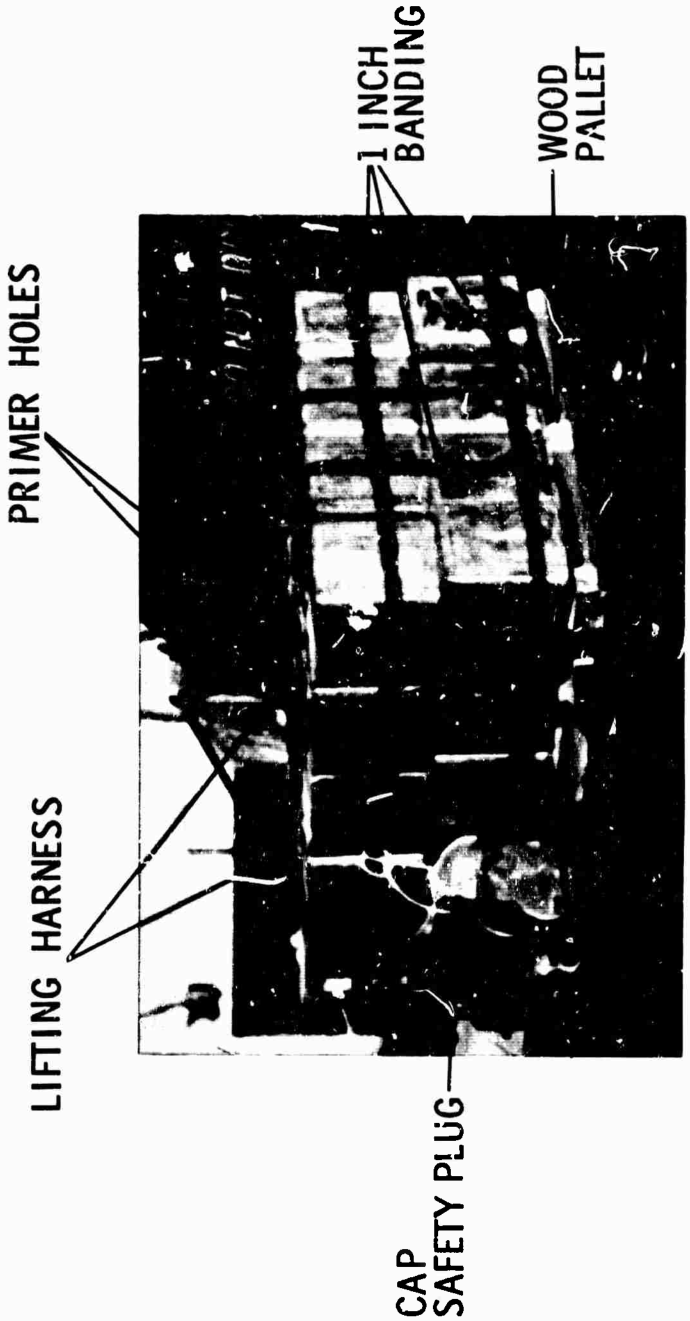


Figure 3. 1-Ton Charge

5.2-Ton Charge — The 5.2-ton charge consisted of 209 cans of explosive packaged in a 4-x-5-x-9.5-ft metal tank (Figure 4). Four primers, four boosters, and four caps were placed at intervals in the middle two rows of cans for charge detonation (with the exception of E7A and E14 where three of each component were used in a similar method). For E12, E13, E7A, and E14, two plywood sheets were used to cover the charge, reducing to half the quantity of banding normally used. These charges were constructed in the launch position.

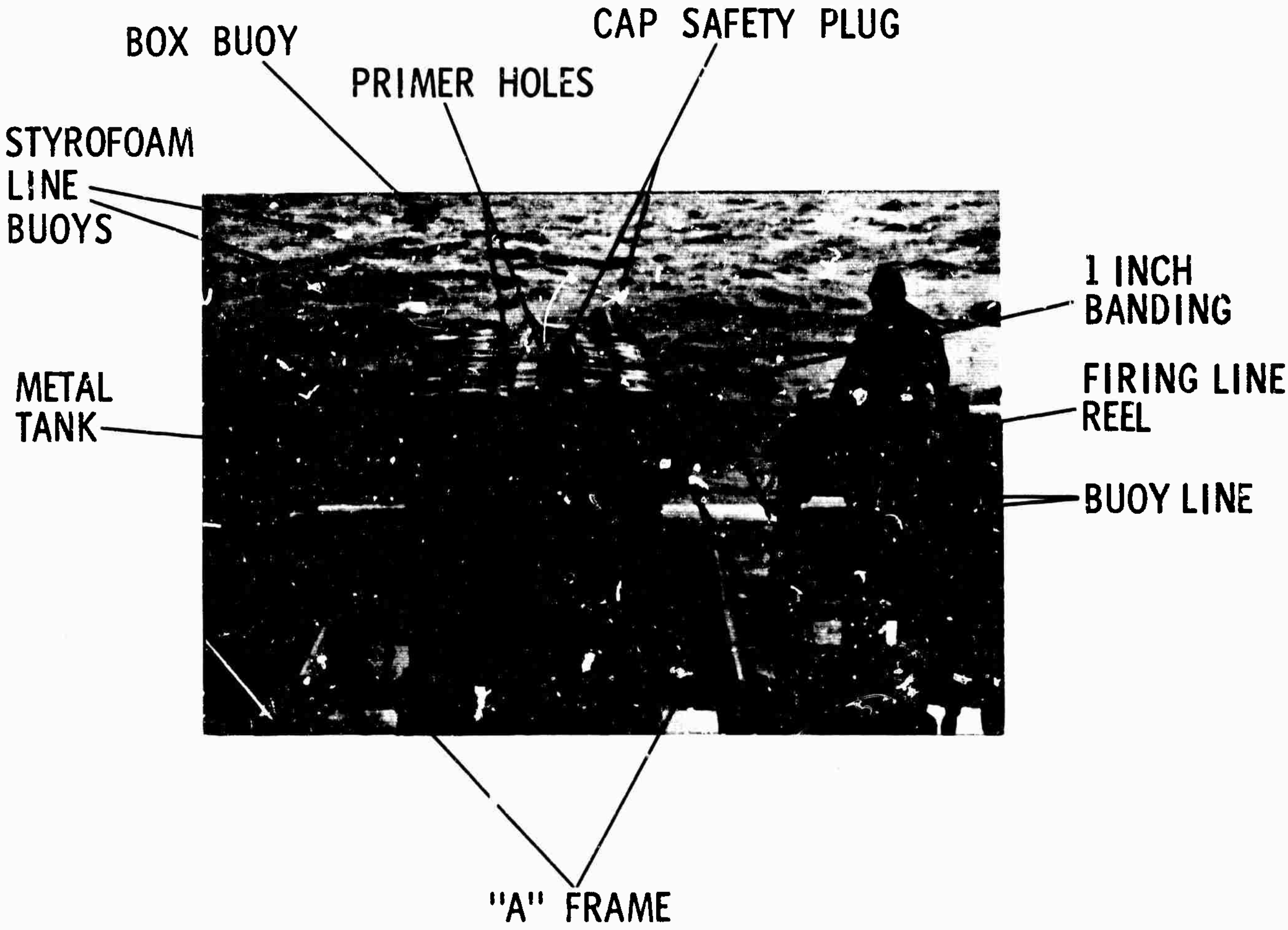


Figure 4. 5.2-Ton Charge

Launching Technique -- A lifting harness made of 3/4-in. dia nylon line was looped around each 1-ton charge. This line was positioned on opposite sides of the charge by 2-x-4-x-36-in. wooden spacers. Then, a 10-ton crane was used to move each charge from the workhouse to the stern of the ship. As stated earlier, each charge was placed on two 2-x-6-x-84-in. wooden skids which were on an inclinable A-frame.

After each 1-ton charge was positioned, a 300-ft, 1-in.-dia nylon buoy line was attached to the lifting harness on the outboard side of the charge.

For flotation, five 30-x-36-in. oval polyurethane surface buoys and three 10-x-20-x-36-in. styrofoam blocks were spaced at 75-ft intervals along the buoy line. Wound on a firing-line reel adjacent to the charge was 1 mi of Type DSA-500-31246 firing line; this lightweight firing line was used because of its comparative ease of handling.

During early shots with the 5.2-ton charge, the buoy line was wrapped around the rim of the charge, resulting in a loss of approximately 30 ft of line per charge; therefore, a separate harness line was used during the latter part of the program.

In addition to the flotation material used for 1-ton charges, three styrofoam blocks used for the buoy line (600 ft of 1 1/2-in. nylon line) and a box buoy filled with styrofoam were required for the 5-ton charge. Type DSA-500-31246 firing line was also used for this charge.

After either 1-ton or 5.2-ton charges were brought into launch position, they were loaded with primers and boosters and the caps placed in safety plugs. The cap leads were connected to the firing line, and both leads and the firing line were tied to the buoy lines. During this time and continuing through the detonation period, radio and radar transmitting equipment was turned off as a safety precaution to prevent premature detonation of the firing caps.

Buoys and line were thrown overboard, with the ship proceeding at a slow speed. Some firing line was released and then the caps placed in the boosters. As the buoys began to pull against the charge, the crane lifted the A-frame, launching the charge.

Detonation — The calibration charges were distributed in a network (Figure 5) which provided optimum recording within the stated restrictions. Charges were detonated from 0.5 to 0.75 mi from the ship and were 300 to 680 ft below the surface of the water. Table 1 presents the operational and observational data for the complete explosion series.

It took approximately 45 sec for the 1-ton charge to reach the 300-ft extent of the buoy line and 75 sec for the 5.2-ton charge to reach 600 ft. For the 1-ton charge, the distance between ship and charge was about 2600 ft; this distance was increased to about 4500 ft for the 5.2-ton charge. When the proper distance was reached, the ship was stopped and the following steps initiated:

- Cap check (firing-line resistance check made from blaster through blasting caps, confirming firing line impedance)
- Firing line connected to blaster
- Marine geophone dropped to depth of 20 ft
- Blaster charged with 2000 v, and time calibration verified from WWV receiver
- Paper recorder started 5 sec before detonation in order to record time of detonation, time signal and marine geophone response
- Charge detonated
- Firing line, buoy and buoy line retrieved

Figure 6 shows the Visicorder recording for a 5.2-ton charge. (Time signals are discussed in Appendix A.)

Table 1

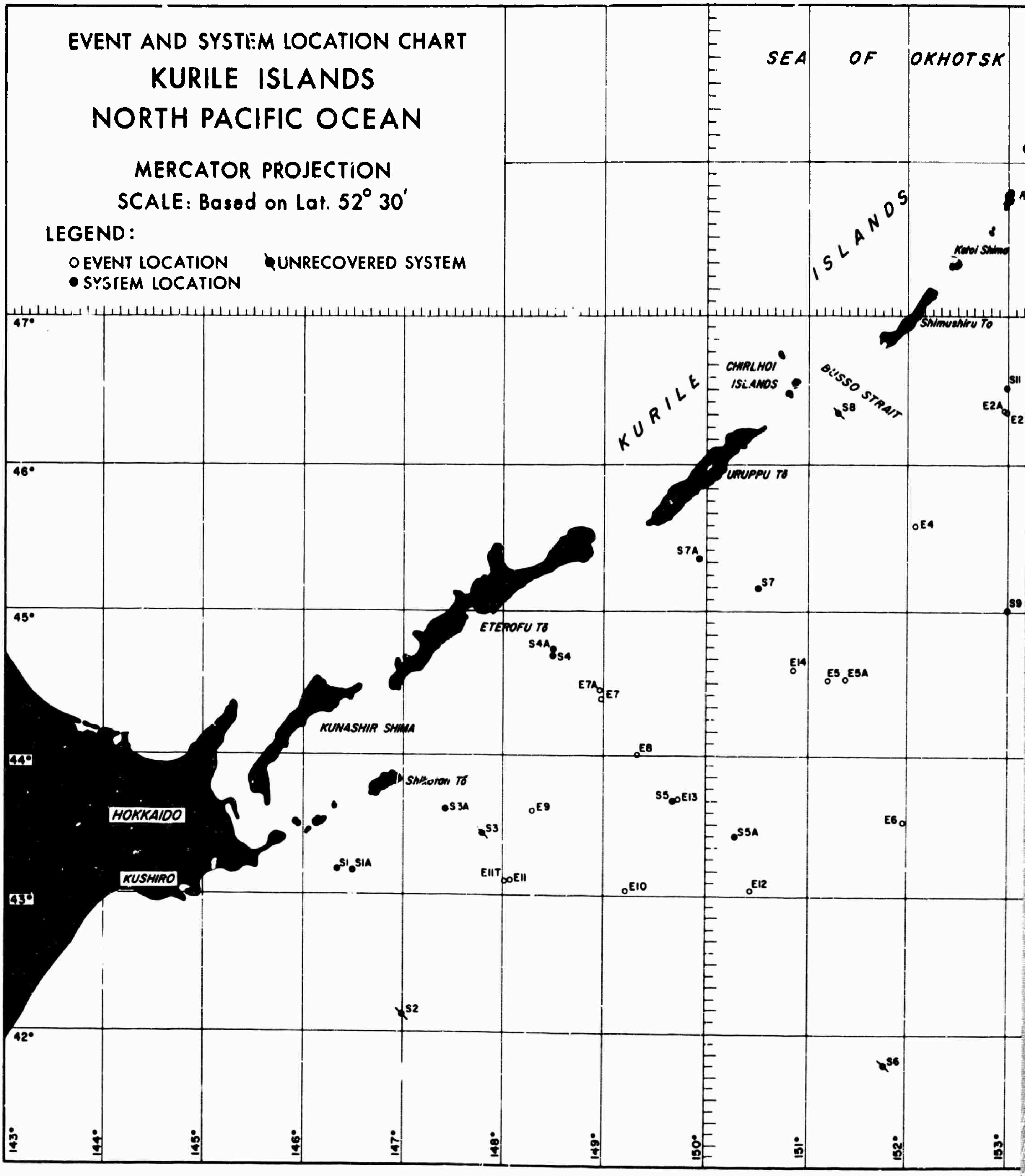
CHARGE DETONATION DATA

Pos. No.	Date (1966)	Location Lat. N	Location Long. E	Charge Size (tons)	Charge Depth* (ft)	Water Depth** (fm)	Detonation Time*** (GMT)	Pressure Wave Arrival*** (GMT)	First Bottom Reflection*** (GMT)	Visicorder Record Quality
			Operational						Observational	
E11	5 Nov	43°06'	148°04'	1.0	315	2206[b]	23:24:03.0	23:24:03.4	23:24:08.4	Fair
E9	6 Nov	43°35'	148°17'	1.0	315	2300[a]	03:33:03.0	03:[illegible].4	03:33:06.2	Poor
E10	7 Nov	43°01'	149°12'	1.0	315	3091[b]	04:03:02.0	04:03:02.4	04:03:09.6	Very Good
E8	8 Nov	44°00'	149°20'	5.2	630	3018[b]	01:50:02.9	01:50:03.4	01:50:10.2	Good
E7	8 Nov	44°23'	148°58'	1.0	315	2288[b]	06:53:02.5	06:53:02.8	06:53:08.1	Poor
E5	9 Nov	44°31'	151°12'	5.2	600	4454[b]	00:09:04.0	00.09:04.6	00:09:14.9	Poor
E6	9 Nov	43°31'	151°57'	5.2	570	2660[a]	06:44:04:1	No Geophone	—	Fair
E4	9 Nov	45°35'	152°04'	5.2	540	2393[b]	23:23:03.0	23:23:03.7	23:23:08.8	Good
E2	10 Nov	46°20'	153°00'	1.0	315	2215[a]	06:25:04:0	No Geophone	—	Poor
E3	12 Nov	46°07'	153°32'	1.0	315	3130[a]	05:55:03.9	No Geophone	—	Poor
E2A	12 Nov	46°21'	152°58'	5.2	510	1990[b]	23:31:03.0	23:31:03.6	23:31:07.8	Poor
E1	13 Nov	46°59'	153°54'	5.2	680	1826[b]	05:48:03.0	05:48:03.6	05:48:07.3	Good
E12	2 Dec	43°02'	150°2[illegible]'	5.2	680	2702[b]	22:30:0[illegible].8	22:30:03.4	22:30:09.3	Poor
E13	3 Dec	43°40'	149°42'	5.2	680	43[illegible]8[b]	05:21:02.9	05:21:03.4	05:21:13.6	Good
E7A	3 Dec	44°25'	148°58'	5.2	680	1417[b]	22:49:03.1	22:49:03.6	22:49:06.4	Very Good
E14	4 Dec	44°35'	150°51'	5.2	680	3945[b]	22:24:03.0	22:24:03.6	22:24:12.6	Good
E5A	5 Dec	44°31'	151°22'	1.5	630	4540[b]	03:22:03:1	03:22:03.6	03:22:14.2	Fair

* Depth values are determined from buoy line measurements, using a 20-ft track as a scale. A stretch factor characteristic of the nylon buoy line (15 ft for 1-ton charges with 300 ft of buoy line and 60 ft for 5.2-ton charges with 600 ft of buoy line) was taken into consideration. Current conditions had very little if any effect on depth measurements. It is estimated that the 1-ton charge depths are accurate to ±10 ft and the 5.2-ton charge depths to ±20 ft. In every case, measurements are made to the top of the charge.

** Water depths are obtained from fathometer data and/or pressure wave travel-time computations with the method [illegible]d indicated by an a (fathometer data) or a b (travel-time computation).

*** Times, representing arrivals of pressure waves received by a marine geophone (see Material Inventory, Appendix B, for description) and recorded on a Visicorder, are converted to GMT and are accurate to ±0.1 sec.


EVENT AND SYSTEM LOCATION CHART
KURILE ISLANDS
NORTH PACIFIC OCEAN
MERCATOR PROJECTION
SCALE: Based on Lat. 52° 30′
LEGEND:
EVENT LOCATION
UNRECOVERED SYSTEM
SYSTEM LOCATION
SEA OF OKHOTSK
KURILE ISLANDS
Ketoi Shima
Shimushiru To
CHIRIHOI ISLANDS
BUSSO STRAIT
URUPPU TO
ETEROFU TO
KUNASHIR SHIMA
HOKKAIDO
KUSHIRO
S1 S1A S2 S3 S3A S4 S4A S5 S5A S6 S7 S7A S8 S9 S11
E2 E2A E4 E5 E5A E6 E7 E7A E8 E9 E10 E11 E11T E12 E13 E14
47° 46° 45° 44° 43° 42°
143° 144° 145° 146° 147° 148° 149° 150° 151° 152° 153°

A.

Figure

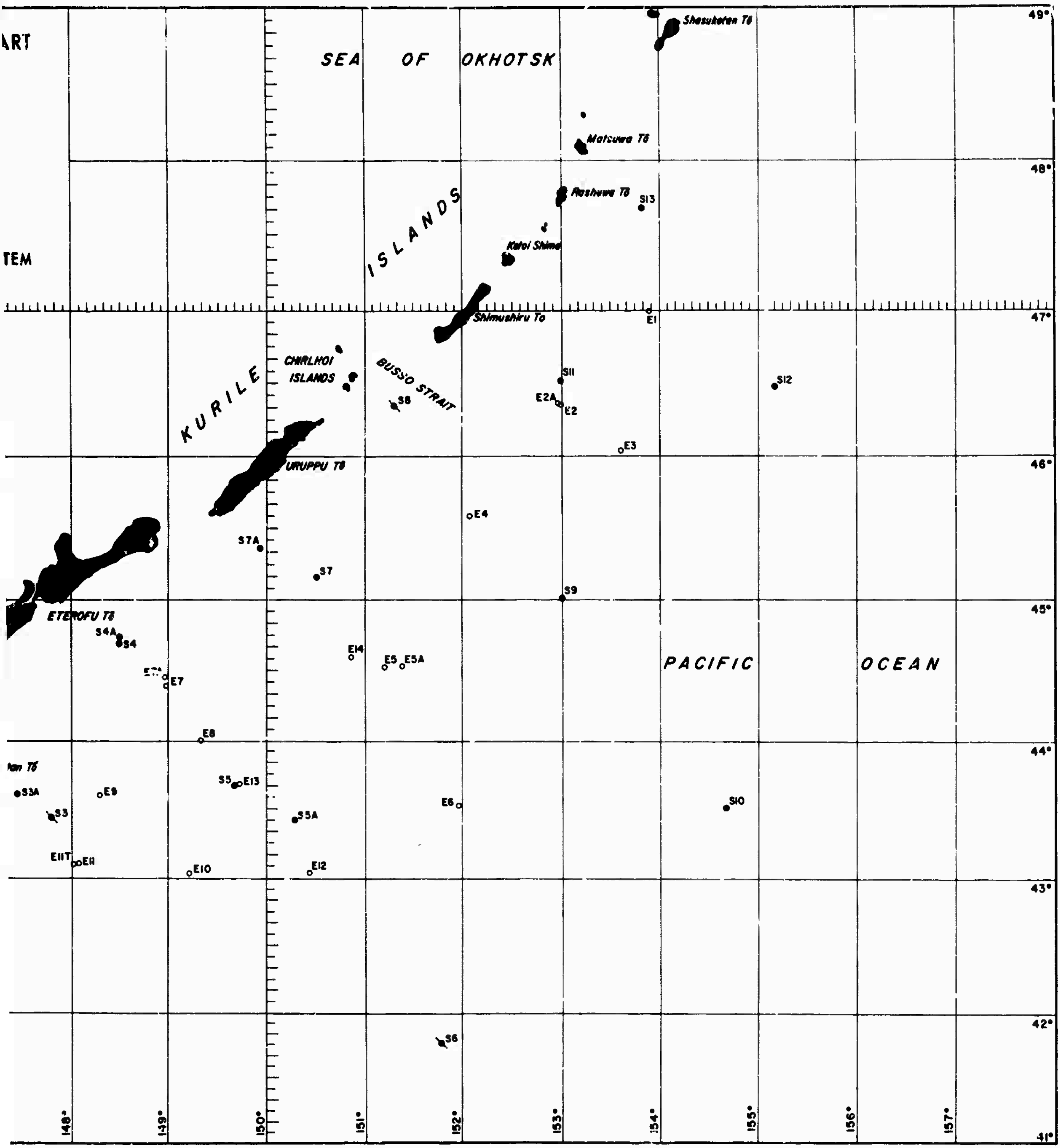
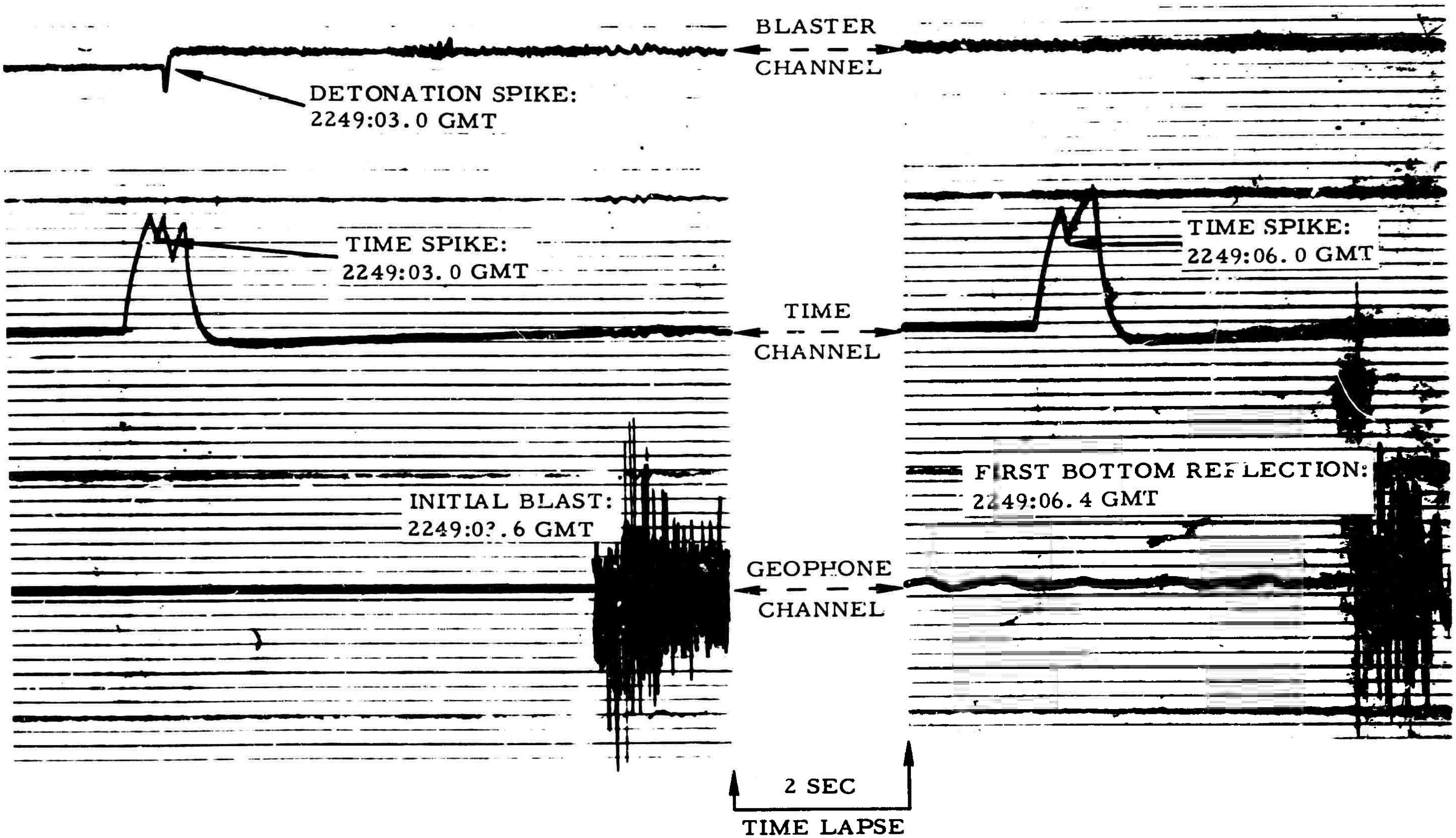


Figure 5. Event and System Chart

B.



POSITION E7A

DECEMBER 3, 1966

5.2 TON CHARGE @ 680 FT
WATER DEPTH: 1417 FM

LOCATION:
44°25.5'N 148°58'E

Figure 6. Visicorder Recording, 5.2-Ton Charge Detonation

SECTION III

CRITIQUE

This program was completed 5 December 1966 without a misfire. The operational procedure gave good data results.

The ship's rigging contributed greatly to the progıam's success. An A-frame and crane combination is recommended for future operations.

A 2000-v blaster was not capable of firing charges when more than 1 mi of Type DSA-500-31246 firing line was used.

Rough weather conditions and the need to rely upon celestial navigation forced some delay in schedule and uncertainty in event locations. The vessel was stable enough that charges could be loaded in 15-ft seas as the ship moved between locations.

APPENDIX A

RELIABILITY DATA

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APPENDIX A
RELIABILITY DATA

Event timing reliability varies with Visicorder record quality and/or time-signal reception. Record quality classification (Table 1) is based upon both, with emphasis on time-signal interpretation. Figure A-1, showing several time traces and their interpretation, gives additional time-signal characteristics. Signal distortion may occur (Figure 6) due to noise, interference, etc.; however, reliable time interpretation is possible with detailed analysis.

Charge-depth reliability is indicated in Table 1 and discussed at the bottom of the table.

Water depths have been computed (Figure A-2) for each event where a geophone recording was available. Disagreements between these and fathometer data are due to ship's drift while the fathometer was off. Depth values in Table 1 have not been corrected for velocity gradient but are the most reliable when computed depths are used and are the best estimate with fathometer depths.

A 2- to 5-mi shotpoint-position accuracy was estimated after considering distance to the nearest celestial fix and weather conditions during fix, voyage traverse and at locations. Additional information on location reliability for events and systems can be found in Special Report No. 3 (Bathymetric Report, Kurile Experiment).

Geophone data on Visicorder recordings are as reliable as record quality. Resulting depth calculations are the most accurate for event locations.

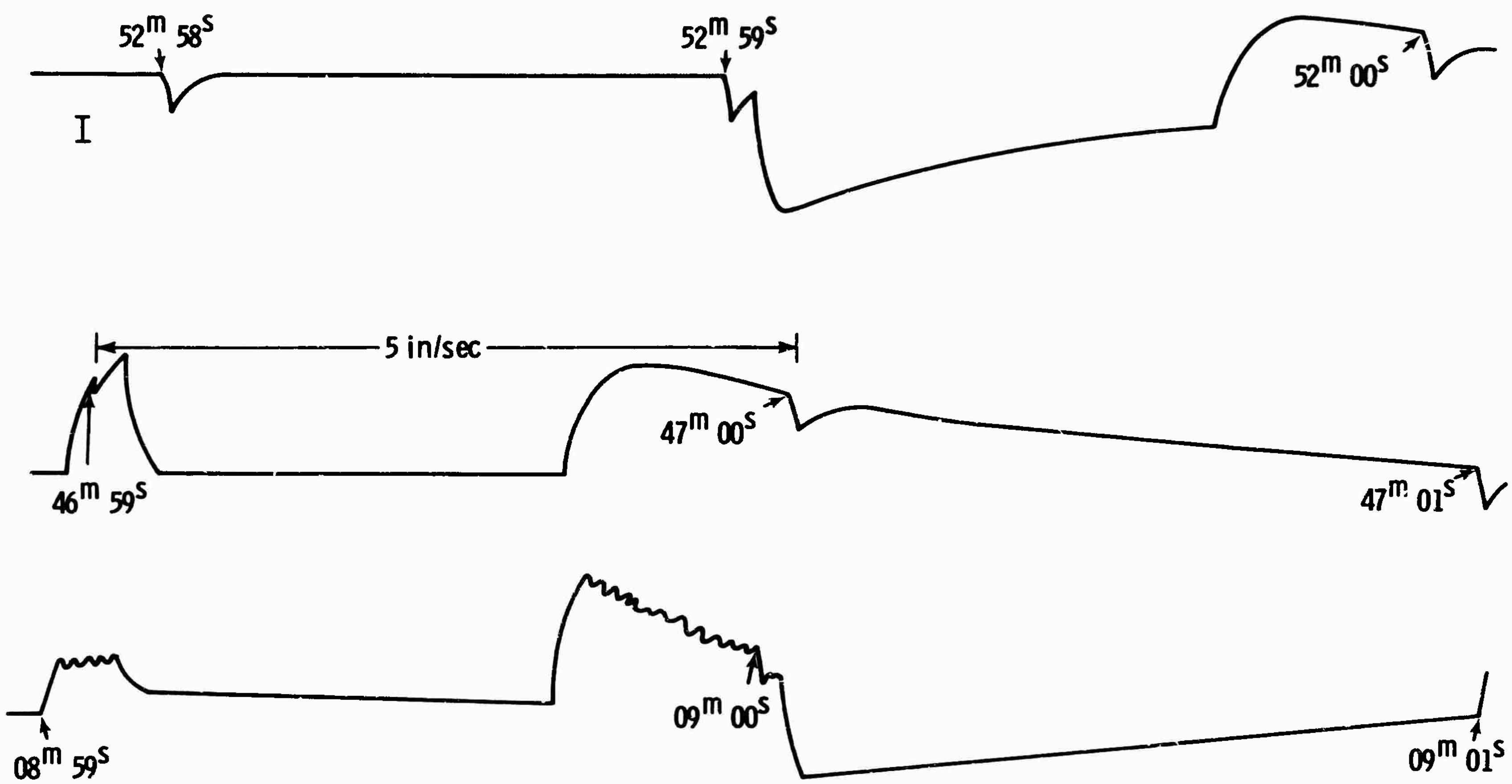
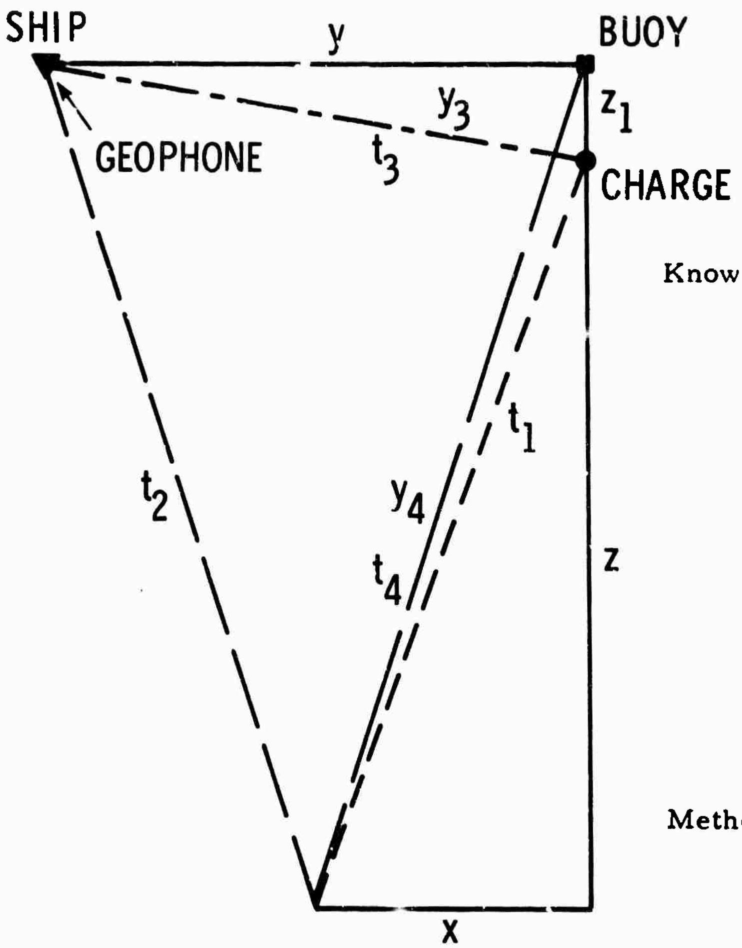


Figure A-1. Visicorder Recording of Three Time Signals Characteristic of Explosive Data



Known:

$y_3 \approx v \cdot t_3$

t_3 = pressu e wave travel time (sec)

z_1 = charge depth (ft)

$t_1 + t_2$ = total travel time of reflected energy (sec)

$v \approx$ 4800 fps (uncorrected for velocity gradient)

Method:

$$y \approx \sqrt{(y_3)^2 - (z_1)^2}$$

$$y/2 \approx x$$

$$t_4 \approx \frac{t_1 + t_2}{2} + \frac{z_1}{v}$$

$$t_4 \cdot v \approx y_4$$

$$z + z_1 \approx \sqrt{(y_4)^2 - x^2}$$

Note: Results from this method are approximate values. Depth accuracy was limited because velocity gradient was not considered, charge depth inaccuracy was ±20 fm maximum and wave propagation angles were workable approximations.

Figure A-2. Travel-Time Computations

APPENDIX B

MATERIAL INVENTORY

APPENDIX B

MATERIAL INVENTORY

A. MATERIAL FOR EXPLOSIVES

1. 120,000-lb Composition B Class HE explosive: 2400—50 lb, 9-1/2- x 9-1/2 x 9-1/2-in. cans
2. 60 primers: EL-637, 4x9 in., 7 ib
3. 100 WW boosters
4. 100 caps with 20-ft leads
5. Two insulated metal explosive boxes
6. Two wood-lined powder bins, 210 x 135 x 38 in.

B. PACKAGING MATERIAL

1. 10 metal tanks, 4 x 5 x 9-1/2 ft, 209-can capacity each
2. Six 650-ft rolls of 1-in. metal banding
3. One Signode coil box: DA/14, size 114
4. One Signode crimping tool: B-1435, size $1\frac{1}{4.035}$, PH 3136
5. 200 Signode metal clips: No. 114 OF
6. One Signode tensioner: 3A-114, PH 1146
7. One cutting tool
8. 2000 ft of 1/2-in. general-purpose nylon line
9. 75 lb of 1/4-in. manila rope
10. Eight 10-ft roller conveyors

C. FLOTATION MATERIAL

1. 10 polyurethane buoys, 30 x 36 in.
2. Two 8 x 4 x 4-ft wooden box buoys filled with styrofoam
3. 1800 ft of 1-1/2-in. nylon line (5-ton charge buoy line)
4. 1800 ft of 1-in. nylon line (1-ton charge buoy line)
5. 42 styrofoam blocks (line buoys), 10 x 20 x 9-ft

D. LUMBER

1. Lumber for one 1-ton charge:

Qty	Dimensions (in.)	Use
2	2 x 4 x 36	Lifting harness spacers
3	2 x 4 x 48	Pallet frame
2	1 x 6 x 38	Pallet cover
4	1 x 12 x 38	Pallet cover
2	2 x 6 x 84	Skids

2. Lumber for one 5-ton charge:

Qty	Dimensions (in.)	Use	
4	1 x 12 x 96	Side spacers	
1	1 x 12 x 108	Bottom board	
1	2 x 6 x 108	Top board	
4	2 x 6 x 84	Skids	Slide boards
2	1 x 6 x 36	Skids	Slide-board spacers
8	1 x 2 x 6	Skids	Slide-board separators

For charge with reduced banding:

Qty	Dimensions	Use
2	1/2" x 19" x 8'	Plywood top covers

3. Nails

   a. 10 lb of Size 6 common nails

   b. 10 lb of Size 10 common nails

E. FIRING-LINE EQUIPMENT

1. Type 18 Tc WPR, Catalog No. 115-0559-01 heavy-duty, 2-conductor copper-coated steel with neoprene insulation, telephone wire. Firing capabilities: 2 mi at 2000 v

2. Type: Catalog No. 6145-243-8466 telephone cable, WD 1/TT on reel RL-159/u, copper-coated steel stranded 2-conductor wire with plastic insulation. Firing capabilities: 1 mi at 2000 v

3. Blasting cap safety plug, styrofoam ball with wood core. Hole for cap drilled in wood. Nail on each side used to secure temporary tag line and cap lead

4. Blaster, SIE (Southwestern Industrial Electronics) high-voltage blaster, SCD-2000 B.., Serial No. 4669E

5. Marine geophone, HPL Model S40P (1956); 30 in. x 2.5 in., 12 lb; frequency response, 0.03 v/in./sec @ 7 cps and 0.1 v/in./sec @ 15 cps; resonance frequency, 10 cps; output resistor, 500 ohms

6. WWV receiver, Specify Products Inc. Model No. WWVT 5-band receiver

7. Visicorder, Minneapolis Honeywell, Inc., Model No. 906, 12-channel paper recorder

8. 6-channel galvo-amplifier, Minneapolis Honeywell, Inc.

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13. ABSTRACT

This report details the procedures developed for the explosion program and gives the reliability of the calibration program. The explosive used was 120,000 lb of high-energy composition B packed in 50-lb cubical cans, which was shot in ten 5.2-ton, six 1-ton and one 1.5-ton packages. These charges were exploded in a network designed to provide optimum recording on the ocean-bottom instruments and minimum damage to marine life. The shots were restricted to the following conditions: daylight hours, 2 mi or more from any approaching vessel, a minimum of 13000 fm of water depth, and/or more than 100 km from land.

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Calibration Program Reliability						
A-Frame, Crane Combination						
Kurile Islands Experiment						
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