The route climbs the slope of the valley up to 1,600 m, decends gently westward, and then reaches the second deeper valley near A/C-12. The bottom of this valley with a width of 4 km and the maximum depth of 2,686 m and the maximum gradient of 11 degrees is covered with several meters of sediments, mainly mud, overlying the basement.

From A/C-12 to A/C-14, the topography often rises up to 1,200 m, and then deepens down to 2,000 m, creating a relief over some 500 m.

Despite this irregular topography, gradients across the slopes were generally less than 10 degrees.

Sediments were scarecely found at each summit and muddy sediment was partially found in some valleys.

The western slopes of the Great Passage deepen down to 4,350 m with a maximum gradient of 17 degrees and reaches the Nicobar Fan. Seabed photographs were taken at several points near the Grate Passage. All photographs indicate that the seabed consists of volcanic rocks. And also, sea bottom currents were found to be mainly the northeast and southwest with about maximum 1 knot at the depth of around 1,500 m.

More northerly and southerly routes were examined in an attempt to avoid a harder ground previously discovered. However, most of the examination of survey results of the Great Passage revealed that rocks and harder ground were also formed.

They are unavoidable in the greater part of the Great Passage, but an excessive relief has been avoided for the proposed cable route.

It should be noted here that definite 'shadow' period appear at these latitudes in a 24-hour cycle when 4-5 hours have elapsed with no satellite field over this area. The positioning buoys whose fixing positions are determined by satellites will be usefull during this 'shadow' period. No good radar response can be obtained, as few high mountains soar on the islands nearby.

On the west of the Great Passage, the abyssal plain of the Bengal and Nicobar Fans spread for some 800 nm except for the 90°E Ridge. The ridge forming the western margin of the Nicobar Fan was surveyed up to the summit of 3,000 m with a maximum gradient of 5 degrees. On the west of this ridge, the seabed deepens down to 4,000 m at the entrance to the Bengal Fan, at a maximum gradient of 5 degrees. The greater part of the seabed of this ridge is covered with soft mud. The proposed cable route runs the most gradual and regular path.

From the western margin of the 90°E Ridge, the bottom topography deepens gradually from 4,000 m down to 4,200 m, yet remaining nearly flat except for several shallow canyons incised into the seabed with a width of 700 to 3,500 m and depth of 10 to 140 m.

Sounding runs indicate that turbidity channels meander like a mature river. A core sample obtained from one of these areas consists of soft yellowish grey clay with no coarse/grain sediment. And also deep-sea photographs indicate no ripple mark on the seabed. They indicate that these channels are inactive at the present.

Rising from the Bengal Fan to the shelf off Colombo, there was an unavoidable steep slope, having a maximum gradient of 21 degrees. Seismic profiling data show scare bottom sediments over the rock basement.

The seabed in Colombo Continental Shelf gradually deepens down to 50 m, then steeply deepens in some distinctive steps down to 4,200 m forming the Continental Slope. From the beach surf line up to 15 m water depth, the seabed was found consisting of an exposed rock basement with slight sand.

At a seaward line of 15 m water depth, the seabed was covered with sediments, mostly sand, overlying a rock basement.

The proposed cable route runs on the relatively flat seabed mostly covered with sand, keeping out of an anchorage area.

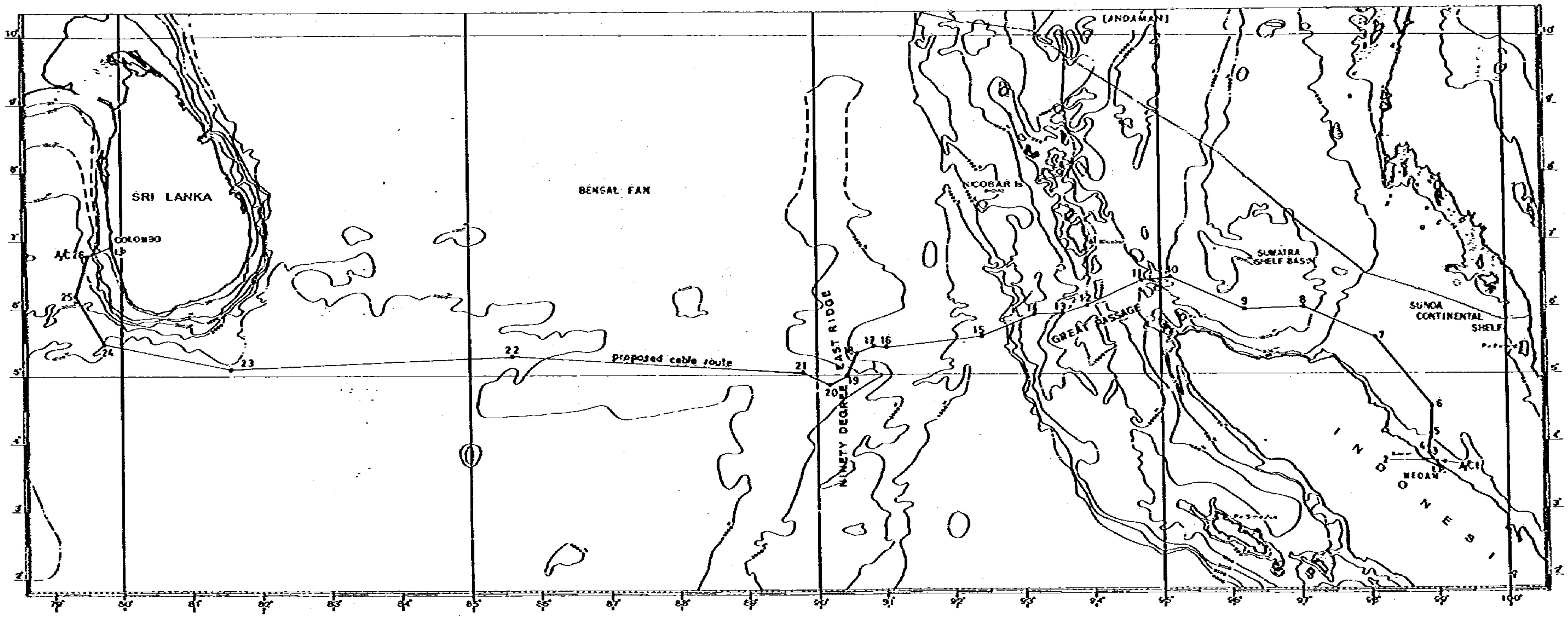


Fig. 5. 2. 1 PROPOSED CABLE ROUTE

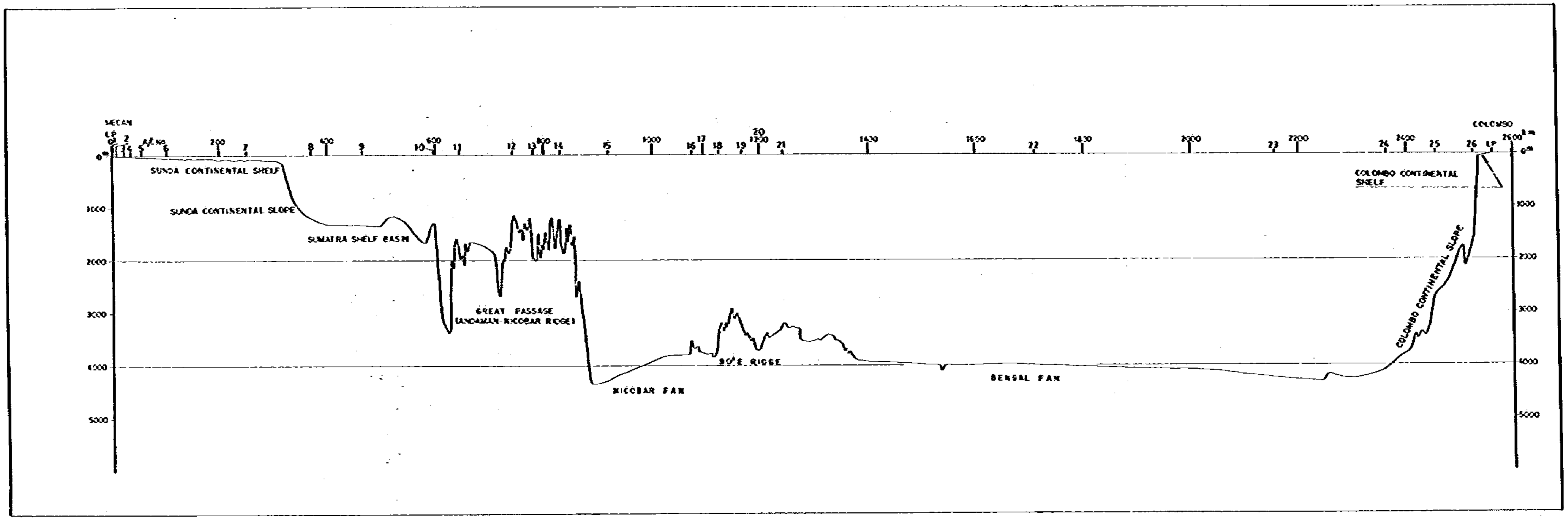


Fig. 5. 2. 2 BOTTOM PROFILE ALONG THE PROPOSED CABLE ROUTE

5.3 Recommended Cable Types and Quantities

A summary of the recommended cable types and quantities are given in Table 5.3.1 together with the nominal slack percentage.

5.3.1 Recommended Cable Types

(1) Land Portion (Cable terminal station to landing point)

The cable should be well protected against possible man-made hazards and radio interference.

At the Medan side, a single armoured screened cable is recommended for direct burying.

At the Colombo side, non-armoured screened duct cable is recommended, as the cable will be well protected by a duct.

(2) Shore Portion (Landing point to 5 m depth)

To protect a cable against possible man-made hazards, waves and radio interference, the cable should be a double armoured and screened one from the landing point or beach manhole through a surf zone to a depth of 5 m.

The cable laid on the beach and surf zone area should be buried so as not to be moved or damaged.

(3) Very Shallow Portion (5 m depth to 50 m depth)

A non-buried double armoured cable is considered suitable to provide the desired security against anchoring.

At the Medan side, the route is well away - more than 12 nm - from the Belawan anchorage area at the depth of 30 m. The nearest point to the anchorage area is A/C 4 and the distance is 7.5 nm.

Table 5.3.1 POSITION LIST, RECOMMENDED CABLE TYPES AND QUANTITIES

Pos. No.	Position (Degs.Mins)		Distance (km)		Slack (%)	Cable Length (km)	Cable Type	Approx. Depth (m)	Remarks
A/C	Latitude (N)	Longitude (E)	Between	Cumulative					
Medan Lp	3 - 38.77	99 - 00.05		0				Beach	
			3.70			2.6	DA(S)	5	
A/C-1	3 - 40.74	98 - 59.67		3.70					
			5.09						
2	3 - 43.00	98 - 58.09		8.79					
			14.78			45.2	DA		
3	3 - 49.70	98 - 53.70		23.57					
			10.26		0.5%				Sunda Shelf
4	3 - 55.00	98 - 52.00		33.83					
			21.02					30	
5	4 - 6.00	98 - 55.00		54.85					
			47.91						
6	4 - 32.00	98 - 55.00		102.76		283.2	SA		
			148.38						
7	5 - 35.00	98 - 5.00		251.14					
			119.94					500	
8	6 - 0.00	97 - 5.00		371.08					
			94.39						Sunda Shelf Basin

Note : Distance is geodetic line distance with Everest.
: Land cable is excluded.
: Slack depends on rough calculations.

Legend
- DA(S) : Double Armoured Screened Cable
- DA : Double Armoured Cable
- SA : Single Armoured Cable
- SP : Specially Protected Cable
- LW : Lightweight Cable

Pos.No	Position (Degs.Mins.)		Distance (km)		Slack (%)	Cable Length (km)	Cable Type	Approx. Depth (m)	Remarks.
A/C	Latitude(N)	Longitude(E)	Between	Cumulative					
			94.39						
9	5 - 56.00	96 - 14.00		465.47	2%	310.0	LW		
			133.09						
10	6 - 26.30	95 - 8.50		598.56					
			46.49		7%				
11	6 - 23.00	94 - 43.50		645.05		40.3	SP	2200	
			99.05		3%	51.7	LW	1650	
12	6 - 1.00	93 - 54.50		744.10				2300	
			37.92						
13	5 - 54.50	93 - 35.00		782.02	7%	155.6	SP		Great Passage (Andaman-Nicobar Ridge)
			49.16						
14	5 - 53.00	93 - 8.40		831.18					
			88.86					2500	
15	5 - 33.90	92 - 24.20		920.04					
			154.93		1%				Nicobar Fan
16	5 - 23.90	91 - 0.90		1074.97					
			21.46						
17	5 - 25.55	90 - 49.40		1096.43			LW		
			28.67						
18	5 - 19.50	90 - 35.10		1125.10					

(Sheet 3/3)

Pos. No.	Position (Degs, Mins)		Distance (km)		Slack (%)	Cable Length (km)	Cable Type	Approx. Depth (m)	Remarks
A/C	Latitude(N)	Longitude(E)	Between	Cumulative					
			43.19						90°E Ridge
19	4 - 58.00	90 - 25.80		1168.29					
			29.65		2%				
20	4 - 51.80	90 - 11.00		1197.94					
			46.33						
21	5 - 1.80	89 - 48.00		1244.27					
			466.34						
22	5 - 16.00	85 - 36.00		1710.61		1698.9	LW		
			449.41		1%				
23	5 - 5.00	81 - 33.00		2160.02					Bengal Fan
			203.96						
24	5 - 28.00	79 - 45.00		2363.98					
			93.30						
25	6 - 12.00	79 - 20.00		2457.28	4%	2.4	SA	500	
			67.92			26.2	DA	48	Colombo Continental Slope
26	6 - 46.96	79 - 31.65		2525.20		0.2	DA(S)	5	
			38.14		0.5%				
COLOMBO LP	6 - 55.55	79 - 50.49		2563.34				Beach	Colombo Continental Shelf

Total Route Length: 2563.34 km (1384.10 nm)
Total Cable Length: 2616.3 km (1412.7 nm)
(1 nm = 1.852 km)

Therefore, in this region, a double armoured cable is recommended to the depth of 30 m. Beyond a 30 m depth line, a non-buried single armoured cable is considered to provide the desired security against fishing activities.

At the Colombo side, the route runs partly in a rocky area through anchorage areas to the continental shelf edge of 48 m in depth. Therefore, a non-buried double armoured cable is recommended. However, from the beach to around a 15 m depth line, 1 km in distance, a trench is recommended for a rocky area to fix the cable against waves. Beyond the edge, as the slope becomes abruptly steeper, a single armoured cable is recommended to traverse the break.

(4) Shallow Portion (50 m to 500 m depth)

A non-buried single armoured cable to the depth of 500 m is considered to provide the desired security against fishing activities in the Sunda Shelf and following slope.

At the Colombo steep slope, a rock area is observed at the depth of 500 m depth. Therefore, a single armoured cable is recommended to cover this rock area as well as the continental break of 50 m depth.

(5) Deep-sea Portion (Deeper than 500 m)

To traverse the rugged Andaman-Nicobar Ridge, where an unusual bottom current exists and many chafe faults were recorded in the old telegraph cables, a greater protection in the form of specially protected cable suitable for laying in a deep portion would ensure a long period of fault-free operation. As the Ridge is divided into two conspicuous rugged regions with no sediment, a specially protected cable is recommended to cover these two regions. However, at less rugged areas covered with sediments a lightweight cable is considered to be safe.

Other deep water portions pose no problem. Therefore, lightweight cable is recommended.

5.3.2 Required Cable Quantities

The required cable quantities are determined on the basis of the following conditions:

- Nominal cable slack is roughly calculated by considering required cable length in correspondence with the bottom profile together with unavoidable observation errors in the measurement of bottom slope, taut-wire speed and cable sinking speed.

- No allowance is made for additional cable required for the final splice, laying resume, tracking errors of cable ship influenced by current, wind and availability of navigational equipment. However, the additional cable length is considered to be less than 1% at deep sea area.

- All cable lengths are subject to minor adjustment after finalization of laying plans, straight line diagram, slack requirements, etc.

- The distances between positions are calculated based on rhumb line distance with Everest, refer to 4.4 Position Fixing. Cable lengths are arrived at by applying nominal slack percentage to the overall distances and rounded up to the nearest 0.1 km.

The total cable distance between landing points is 2616.3 km, 2.07% average slack over the route length of 2563.34 km.

The required cable quantity of each type is:

(1) Submarine Section

Double Armoured Screened Cable	2.8 km
Double Armoured Cable	71.4 km
Single Armoured Cable	285.6 km
Specially Protected Cable	195.9 km
Lightweight Cable	2060.6 km
Grand Total of Submarine Section Length Including Nominal Slack	2616.3 km

(2) Land Section

Single Armoured Screened Cable	1.3 km
Non-Armoured Screened Duct Cable	1.5 km
Grand Total of Land Section Length	2.8 km

Note - The required cable inside the terminal station is roughly estimated and no allowance is made for a coil of slack cable.

APPENDICES

Appendix 1

Résumé of Events

Résumé of events in the cable route survey is as follows.

From Inception Report to Boarding Survey Vessel

Aug. 30 Left Tokyo (11:15). Arrived at Jakarta (21:15). Consulted with Mr. Suzuki, First Secretary of Japanese Embassy.

Aug. 31 Visited POSTEL (Ministry of Posts and Telecommunications) to pay respects, and explained Inception Report (9:00). Visited INDOSAT to pay respects and explained Inception Report (13:00).

Sep. 1 Visited Mr. PARAPAK, President of INDOSAT, to pay respects (9:00). Explained Inception Report at INDOSAT (10:00).

2 Explained Inception Report at INDOSAT and confirmed consultation procedures. Prepared minutes.

3 Signed minutes and reported it to Japanese Embassy and JICA Office.

4 Left Jakarta (16:00). Arrived at Colombo (22:00).

5 Made consultation at JICA Office in Colombo (9:00). Consulted with Mr. Itami, First Secretary of Japanese Embassy in Sri Lanka (10:00). Visited Assistance Department to Pay respects (16:00).

6 Visited SLTD (Sri Lanka Telecommunications Department) to pay respects. Explained Inception Report (14:30).

7	Explained minutes at SLTD (9:00). Asked Land Survey Department for survey (10:00). Visited Assistance Department to pay respects.
8	Left Colombo. Arrived at Singapore.
9	Visited JICA Office at Singapore.
Sep.9-14	Arrangements about preparation for boarding.
Sep. 15	Oceanic survey team members arrived at Singapore (18:00).
Sep. 16	Made preparation for boarding.
Sep. 17	Survey vessel Wakashio-maru entered Singapore.
Sep. 18	All members of survey team boarded Wakashio-maru (13:00).
Sep. 19	Survey vessel Wakashio-maru left Singapore (16:00).
	For details of the route survey, refer to Appendices
	From Leaving Wakashio-maru to Returned to JAPAN
Nov. 13	All members of survey team left Wakashio-maru at Singapore (13:00).
14-23	Examined survey results. Prepared Interim Report.
24	Left Singapore (11:00). Arrived at Jakarta (15:00). Met Mr. Uchida (Ministry of Posts and Telecommunications), Survey Team Leader. Consulted with Mr. Suzuki, First Secretary of Japanese Embassy.

25 Visited POSTEL to pay respects. Explained Interim Report (9:00). Explained Interim Report at INDOSAT (14:00).

26 Collected data.

27 Survey team members consulted with one another (in the morning).

28 Explained Interim Report at INDOSAT. Prepared minutes.

29 Signed minutes at POSTEL (9:00). Left Jakarta (16:45). Arrived at Colombo (22:00).

30 Consulted with Mr. Kobayashi, Third Secretary of Japanese Embassy (10:00). Visited Assistance Department to pay respects (14:00).
Visited SLTD to pay respects and explained Interim Report (15:00).

Dec. 1 Explained Interim Report at SLTD (9:00). Prepared and signed minutes (15:00).

2 Held meeting for discussing matters given in Interim Report among members of survey team. (9:00).

3 Left Colombo (8:45). Arrived at Bangkok (13:00). Stayed overnight in Bangkok.

4 Left Bangkok (8:00). Arrived at Tokyo (21:15).

Draft Final Report

Jan. 24 Left Tokyo (11:00). Arrived at Jakarta (21:00). Consulted with Mr. Suzuki, First Secretary of Japanese Embassy.

25 Visited POSTEL to pay respects, and Explained Draft Final Report (9:30). Explained Draft Final Report at INDOSAT (9:15).

26 Explained Draft Final report at INDOSAT (9:15).

27 Explained Draft Fianl report at INDOSAT and prepared minutes (9:00). Signed minutes at POSTEL (11:30) and reported it to Japanese Embassy and JICA Office.

28 Left Jakarta (18:15). Arrived at Colombo (22:45).

29 Held meeting among members of survey team.

30 Made consultation at JICA Office in Colombo (9:00). Consulted with Mr. Itami, First Secretary of Japanese Embassy in Sri Lanka (10:00). Visited Assistance Department to pay respects (11:00). Explained Draft Final Report at SLTD (15:00).

31 Signed minutes at SLTD (9:00).

Feb. 1 Reported minutes to JICA Office (10:00). Left Colombo (10:00). Arrived at Bangkok (18:00).

2 Left Bangkok (11:30). Arrived at Tokyo (21:15).

Appendix 2

Survey Vessel's Log

The vessel's log contained in this appendix covers the vessel's voyage starting with the entry into Belawan on September 21, 1983 and ending with the completion of survey on November 9, 1983.

The survey extended from Medan (Patai Cermin) to Colombo via Indonesian shallow sea, Great Passage and Bengal Fan. A thorough examination of the survey was made jointly with the attendants onboard in order to facilitate the survey besides the minute checks and servicings of the survey facilities and equipment onboard the survey vessel "Wakashio-maru". The descriptions of works, as stated below against each day of survey, are an excerpt of the vessel's voyage log.

Wed. 21st September, 1983

09:40 Arrived Belawan and admitted into the country.

11:00 Assembled the vibro-corer.

18:00 Left Belawan; one counterpart (of Indonesia), one observer (of France) and two Navy officers (of Indonesia) embarked.

20:20 Arrived at the anchorage off Belawan.

Thurs. 22nd September, 1983

08:00 Weather; Wind W, Force 2

08:00 Installed the current meter at Point A/C4 (using a small local boat).

11:25 Carried out the echo sounding and seismic prospecting survey off Pantai Cermin from A/C4.

15:50 Moored off Pantei Cermin.

16:30 Landed on Pantai Cermin from a small boat to ascertain the control point.

Friday, 23rd September, 1983

08:00 Weather; Wind N, Force 2, sea smooth.
Carried out the echo sounding, seismic prospecting, bottom sampling and temperature measurement on the seashore from the survey ship as well as the survey on the control point on Pantai Cermin.

17:30 All works on the seashore on Pantai Cermin completed and returned to Wakashio-Maru.

Saturday, 24th September, 1983

08:00 Weather; Wind S, Force 2, sea calm.

09:00 Landed on Pantai Cermin.

10:00 Carried out the echo sounding, seismic prospecting and bottom sampling onboard the survey boat.

17:30 All works completed and returned to Wakashio-Maru.

Sunday, 25th September

08:00 Weather; Wind W, Force 1, sea calm.

13:30 Position: off Pantai Cermin.

18:00 Recovered the current meter from Point A/C4.

19:55 Anchored near Point A/C4.

Monday, 26th September, 1983

08:00 Weather; wind SW, Force 3, sea calm.
Position: near Point A/C4.

10:35 Continued the echo sounding, seismic prospecting on the Indonesian shallow water from A/C4 to A/C2.

Tuesday, 27th September, 1983

08:00 Weather; Wind SSW, Force 2, sea calm.
Position: 04°-4'N, 98°-53'E
Continued the depth sounding on the Indonesian shallow water.

09:40 Carried out the bottom sampling and temperature measurement at Point V1.

12:08 Continued the echo sounding on the Indonesian shallow water.

14:00 Carried out the bottom sampling and temperature measurement at Point P1.

14:50 Continued the echo sounding on the Indonesian shallow water.

17:35 Carried out the bottom sampling and temperature measurement at Point V2.

19:20 Continued the depth sounding on the Indonesian shallow water.

22:34 Carried out the bottom sampling and temperature measurement at Point V3.

Wednesday, 28th September, 1983

00:50 Continued the echo sounding on the Indonesian shallow sea.

03:37 Carried out the bottom sampling and temperature measurement at Point P2.

05:00 Continued the echo sounding on the Indonesian shallow water.

07:15 Carried out the bottom sampling and temperature measurement at Point P3.

08:00 Weather; Wind SW, Force 2, sea slight

Position: 4°-49'N, 98°-44'E

Continued the echo sounding on the Indonesian shallow water.

09:50 Carried out the bottom sampling and temperature measurement at Point P4.

11:10 Continued the echo sounding on the Indonesian shallow water.

13:25 Carried out the bottom sampling and temperature measurement at Point P5.

14:30 Continued the echo sounding on the Indonesian shallow water.

16:45 Carried out the bottom sampling and temperature measurement at Point P6.

17:20 Continued the echo sounding on the Indonesian shallow water.

19:10 Carried out the bottom sampling and temperature measurement at Point P7.

20:20 Carried out the bottom sampling and temperature measurement on the Indonesian shallow water.

Weather; Wind SW Force 3, sea slight.

Position: 5°-20'N, 98°-20'E

21:54 Carried out the bottom sampling and temperature measurement at Point P8.

22:30 Continued the echo sounding on the Indonesian shallow water.

Thursday, 29th September, 1983

00:00 Carried out the bottom sampling and temperature measurement at Point P9.

01:30 Continued the echo sounding on the Indonesian shallow water.

02:52 Carried out the bottom sampling and temperature measurement at Point P10.

04:00 Continued the echo sounding on the Indonesian shallow water.

05:40 Carried out the bottom sampling and temperature measurement at Point P11.

06:15 Continued the echo sounding on the Indonesian shallow water.

07:25 Carried out the bottom sampling and temperature measurement at Point P12.

08:00 Weather; Wind SW, Force 2, sea smooth.

Position: 5°-48'N, 97°-38'E

Continued the echo sounding on the Indonesian shallow water.

10:40 Carried out the bottom sampling and temperature measurement at Point P13.

11:50 Continued the echo sounding on the Indonesian shallow water.

14:02 Carried out the bottom sampling and temperature measurement at Point P14.

15:02 Continued the echo sounding on the Indonesian shallow water.

16:15 Carried out the bottom sampling and temperature measurement at Point P15.

18:00 Continued the echo sounding on the Indonesian shallow water.

Friday, 30th September, 1983

08:00 Weather; Wind SE, Force 3, sea smooth.

Position: 4°-52'N, 98°-37'E

Continued the echo sounding on the Indonesian shallow water.

11:28 Carried out the bottom sampling and temperature measurement at Point P16.

14:10 Carried out the echo sounding, seismic prospecting and bottom scanning on the Indonesian shallow water.

Saturday, 1st October, 1983

03:50 Carried out the echo sounding, seismic prospecting and bottom scanning on the Indonesian shallow water.

08:00 Weather; Wind S, Force 2, sea calm.

Position: 5°-45'N, 97°-41'E

Proceeded to the survey on Sumatra Shelf Basin from Sunda Continental Shelf including the echo sounding, seismic prospecting and bottom scanning.

Sunday, 2nd October, 1983

08:00 Weather; Wind W, force 5, sea moderate.

Position: 6°-6'N, 95°-52'E

Echo sounding from Sumatra Shelf Basin to Great Passage. Part of the northern route from A.C9 to A/C12 was excluded due to a large deviation.

Monday, 3rd October, 1983

08:00 Weather; Wind SW, Force 4, sea moderate.

Position: 6°-0'N, 93°-24'E

Carried out the echo sounding and sesmic prospecting on Great Passage.

Tuesday, 4th October, 1983

08:00 Weather; Wind SSW, Force 4, sea slight.

Position: 5°-58'N, 93°-20'E

Carried out the echo sounding and seismic prospecting on Great Passage.

12:15 Installed the current meter at Point St.1 (near A/C12).

14:20 Carried out the echo sounding and seismic prospecting on Great Passage.

Wednesday, 5th October, 1983

08:00 Weather; Wind SSW, Force 3, sea slight.

Position: 06°-19'N, 94°-28'E

09:40 Installed the current meter at Point St.3 (near A/C10).

13:00 Continued the echo sounding on Great Passage.

18:49 Installed the current meter at Point St.2 (between A/C12 and A/C11).

19:00 Headed for Krueng Raya to disembark two Indonesian Navy officers.

Thursday, 6th October, 1983

10:40 Arrived at Krueng Raya; two Indonesian Navy officers left the vessel and took in 70 tons of drinking water.

Friday, 7th October, 1983

08:00 Weather; Wind S, Force 1, sea smooth.

Position: Krueng Raya pier.

13:15 Left Krueng Raya to Great Passage

19:00 (C.S.T.) Arrived at Great Passage (near A/C9) and carried out the echo sounding and seismic prospecting on Great Passage.

Saturday, 8th October, 1983

08:00 Weather; Wind W, Force 2, sea smooth.

Position: 6°-24'N, 94°-54'E

Carried out the echo sounding and seismic prospecting as well as the re-survey of line of soundings on Great Passage.

11:20 Recovered the current meter from Point St.3 and carried out the temperature measurement. An auxiliary line of sounding was set up on the south of the planned line of soundings because of extremely complicated contour of Great Passage.

Sunday, 9th October, 1983

05:10 Recovered the current meter from Point St.2.

08:00 Weather; Wind S, Force 3, sea moderate.

Position: 5°-59'N, 93°-49'E

11:16 Recovered the current meter from Point St.1 and carried out the temperature measurement. Proceeded with the echo sounding on Great Passage.

Monday, 10th October, 1983

08:00 Weather; Wind SW, Force 4, sea moderate.

Position: 5°-31'N, 92°-27'E

Continued the echo sounding on Nicobar Fan.

Tuesday, 11st October, 1983

08:00 Weather; Wind S, Force 2, sea smooth.

Position: 5°-18'N, 90°-40'E

Carried out the echo sounding and seismic prospecting on Ninety-degree East Ridge. Additional echo soundings carried out due to complicated contour.

15:00 Commenced the echo sounding from Ninety-degree East Ridge to Bengal Fan.

Wednesday, 12nd October, 1983

08:00 Weather; Wind W, Force 4, sea moderate.

Position; 5°-10'N, 87°-39'E

Continued the echo sounding on Bengal Fan.

Thursday, 13rd October, 1983

08:00 Weather; Wind WSW, Force 5, sea moderate.

Position: 5°-13'N, 84°-33'E

Continued the echo sounding on Bengal Fan.

Friday, 14th October, 1983

08:00 Weather; Wind WSW, Force 4, sea moderate.

Position: 5°-8'N, 81°-17'E

Continued the echo sounding on Bengal Fan.

17:30 Commenced the echo sounding from Bengal Fan to Colombo Continental Shelf (to A/C20).

Saturday, 15th October, 1983

08:00 Weather; Wind WSW, Force 3, sea smooth.

Position: 6°-49'N, 79°-42'E

On stand by for the orbitting satellite.

12:40 Carried out the echo sounding, seismic prospecting and bottom scanning on Colombo Continental Shelf (to A/C21).

21:00 Arrived at the anchorage off Colombo Port.

Sunday, 16th October, 1983

08:00 Weather; Wind SSE, Force 2

Position: Anchorage off Colombo Port.

Headed for Colombo Port.

09:08 Arrived at Colombo (Queen Elizabeth Quay).

Monday, 17th October, 1983

Consulted with OTS for the work and discussed on the local survey and landing point. Further negotiation took place at the Survey Department and Port Authority.

08:00 Weather; Wind SW, Force 2, sea smooth.

Position: Colombo Port

10:00 Installed the current meter at Point St.A (off Galle Face).

Tuesday, 18th October, 1983

Carried out the inland route survey in Colombo and the landing point (LP point).

Wednesday, 19th October, 1983

Carried out the inland route survey in Colombo (from the landing point to O.T.S building).

08:00 Weather; Wind SSW, Force 2, sea calm.

Position: off Galle Face

Carried out the echo sounding and seismic prospecting as a part of the Colombo shore survey (approach)

Thursday, 20th October, 1983

08:00 Weather; Wind SSW, Force 2, sea calm.

Position: off Galle Face

Carried out the levelling on seashore, sea bottom photographing (by divers) and earth resistivity measurement as a part of the Colombo seashore survey (approach).

Friday, 21st October, 1983

Arrangement of various data for the approach surveys as acquired in Colombo.

Saturday, 22nd October, 1983

Arrangement of the data and serviced the survey facilities and equipment; took in 65 tons of drinking water; invited the officials and others concerned into the vessel to show various facilities onboard.

Sunday, 23rd October, 1983

12:00 Weather; Wind NW, Force 3, sea smooth.

Position: Colombo Port

Left Colombo.

Commenced reterning run survey from Colombo shallow water. One counterpart of SLTD embarked.

13:54 Carried out the bottom sampling and temperature measurement at Points V5 and V4 (LP to A/C20) as well as the succeeding echo sounding.

Monday, 24th October, 1983

06:35 Carried out the bottom sampling and temperature measurement at Point P17.

08:00 Weather; Wind NW, Force 2, sea smooth.

Position: 6°-49'N, 79°-37'E

Carried out the echo sounding on Colombo Continental Shelf.

23:37 Carried out the bottom sampling and temperature measurement at Point P18.

Tuesday, 25th October, 1983

07:36 Carried out the bottom sampling and temperature measurement at Point P19.

08:00 Weather; Wind NW, Force 3, sea slight.

Position: 5°-24'N, 80°-2'E

Carried out the echo sounding on Bengal Fan, (on the route 2 miles south of the main line).

19:01 Carried out the bottom sampling and temperature measurement at Point P20 and continued the echo sounding (to A/C16).

Wednesday, 26th October, 1983

04:29 Carried out the bottom sampling and temperature measurement at Point P21 and continued the echo sounding (to A/C16).

08:00 Weather; Wind W, Force 3, sea slight.

Position: 5°-7'N, 82°-11'E

Continued the echo sounding on Bengal Fan.

17:13 Carried out the bottom sampling, temperature measurement and seabed photographing at Point P22. Then continued the echo sounding on Bengal Fan.

Thursday, 27th October, 1983

08:00 Weather; Wind SW, Force 2, sea calm.

Position: 5°-11'N, 84°-15'E

Carried out the echo sounding on Bengal Fan.

12:50 Carried out the echo sounding on Bengal Fan.

12:50 Carried out the bottom sampling and temperature measurement at Point P23; then continued the echo sounding on Bengal Fan.

Friday, 28th October, 1983

07:03 Carried out the bottom sampling and temperature measurement at Point P24; then continued the echo sounding on Bengal Fan.

08:00 Weather; Wind W, Force 2, sea slight.

Position: 5°-10'N, 87°-11'E

Continued the echo sounding on Bengal Fan.

20:55 Carried out the bottom sampling and temperature measurement at Point P25; then continued the echo sounding on Bengal Fan.

Sunday, 29th October, 1983

08:00 Weather; Wind W, Force 2, sea calm.

Position: 4°-51'N, 90°-12'E

10:00 Passed Point A/C20 and commenced the echo sounding on Ninety-degree East Ridge area, the line of soundings being south of the planned route.

10:58 Carried out the bottom sampling, temperature measurement and seabed photographing at Point P26 as well as the echo sounding of the auxiliary line of survey on Ninety-degree East Ridge.

Indonesian Standard Time Hereafter

Sunday, 30th October, 1983

03:35 Carried out the bottom sampling and temperature measurement at Point P27.

06:48 Carried out the temperature measurement and seabed photographing at Point P28 as well as the echo sounding of the auxiliary line of survey on Ninety-degree east Ridge.

08:00 Weather; Wind W, Force 2, sea calm.

Position: 4°-58'N, 90°-26'E

Carried out the echo sounding on Ninety-degree East Ridge.

14:16 Carried out the temperature measurement and seabed photographing at Point P29 as well as the echo sounding on Ninety-degree East Ridge.

18:44 Carried out the bottom sampling and temperature measurement at Point P30.

23:22 Carried out the bottom sampling, temperature measurement and seabed photographing at Point P31.

Monday, 31st October, 1983

06:45 Carried out the bottom sampling and temperature measurement at Point P32.

08:00 Weather; Wind ESE, Force 3, sea slight.

Position: 5°-26'N, 90°-50'E

Carried out the echo sounding on Nicobar Fan.

10:10 Carried out the bottom sampling, temperature measurement at Point P33 and the echo sounding on Nicobar Fan.

22:53 Carried out the bottom sampling and temperature measurement at Point P34 and the echo sounding of the auxiliary line of survey on Nicobar Fan.

Tuesday, 1st November, 1983

08:00 Weather; Wind SSE, Force 1, sea smooth.

Position: 5°-25'N, 91°-16'E

19:15 Carried out the bottom sampling and temperature measurement at Point P35; continued the echo sounding on Nicobar Fan.

Wednesday, 2nd November, 1983

07:36 Carried out the bottom sampling, temperature measurement and seabed photographing at Point P36.

08:00 Weather; Wind southerly, Force 4, sea moderate.

Position: 5°-49N, 92°-59'E

Continued the echo sounding on Great Passage.

21:00 Carried out the bottom sampling, temperature measurement and seabed photographing at Point P37.

22:41 Carried out the bottom sampling and temperature measurement at Point P38.

Thursday, 3rd November, 1983

02:05 Carried out the bottom sampling, temperature measurement and seabed photographing at Point P39; then continued the echo sounding of the auxiliary line of survey on Great Passage.

06:35 Carried out the bottom sampling and temperature measurement at Point P40; then continued the echo sounding of the auxiliary line of survey on Great Passage.

08:00 Weather; Wind SW, Force 3, sea moderate.

Position: 5°-59'N, 93°-56'E

Continued the echo sounding of the auxiliary line of survey on Great Passage.

18:40 Carried out the bottom sampling and temperature measurement at Point P42.

Friday, 4th November, 1983

00:27 Carried out the temperature measurement and seabed photographing at Point P41.

08:00 Weather; Wind WSW, Force 5, sea rough.

Position: 6°-4'N, 93°-52'E

10:04 to
18:17 Installed two positioning buoys in Great Passage (near A/C12).

On stand by on the sight for the echo sounding by positioning buoys, as the radar position finding was prevented by squall.

Saturday, 5th November, 1983

08:00 Weather; Wind WSW, Force 5, sea rough.

Position: 5°-59'N, 94°-01'E

Moved to A/C10 due to bad weather.

12:50 Carried out the echo sounding of the auxiliary line of survey east of Great Passage.

21:35 Sailed to the installation points of positioning buoys (near A/C12).

Sunday, 6th November, 1983

08:00 Weather; Wind SSW, Force 5, sea rough.

Position: 6°-11'N, 94°-12'E

Carried out the supplemental survey on Great Passage (near A/C12).

12:00 to 19:47 Searched the lost positioning buoys installed on 4th November and installed new positioning buoys.

20:00 Carried out the supplemental survey by the newly installed buoys.

Monday, 7th November, 1983

08:00 Weather; Wind SSW, Force 3, sea smooth.

Position: 6°-5'N, 93°-52'E

Carried out the supplemental survey by the new positioning buoys.

17:42 to 24:00 Recovered two new positioning buoys and searched two lost buoys.

Tuesday, 8th November, 1983

08;00 Weather; Wind S, Force 3, sea slight.

Position: 6°-30'N, 95°-03'E

08;54 Carried out the temperature measurement and seabed photographing at Point P43; then continued the echo sounding on Sumatra Shelf Basin.

15;12 Carried out the temperature measurement at Point P44; then continued the echo sounding on Sumatra Shelf Basin.

20;24 Carried out the temperature measurement at Point P45; then continued the echo sounding on Sumatra Shelf Basin.

Wednesday, 9th November, 1983

02;02 Carried out the bottom sampling, temperature measurement and seabed photographing at Point P46.

08;00 Weather; Wind SE, Force 2, sea slight.

Position: 5°-49'N, 97°-33'E

08;10 Carried out the bottom sampling and seabed photographing at Point P12'.

09;40 All surveys completed. Headed for Singapore.

Appendix 3

Survey Vessels

When conducting the route survey, the survey ship Wakashio-maru was used in offshore areas, and Golden Seahorse (Belawan) and Mahawell Nadee (Colombo) chartered at the site and the workboat mounted aboard the Wakashio-maru were used in inshore areas. Ships with sufficient functions as the cable route survey ship were selected. Particulars of the ships used for the route survey are given below, and outfitting of Wakashio-Maru is shown in Fig. 3.1. Photographs of the survey ships are shown in Fig. 3.1.

Survey Ship Wakashio-maru (Nippon Salvage Co., Ltd.), Japan

Gross tonnage	:	493.16 gross tons
Principal dimensions	:	49 x 8.8 x 4.05 m
Full load draft	:	3.823 m
Main engines	:	1,000 BHP x 2 (sets)
Propeller	:	Changeable pitch propeller (CPP)
Cruising speed	:	12.5 kt
Navigational aids	:	Radar, NNSS, OMEGA, etc.

Survey Ship Golden Seahorse

Classification	:	Fishing boat
Gross tonnage	:	Approx. 20 tons

Survey Ship Mahawell Nadee

Classification	:	Traffic boat
Gross tonnage	:	Approx. 20 tons

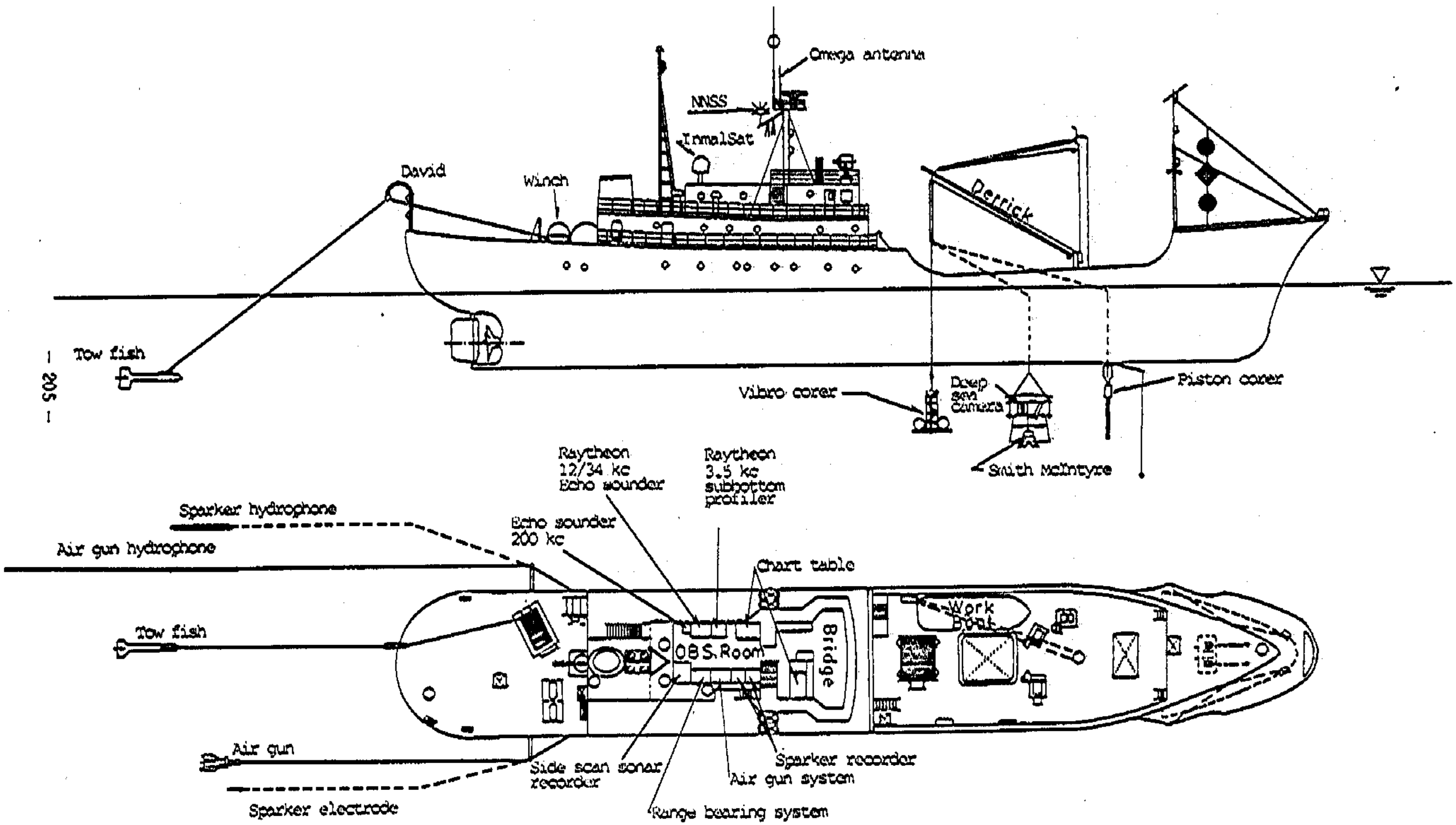
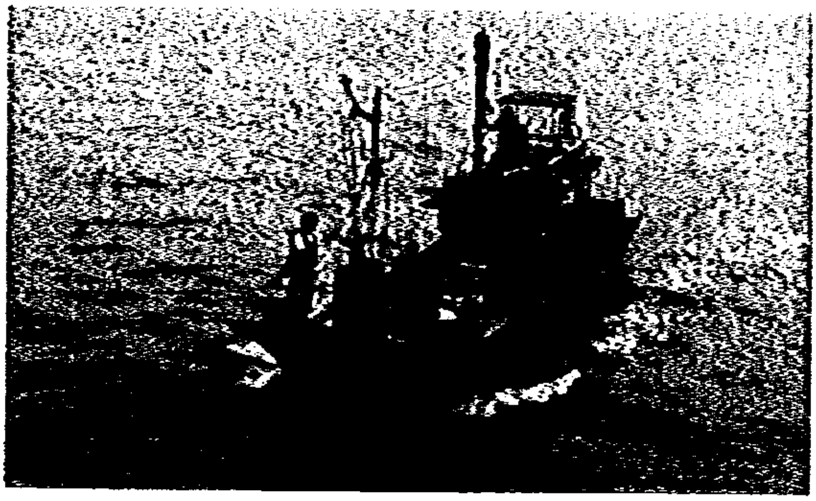
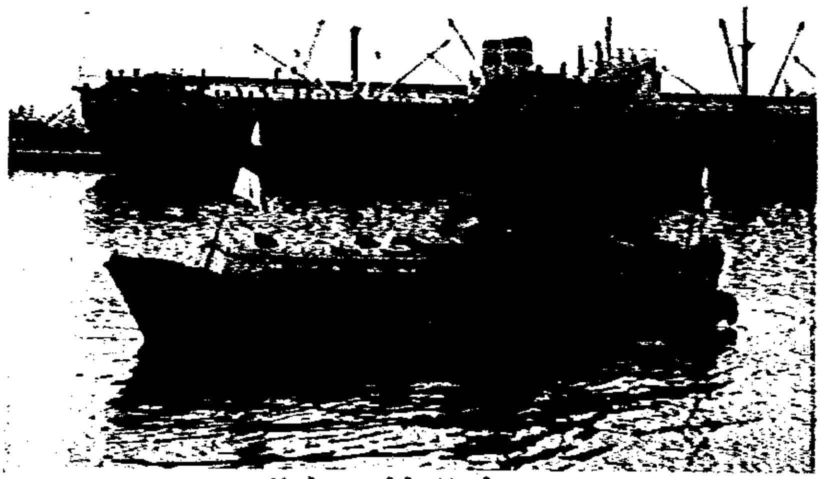


Fig. 3.1 OUTFITTING OF WAKASHIO-MARU FOR SURVEYING

Wakashio-maru



Golden Seahors



Mahawell Nadee

Fig. 3.2 SURVEY SHIPS

Appendix 4

Survey Equipment and Survey Method

Main equipments used for the route survey are given in the table below.

Applications	Name of Equipment	Q'ty	Maker	Model
Positioning	NNSS	1	Furuno Electric Co., Ltd.	FSN-20
	OMEGA	1	Furuno Electric Co., Ltd.	FORM-100
	Radar	1	J.R.C	RAS4NM9-25KP0-3
	Positioning Buoy	4		
	Electric Positioning System	1	SPC Electronics Corp.	8D030
Sounding	Echo Sounder for Deep Sea	1	Raytheon Company	12/34 kHz
	Echo Sounder for Shallow Sea	1	Senbon Denki Co., Ltd.	PDR101
	Portable Echo Sounder	2	Rasa Corp.	RS-61
Seismic prospecting	Sparker	2	NEC	NE19C
	Air Gun	1	Bolt Associates Inc.	600B
	Raytheon (3.5 kHZ)	1	Raytheon Company	
Bottom Scanning	Side Scan Sonar	1	EG & G	SMS960 (for deep sea)
	Side Scan Sonar	2	EG & G	Mark 1B

Applications	Name of Equipment	Q'ty	Maker	Model
Bottom Sampling	Vibrocorer	1	Nichiyu Giken	Seabed settling type
	Piston Corer	3	Rigo Sha	Piston corer: 2 Gravity-type corer: 1
	Smith.McIntyre Sampler	2		
Temperature Measurement	Reversing Thermometer	1	Yoshino Keiki Co., Ltd.	
	X.B.T.	1	Tsurumi Seiki Co., Ltd.	1825 m probe
	Electric Water Thermometer	1	Toho Dentan Co., Ltd.	ET-5
Current Observation	Aanderaa Current Meter		Aanderaa	RCM-4, -5
	Acoustic Releaser	4	EG & G	723A
Seabed Photographing	Deep Sea Camera	1	Benthos Inc.	
	Underwater Camera	1	Nikon	
Earth Resistivity Measurement	Resistivity Measuring Set	1	Yokogawa Denki Co., Ltd.	L-10

Operating methods and specifications of the main equipments given in the above table are described hereunder.

(1) Positioning

1) Navy Navigation Satellite System (NNSS)

The Navy Navigation Satellite System (NNSS) is composed of five navigation satellites which are in operation at the present and a command earth station which measures orbits of the satellites and transmits their orbital data to the satellites.

These satellites all fly on a circular polar orbit which passes just above the north and south poles located at both ends of the axis of the earth. The satellites fly around the earth at an altitude of about 1,100 km and cycles of about 108 minutes, and the earth rotates on its axis eastward by about 26.5° during this period. The five satellites can, therefore, be used one by one is succession as the earth rotates on its axis (see Fig. 4.1).

The sea area where the survey was conducted is located in a range between latitudes of 3° N and 7°N, and the number of satellites which fly over this area is about twenty (20) per one day.

The positioning principle of the NNSS is as follows. A satellite of the NNSS transmits signals of two frequencies; f_1 = 399.968 MHz and f_2 = 3/8 f_1 = 149.988 MHz, and transmits also time signals at two-minute intervals and data required for calculating the satellite position, as illustrated in Fig. 4.1.

The satellite transmits time signals at positions (time) of t_0, t_1, t_2 .... rotating on a circular orbit. Consequently, the time of $t_1 - t_0$, $t_2 - t_1$, ... $t_i - t_{i-1}$ is all two minutes and, at this time, the satellite gradually approaches the earth in the order of D (t_0), D (t_1) .... D(t_i), thereafter leaves the earth in the reverse order, and sinks below the horizon. The receiving frequency is counted at this time. Applying the Doppler effect to the above proves that a doppler shift is zero when the distance between the satellite and the earth becomes minimum, and accumulation in one cycle is counted, supposing that the transmitting frequency of the satellite is 399.968 MHz x 2 minutes. On the other hand, since the satellite always moves in reality, the accumulated value differs from the value mentioned above. In other words, variations of the distance between the satellite and a receiving point can be found if the wavelength of radio wave is known.

Points where the distance difference $D(t_i) - D(t_{i-1})$ thus obtained becomes constant form a hyperboloid of revolution, and considering the condition that a ship is on the surface of the earth, a line on which the hyperboloid and the surface of the earth cross each other represents a positional line of the ship. The positioning principle of the NNSS is a sort of hyperbolic navigation like the Loran or OMEGA system.

2) OMEGA System

The OMEGA system adopted for the route survey is used as a hybrid navigation system, which is combined with the NNSS as an auxiliary system, for continuously determining the position of the survey ship at other time than during the positioning using a satellite.

Eight OMEGA stations are located on the earth, and the ship's position can be found by this system. By combining this OMEGA system with the NNSS, the positioning is achieved by correcting a deviation of the propagation characteristic of the OMEGA wave (which always varies with conditions of the ionosphere). Fig. 4.2 shows the hybrid navigation system consisting of a combination of the NNSS and OMEGA system.

. Specifications of Satellite Navigation System FSN-70

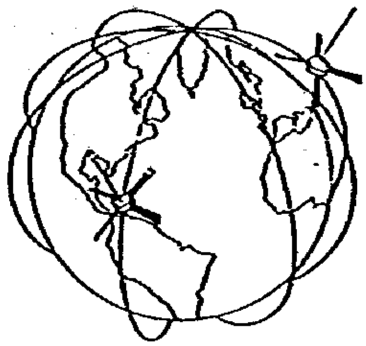
Positioning accuracy	:	0.1 nm when ship is at rest. 0.2 nm ∿ 0.5 nm when ship is cruising.
Power	:	DC 10 ∿ 42 V, 40 W. AC 100/110/220 V, 50 ∿ 60 Hz.
Operating temperature	:	-30° ∿ +70°C (antenna section). 0° ∿ +50°C (other sections).

<u>Receiver</u>

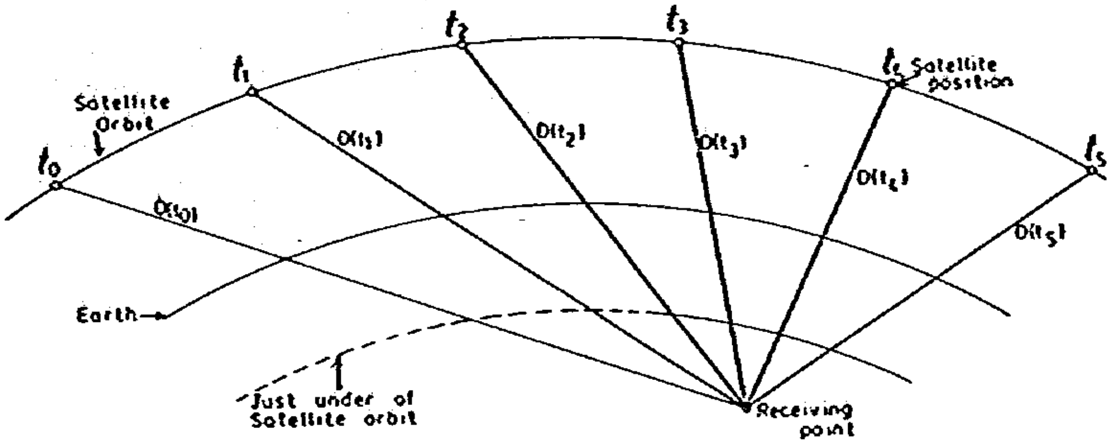
Receiving frequency	:	399.968 MHz ±10 kHz
Tuning	:	Automatic tuning.
Sensitivity	:	-140 dBm.
Dynamic range	:	-140 ∿ -80 dBm.

. Specifications of Omega Receiver FORM-100

Receiving frequency	:	10.2 kHz
Sensitivity	:	-40 dB (0.01 μV).
Dynamic range	:	100 dB.
Phase tracking	:	10.2 kHz Automatic tracking for 8 stations.
Segment synchronization	:	Automatic synchronization.
Power	:	DC 24 ∿ 32 V. AC 100/110/115/220 V, single phase, 50 ∿ 60 Hz.



Orbit of Satellite



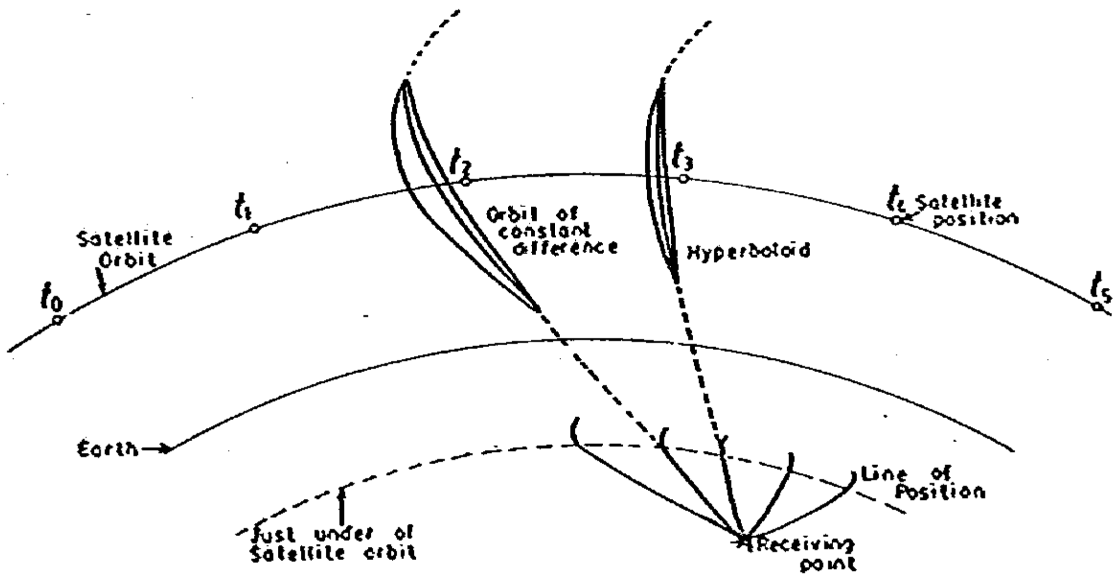
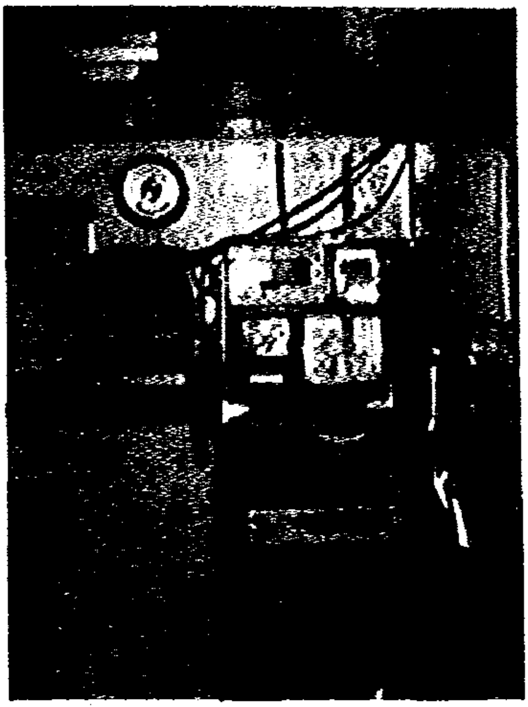
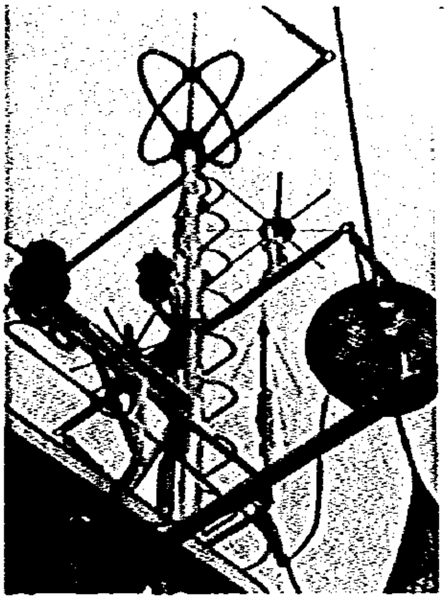


Fig. 4.1 PRINCIPLE OF POSITIOING BY NNSS



Receiver (NNSS and OMEGA)



Antenna

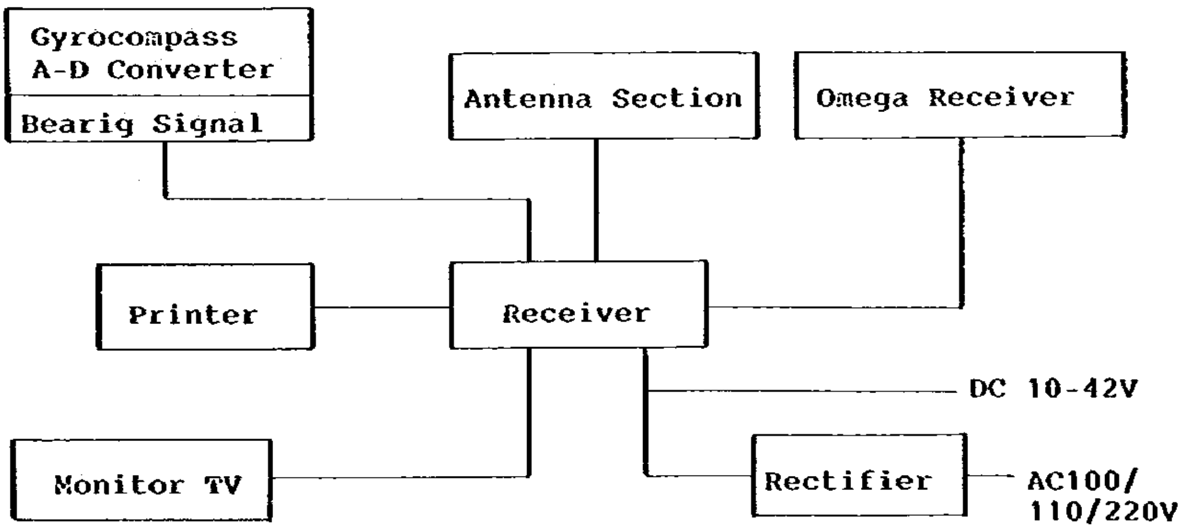


Fig. 4.2 HYBRID NAVIGATION SYSTEM CONSISTING OF A COMBINATION OF NNSS FSN-70 AND OMEGA FORM-100

3) Radar

The radar is a device for determining the ship's position by detecting the distance (range) and bearing of a target utilizing radio waves transmitted from an antenna. In the route survey, the radar was used for determining the ship's position during period from the position fixing using one satellite and that using a next satellite in the shallow water. The radar consists of a transmitter, receiver and antenna as shown in Fig. 4.3.

The radar transmits and receives radio waves at same point, and utilizes rectilinear propagation, constant speed and reflectivity characteristics of radio waves. It transmits directional waves from an antenna, receives waves reflected from objects such as conspicuous targets and makes them depict an image on a cathode-ray tube (CRT), thus positioning are conducted by measuring the distance (range) and bearing. Specifications of the Radar JMA259 are given below.

Peak transmitting output	:	50 kW.
Diameter of CRT	:	403 mm (16 inches).
Distance range	:	0.75, 1.5, 3, 6, 12, 24, 48 and 96 miles.
Frequency band	:	9,330 ∿ 9,420 MHz.
Center frequency	:	9,375 MHz (3.2 cm)
Horizontal beam width	:	1°
Vertical beam width	:	20°.
Number of revolutions	:	22 rpm (60 Hz). 18 rpm (50 Hz).

Pulse width	:	0.08 μs (0.75, 1.5 and 3 miles). 0.8 μs (6, 12, 24, 48 and 96 miles.)
Modulation system	:	Thyratron modulation
Minimum detecting distance	:	25 m.
Distance resolution	:	20 m.
Bearing resolution	:	1°.

JNA 259 Radar

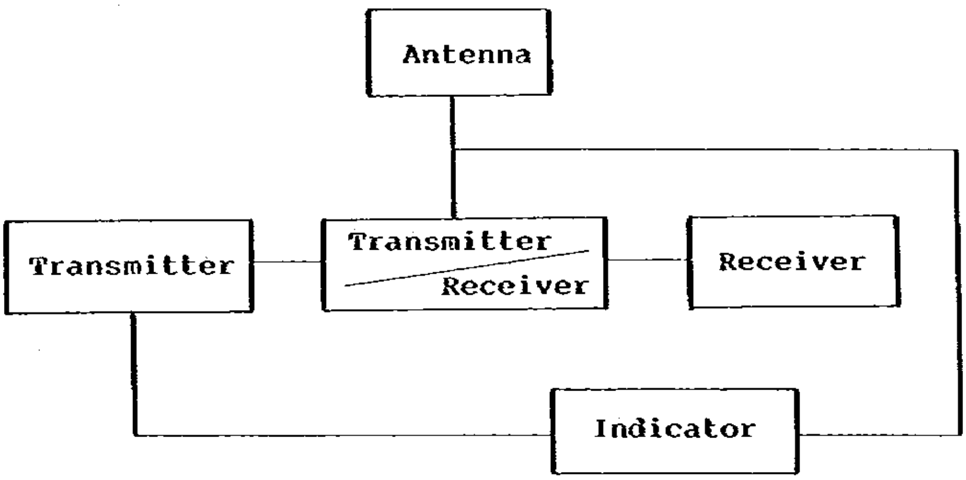


Fig. 4.3 RADAR SYSTEM

4) Positioning Buoy

The positioning buoy system consists of buoy, its mooring system and radar system as shown in Fig. 4.4, and is used for finding continuous positions by means of the radar from positions of several buoys, based on position data supplied from the Navy Navigation Satellite System (NNSS), in a sea area where sufficient positioning means are unavailable.

This system is installed after determing the optimum number of floats, weight and rig length through numerical calculation according to the water depth, surface current velocity and waves of a sea area where this system is to be installed.

The position of a survey ship is thereafter determined by the NNSS and, at the same time, the positions of buoys are found by the radar, and then the position of the survey ship is determined from the distance among the buoys and the survey ship.

When conducting the route survey, two buoys were installed at points of relatively complicated topography in the Great Passage area. An outside view of the positioning buoy is shown in Fig. 4.4, and specifications are given below.

Height above water surface : 5m

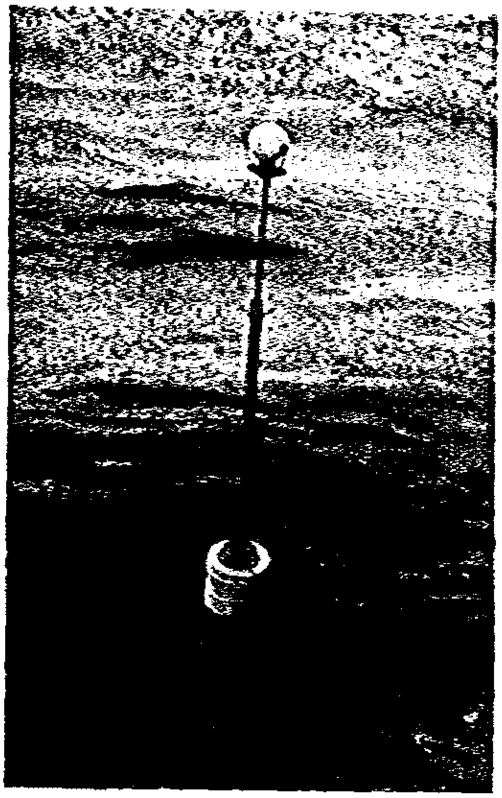
Weight

- Main body : 59.0 kg
- Internal weight : 4.5 kg x 10 (max.)
- External weight : 5.0 kg x 10 (max.)

Buoyancy

- Main body : 67.2 kg
- Float : 50.0 kg x 12 (max.), net buoyancy.

Material		
Main Body	:	Corrosion-proof aluminum alloy
Float	:	Foam polyethylene
Detectability	:	7 ∿ 8 miles (on calm sea)
		5 ∿ 5.5 miles (on rough sea)



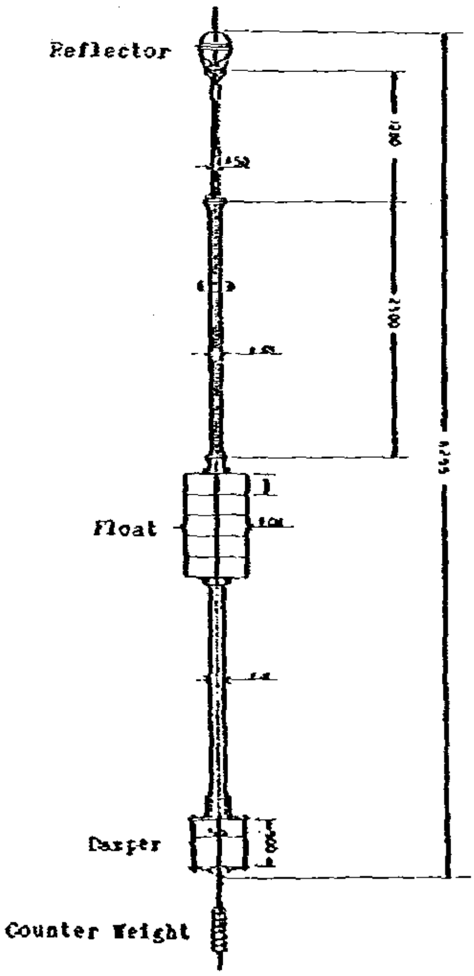


Fig. 4.4 POSITIONING BUOY

5) Audister

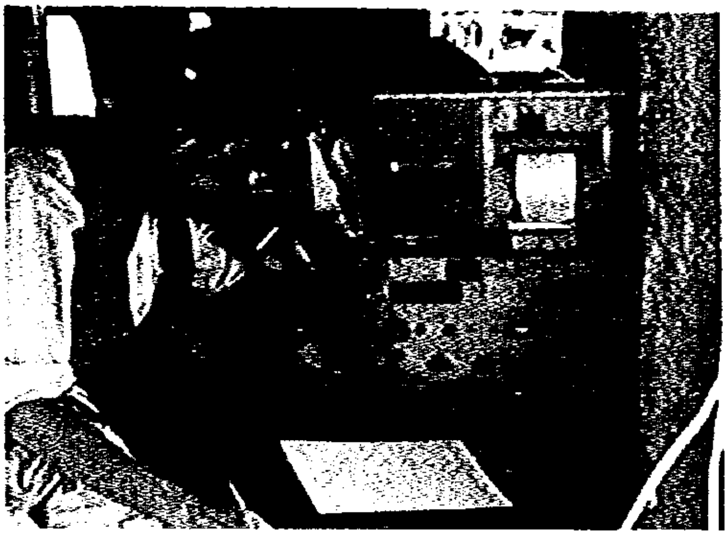
The Audister is a highly accurate distance measuring device using microwaves. The Audister system consists of a master station (interrogater) on a survey ship and a slave station (responder) on the land (see Fig. 4.5).

The theory of operation of Audister is described hereunder. A radio wave (f_1) signal is transmitted from the master station, and (f_2) signal is transmitted from the slave station units a composite two-frequency (f_1-f_2) signal consisting of a combination of the (F_2) signal and (f_1) signal received from the master station is transmitted from the slave station.

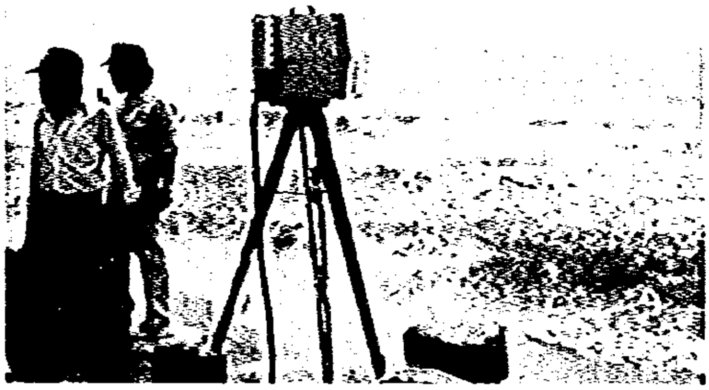
The master station combines the (f_2) signal received from the slave station with its own (f_1) signal, thus obtaining the (f_1-f_2) signal, and compared the phase of this composite signal with that of the (f_1-f_2) signal received from the slave station. Therefore, the propagation time required for the f_1 signal of the master station to return from the slave station is measured, and the distance between these two stations is measured accordingly.

Specifications of the Audister are given below.

Maximum measuring distance	:	100 km.
Maximum indicating value	:	9999.9 m.
Measuring accuracy	:	0.1 m.
Frequency		
Master station	:	2,985 MHz.
Slave station	:	2,940 or 2,930 MHz.



Master Device



Slave Device

Fig. 4.5 AUDISTER SYSTEM

(2) Echo Sounding

The echo sounder shown in Fig. 4.6 is composed of a recorder, transducer, signal processor, etc. It finds the water depth just below a survey ship by emitting an acoustic pulse to the seabed, and measuring the time required for the pulse reflected from the seabed return to the ship.

When conducting the route survey, the 12/34 kHz precision echo sounder for deep sea and the precision echo sounder for shallow sea, those are mounted aboard the survey ship, "Wakashio-maru", were used in the deep and shallow seas. When conducting the survey in the inshore area, a portable echo sounder mounted aboard a small work boat was used.

The echo sounders excepting the echo sounder for deep sea are light in weight and small in size. The 12/34 kHz precision depth sounder consists of a recorder, signal processor, transducer and digitizer. The water depth is recorded in two methods; the analog system in which the water depth is depicted on a dry recording paper, and the digital system.

Since this device has adopted a correlation echo sound processor (CESP), it is nearly free from noise. Since, moreover, it emits a long pulse of 25 ms, its transmitting wave energy is large and its depth sounding performance is greatly improved. In addition, its resolution is extremely high because a receiving signal is recorded in the form of short pulse of 0.5 ms.

The precision echo sounder for shallow sea (Model PDR101 and RS-61) is a lightweight and small-sized echo sounder extensively employing transistors and IC's. Its water depth recording system is that receiving signals are recorded on a dry discharge recording paper, and the water depth is depicted with a recording pen which moves rotationally.

A noise, which is produced when the recording pen rotates, is reduced by adopting a DC brushless motor for driving the recording pen.

The transmission is made by the phototransistor system. In this system a rotary slit disk is incorporated into the echo sounder, and a phototransistor receives light, which is generated by a photodiode, at the moment the light passes through the slit, and generates an electric pulse. This pulse is converted into an acoustic pulse by being passed through a separate converter, and sent to the seabed from the transducer.

The signal reflected from the seabed and reached the transducer is converted into an acoustic pulse, and supplied through a duplexer to a receiver. The recorder records both of this signal and a transmitting pulse, thus depicting a topography of the seabed.

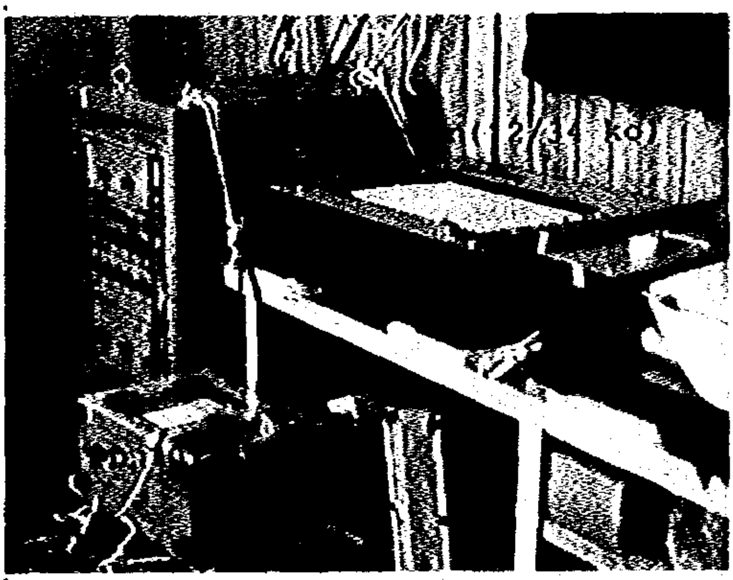
The water depth recorded in the above method is subject to adjustment according to the underwater sound speed, draft, tidal height, etc., and then a real water depth is indicated.

Description of specifications of the Precision Echo Sounder RS-61 is omitted here, since the specifications of the RS-61 are similar to those of the precision echo Sounder.

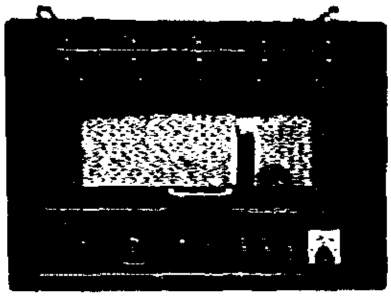
Specifications of the precision depth sounder for deep sea (Model PDR101) are as follows.

Recording range	:	0 ∿ 60 m (shallow sea).
		0 ∿ 120 m (deep sea).
Accuracy angle	:	±3 cm + D/1000 (D: depth m).
Beam angle	:	6° (beam width)

Frequency	:	200 kHz.
Power	:	DC 24 V, 1.5 A



Raytheon(12/34 kc)····Echo sounder for deep sea
PDR 101···············Echo sounder for shallow sea



Portable echo sounder(RS-61)

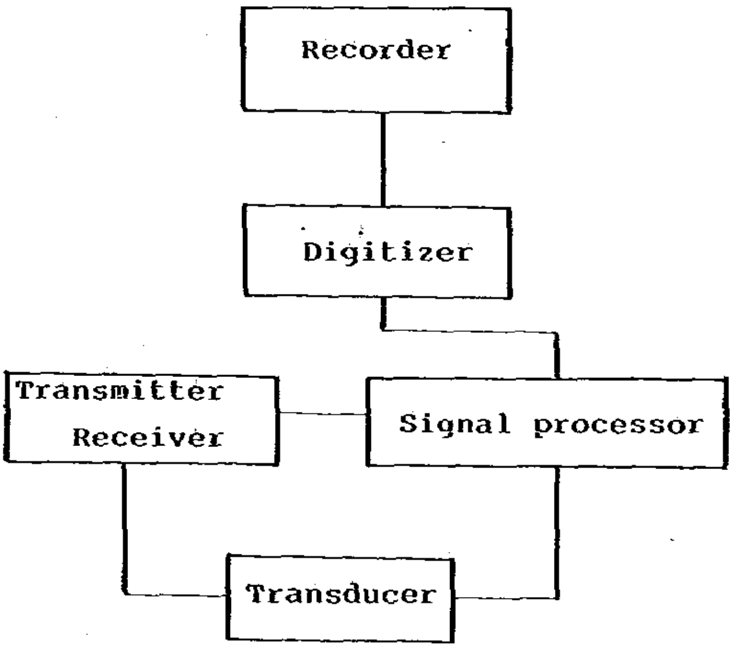


Fig. 4.6 ECHO SOUNDER SYSTEM

(3) Seismic Prospecting

A low-frequency acoustic wave with a large output is used for investigating a geological structure under the seabed. Although a part of it is reflected from the seabed, this low-frequency large-output acoustic wave penetrates under the seabed, and gradually attenuates while repeating reflection at each boundary between strata.

On the other hand, acoustic waves reflected from the seabed are amplified after having been received by the transducer, and depict a geological profile on a recording paper. Theoretically speaking, the lower frequency is, or the larger the output is, the deeper the exploration range reaches, but, on the other hand, the resolution deteriorates, and it becomes difficult to grasp a minute geological structure.

Seismic profiler used for the route survey are a discharge type (sparker), air pressure type (air gun), electro-striction and vibration type (3.5 kHz Raytheon). They are used according to their prospecting capabilities. Outlines of these seismic profiler are described below.

1) Sparker

In the transmitter, voltage boosted by a transformer is rectified to DC high voltage, and stored in a high-tension capacitor. A high voltage on-off circuit is actuated by a starting trigger from the receiver, and high-voltage DC charge is supplied to an underwater discharge electrode to make it discharge.

A powerful low-frequency acoustic wave generated by discharge propagates through water and under the seabed, and is reflected from various acoustic boundaries, and then returns again into the water. This reflected acoustic wave is caught by a towed transducer, converted into a voltage signal, and sent to the receiver. In the receiver, this feeble signal is amplified, filtered, controlled and amplified, and thus light and dark patterns are depicted on a recording paper. (Fig. 4.7)

Specifications of Speaker NE-19C

Transmitting energy	:	200 joules.
Recording range	:	100, 200, 400 and 800 m.
Width of recording paper	:	200 mm x 2 tracks.
Recording paper feed speed	:	120 and 60 mm/min.
Receiving frequency band	:	100 ∿ 5,000 Hz.

2) Air Gun

This device uses compressed air for an acoustic source. High-pressure air of 50 ∿ 150 kg/cm^2 stored in a cylinder is set from a compressor to an airtight vessel (air gun), and high-pressure air is momentarily emitted into the sea by opening and closing an electromagnetic valve of the air gun, and thus an acoustic wave is generated.

The powerful low-frequency acoustic wave thus generated propagates through the sea down to the seabed and under the seabed, reflected from an acoustic boundary between seabeds of different geological features, and returns again into the water. This reflected acoustic wave is received by the hydrophone, and converted into an electrical signal. In the receiver, this feeble signal undergoes amplification, signal processing, control and power amplification, and thus light and dark patterns are depicted on a recording paper. Fig. 4.8 shows a block diagram of the air gun. Specifications of the air gun are as follows.

Recording system	:	Dry discharge breakdown recording.
Frequency	:	30 ∿ 300 Hz.
Air chamber	:	10 and 20 $in.^3$
Scanning speed	:	1/4, 1/2, 1, 2, 5 and 10 sec/scan.
Compressor capacity	:	150 kg/cm^2 (maximum pressure).
Power	:	AC 115 V.

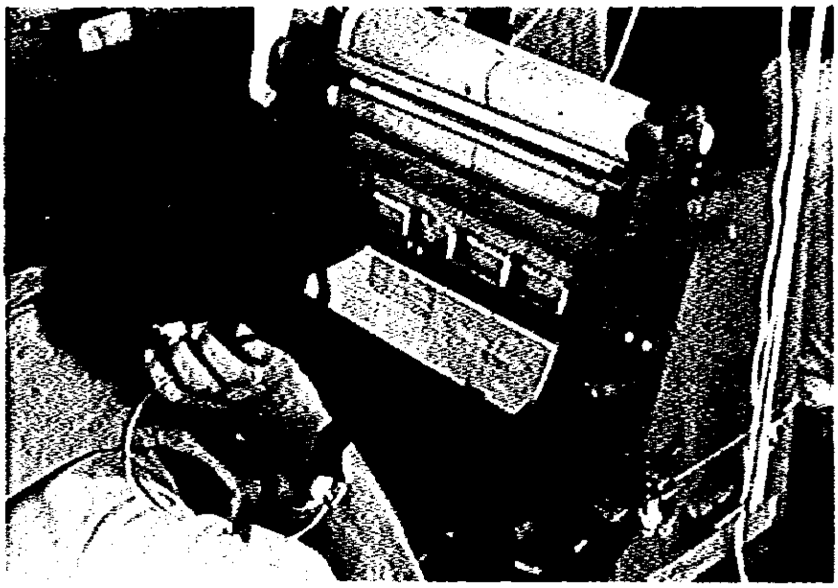
3) 3.5 kHz Raytheon

This device has such features that nine elements of electrostriction type are combined together in parallel, and transmitting output is large, while a directive angle is small as a whole. It consists of a recorder, transducer, signal processor, etc. Its center frequency is 3.5 kHz, and since this value is relatively high as an acoustic explorer, as compared with two types of devices described above, its resolution is high.

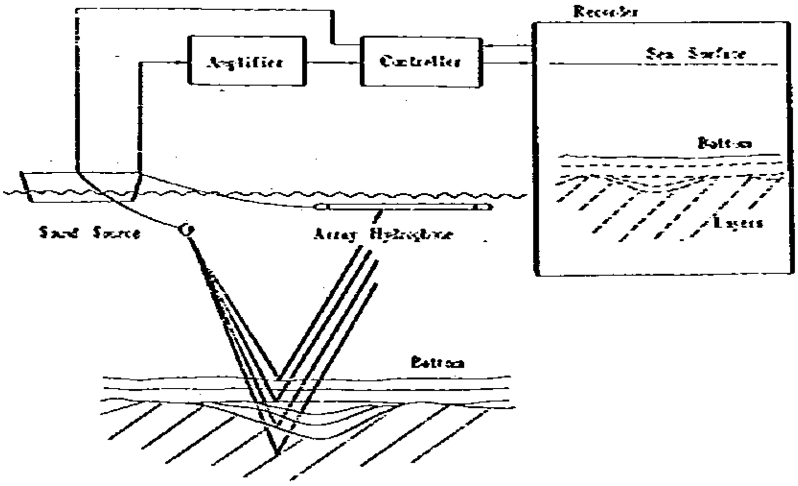
This device is, therefore, suitable for the stratum investigation near the surface of the seabed of mid and deep seas. It is not different from other two types of devices in operating principle. A transmitting acoustic wave (sweep wave) is generated by a transmitting trigger signal applied from the recorder. A reflected signal received by the receiver undergoes amplification, signal processing and comparison detecting, and then sent to the recorder. Since this recorder is the same as that for the air gun, a record can be enlarged according to the depth (Fig. 4.9).

Specifications of the 3.5 kHz Raytheon are as follows.

Frequency	:	3.5 kHz
Transmitting output	:	0 ∿ 2 kW.
Beam angle	:	30° ∿ 80° (depending upon the number of transducers).
Operating water depth	:	0 ∿ 10,000 m.
Resolution	:	30 cm.
Towing speed	:	0 ∿ 12 knots.

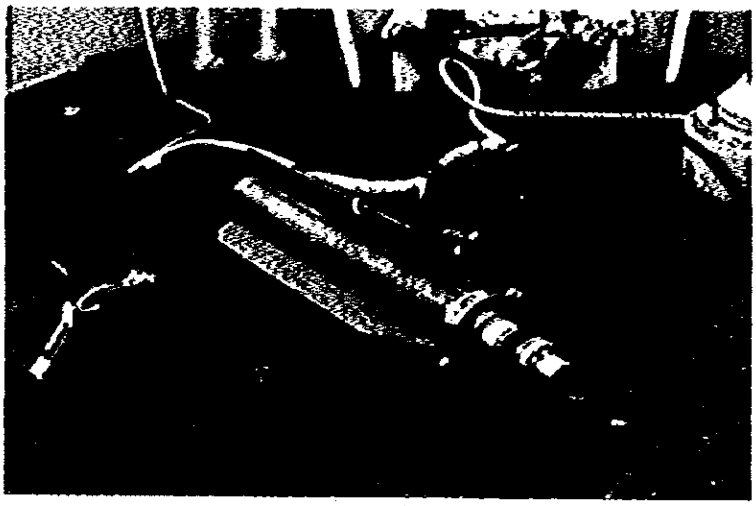


Sparker



Sub-bottom Profiling

Fig. 4.7 SPARKER SYSTEM



Air Gun

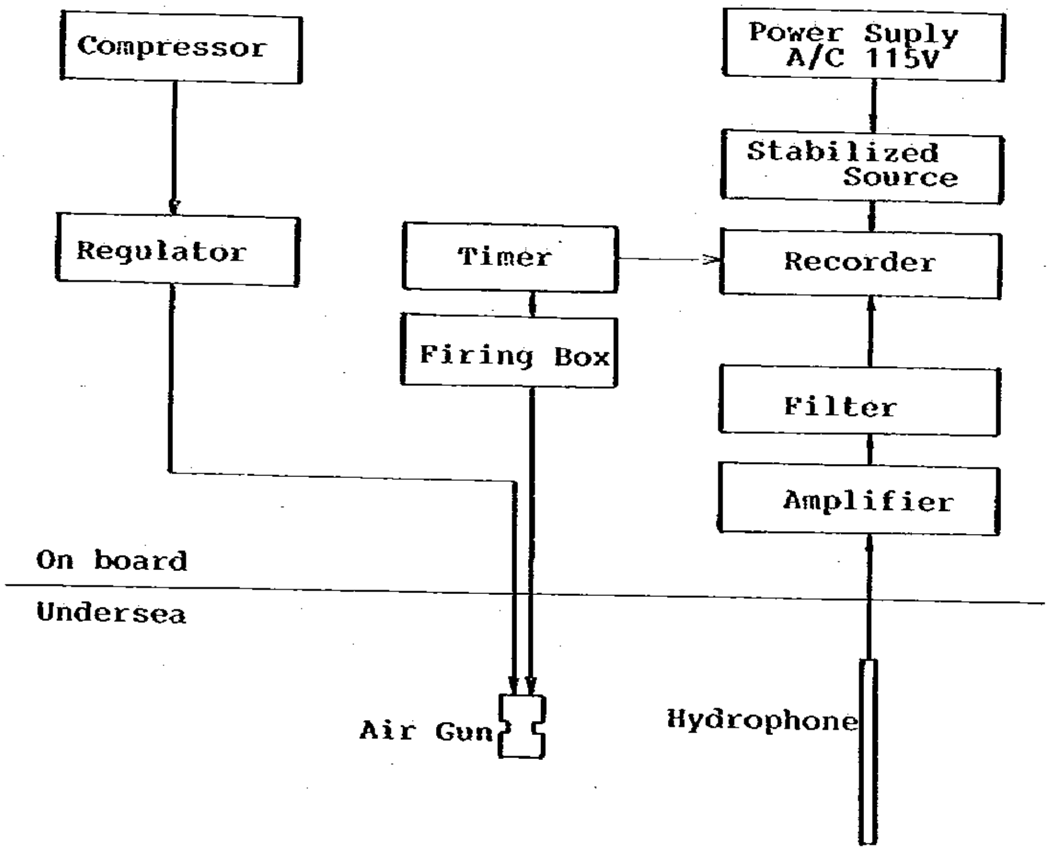


Fig. 4.8 AIR GUN SYSTEM

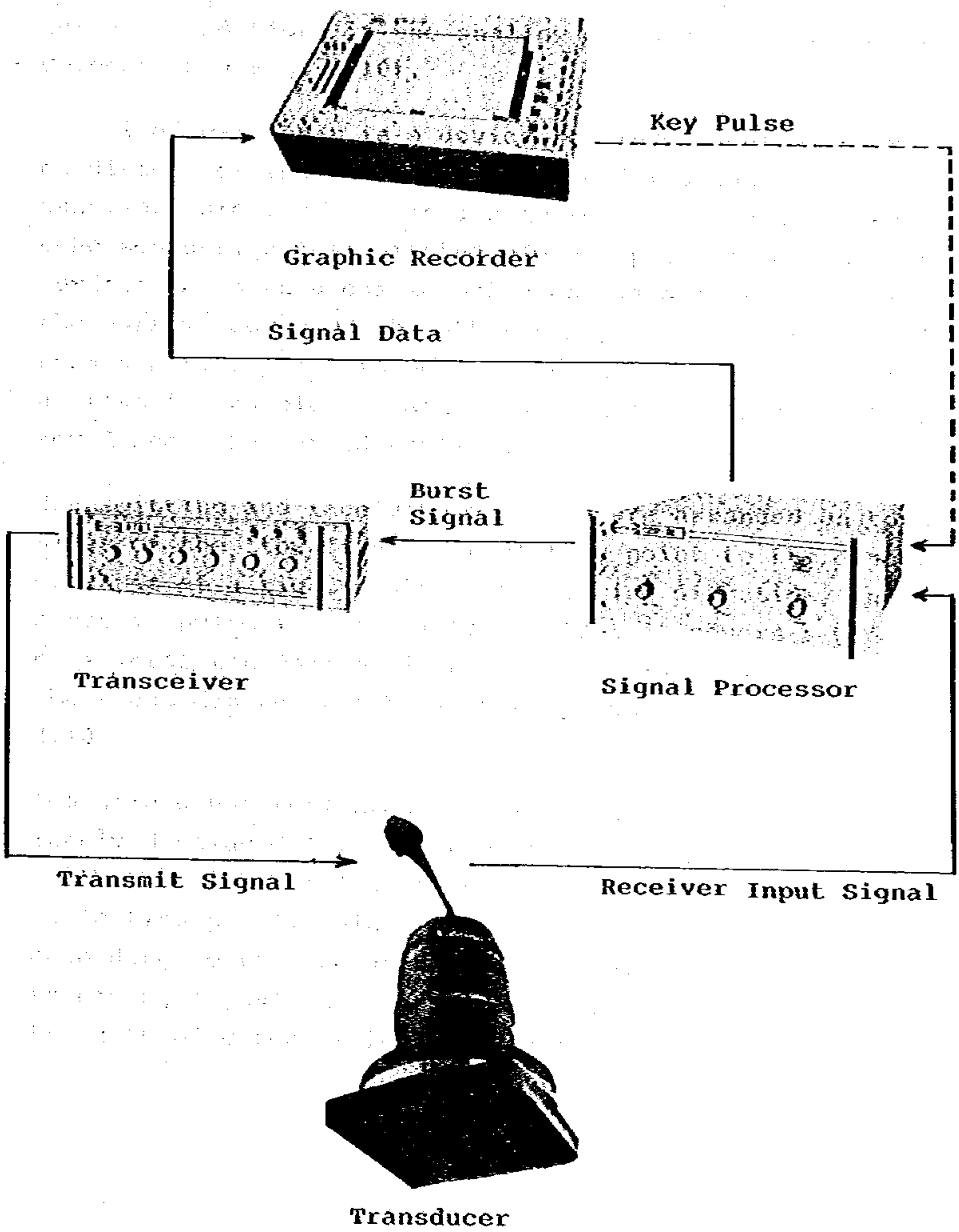
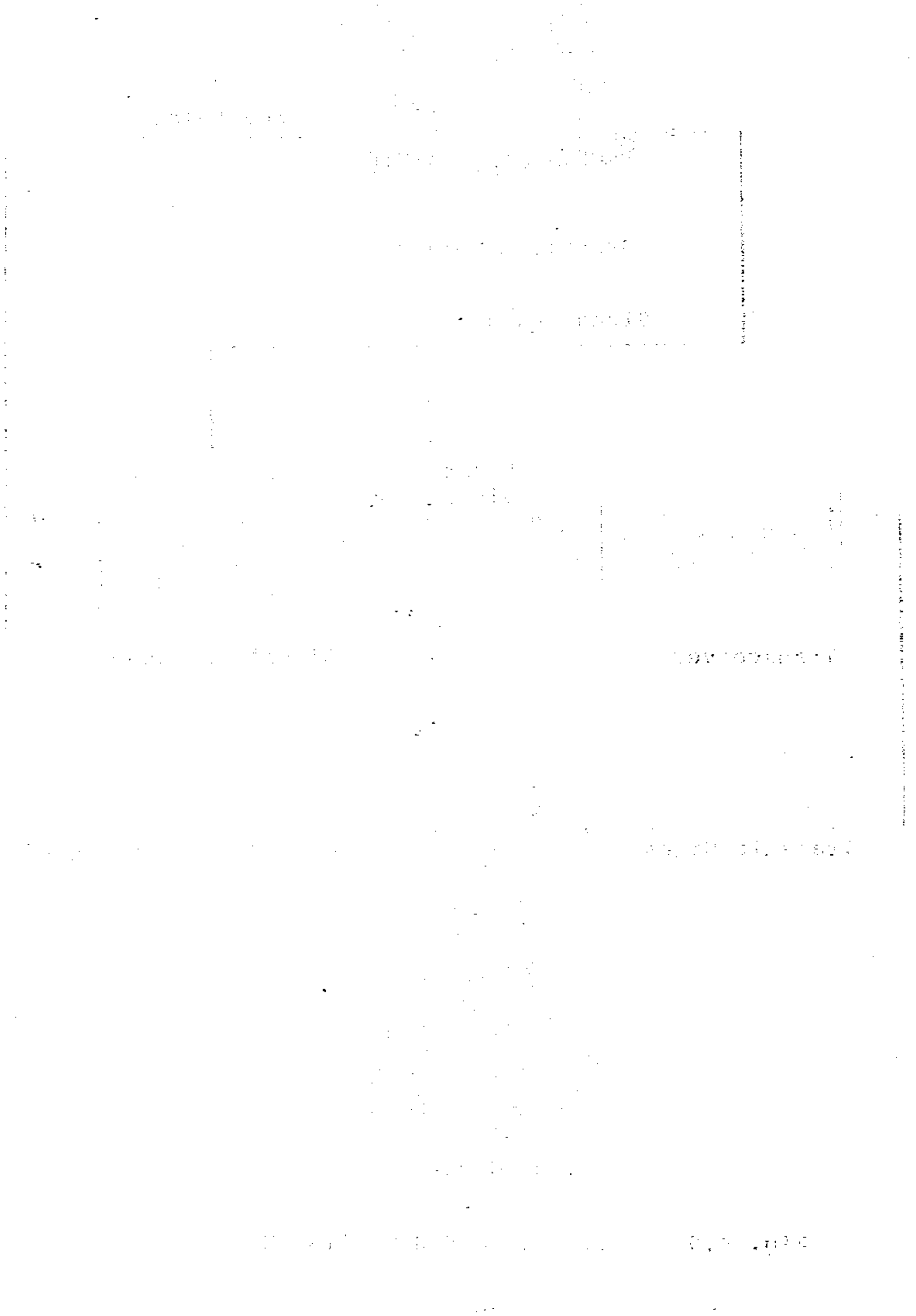


Fig. 4.9 3.5 kc RAYTHEON SYSTEM



(4) Bottom Scanning

When conducting the route survey, the side scan sonar (MARK 1B) for shallow sea and the side scan sonar for deep sea (Model 990/996) were used for investigating the seabed surface conditions in the shallow sea areas of Indonesia and Colombo (See Fig. 4.10).

The side scan sonar is a device for investigating uneven conditions of the seabed surface, and its fundamental functions are the same as a echo sounder. In the case of a echo sounder, a transmitting element positioned near the sea surface emits an acoustic pulse downward just below it in the narrow beam. On the other hand, in the case of a side scan sonar, a pulse is emitted obliquely to the seabed from a transmitting element attached to a 'tow fish' which is towed near the seabed surface.

Transmitting and receiving elements are arranged on both sides of the 'tow fish' so that they point to the direction which is at a right angle to the towing direction, and an acoustic pulse is transmitted so that it covers a wide angle of several ten degrees in a vertical plane, and an angle of about one degree in a horizontal plane, as shown in Fig. 4.10.

Acoustic waves reflected from the seabed are continuously received being delayed by the time corresponding to the distance between a 'tow fish' and an acoustic wave reflecting point. Since an acoustic wave is attenuated according to the propagation distance, the difference in receiving signal intensity is equalized by a time equalizer the gain of which varies with time.

Output signals of the receiving amplifier are recorded on a recording paper at positions corresponding to the distance between the 'tow fish' and the acoustic wave reflecting point. By towing the fish, conditions of the seabed surface are recorded in two dimensions like a photo showing light and dark patterns a corresponding to the unevenness of the seabed surface.

Since a towing cable of a tow fish of the SMS 990/960 Side Scan Sonar is paid out up to several thousand meters, the SMS 990/960 has a function of determing the position from a range and bearing by receiving an acoustic output of a responder of the tow fish with a transducer mounted on the broadside of a survey ship. It has also such a function that a strain of a seabed record depending upon a range and ship's speed is corrected at the real time, the record is scaled down by an aspect ratio of 1:1, and a topography of the seabed is depicted like an aerial photograph.

Specifications of the side scan sonar for shallow sea (Mark 1B) and that for deep sea (SMS 990/960) are as follows.

	Mark 1B	SMS 990/960
Range scale	50, 100, 125, 200 250, 500 m	100, 150, 200, 300, 400, 500 m
Scale line	25 m	25 m
Input power	DC 30 V, 4 ∿ 8 A	AC 115 V
Recording paper	Wet type, 28 cm x 37 m	Dry type, 28 cm x 50 m
Weight	38 kg	75 kg

Dimensions (272 tow fish)	28 x 84 x 44 cm	94 x 72 x 45 cm (990 two fish)
Operating frequency	105 ±10 kHz	59 kHz
Pulse length	0.1 ms	0.1 ms
Peak output	128 dB	220 dB
Horizontal beam angle	1.2°	1.2°
Vertical beam width	20° or 50°	30° or 40°
Scanning width	Max. 1,000 m	Max. 1,000 m
Towing speed	0 ∿ 15 knots	2 ∿ 12.7 knots
Maximum operating water depth	600 m	6,000 m
Weight	22 kg	90 kg
Dimensions		
Total length	118 cm	165 cm
Diameter	11.4 cm	26.0 cm

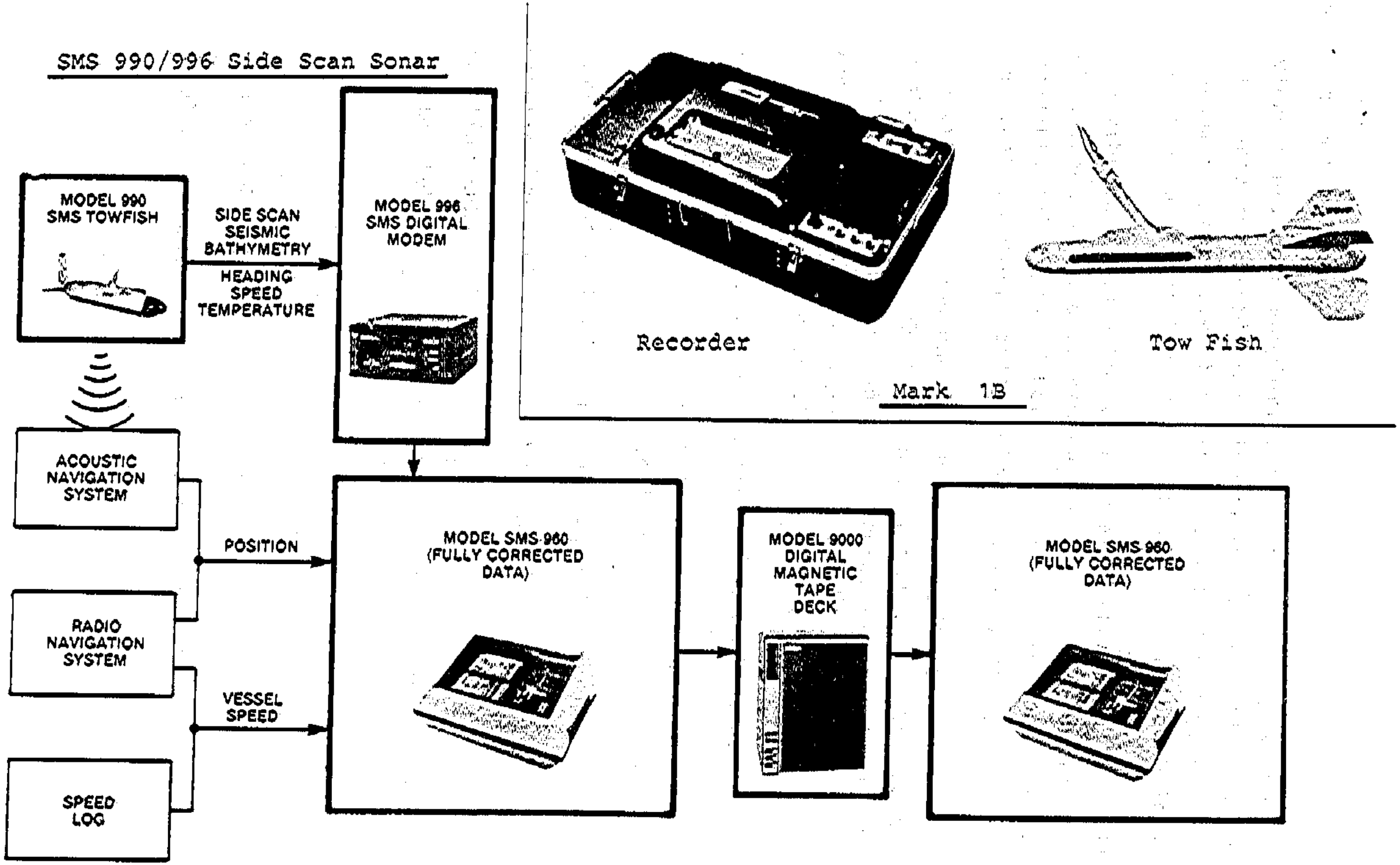


Fig. 4.10 MARK 1B AND SMS 990/996 Side SCAN SONAR

(5) Bottom Sampling

Vibrocorer, core sampler, Smith.McIntyre sampler and dredger were used for sampling sediments of the seabed. These bottom samplers are shown in Fig. 4.11 and Fig. 4.12. Outlines of these bottom samplers are described below.

The vibrocorer is a bottom sampler utilizing a liquiditying phenomenon of sand resulting from vibration, unlike conventional types of bottom samplers. It consists of an underwater motor, battery, control unit, etc.

The vibrocorer suspended from a survey ship down to the seabed samples sandy sediments of the seabed by actuating an exciter at the upper end of the corer by operating the control unit, which is submerged in the sea, from an ultrasonic device mounted aboard the survey ship.

Specifications of the vibrocorer are as follows.

Applicable soil	:	Soft mud, viscous soil, sandy soil and sand.
Operating water depth	:	less than 200 m.
Penetrating depth	:	Max. 3 m.
Sampling tube		
Outer tube	:	ϕ89 mm x T3 mm; 3m length (stainless). ϕ97 mm x T3 mm; 3 m length (steel).
Inner tube	:	ϕ 77 mm x T3 mm; 3m length
Sampling system	:	Piston system.

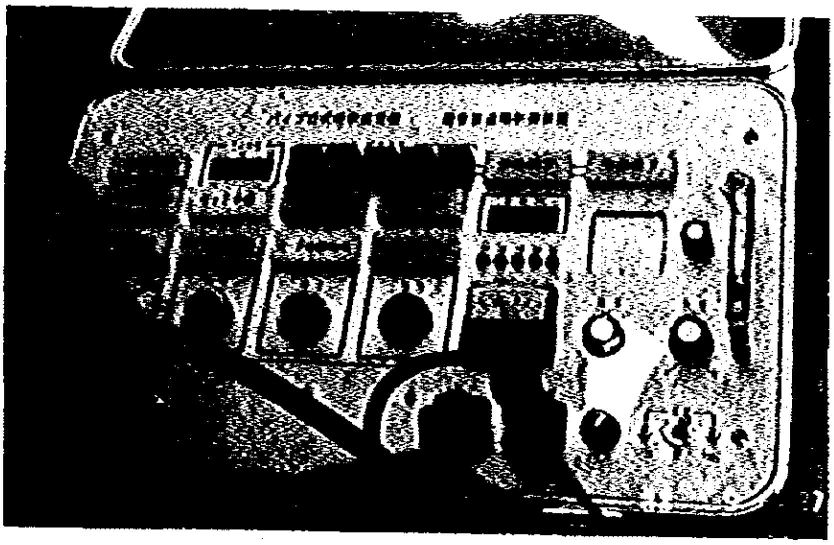
Core length	:	Max. 3m.
Weight	:	2,000 kg; additional weight 432 kg.
Rough dimensions	:	2,000 (W) x 2,000 (L) x 4,500 (H) mm.
Operating current speed	:	less than 2 knots

The piston corer is dropped down to the seabed from 2 m above the seabed by the lever action which is made when a weight, which reaches to the seabed, prior to a bottom sampler reaches the seabed. When lifting up the piston corer, the piston sacks up sediments of the seabed into an acryl pipe and holds them.

A stainless steel catcher at a port of the corer also serves for preventing sediments from flowing into the water during recovery of the piston corer by means of such a mechanism as to allow an object to move only in the inward direction. A seabed excavating depth of a cable layer can be roughly estimated from a seabed penetrating depth of the piston corer.

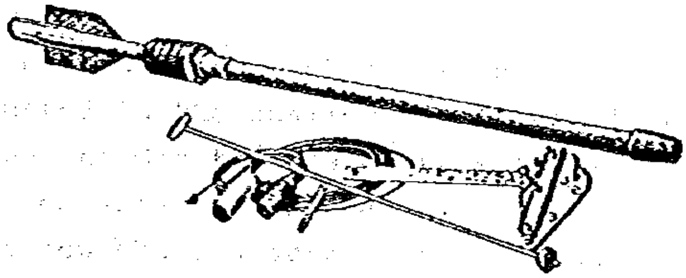
The bottom sampler of gravity type consists of a fin, weight and cylinder provided with a catcher at its end, and samples sediments when it is thrown into the sea as it is. The Smith.McIntyre sampler of grab type is so designed that when it reaches the seabed, a spring in it is released, and sediments of the seabed are taken in a grab.

Vibrocorer

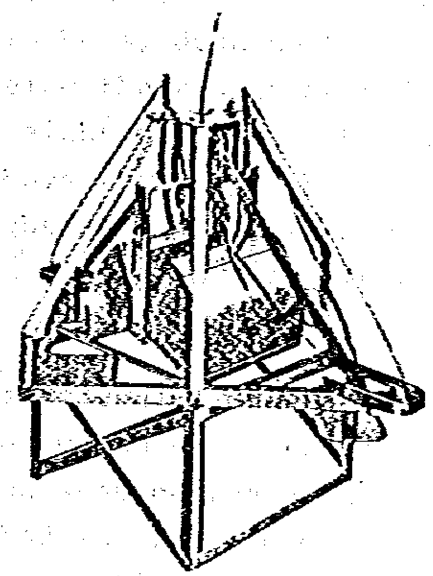


Acoustic Controler

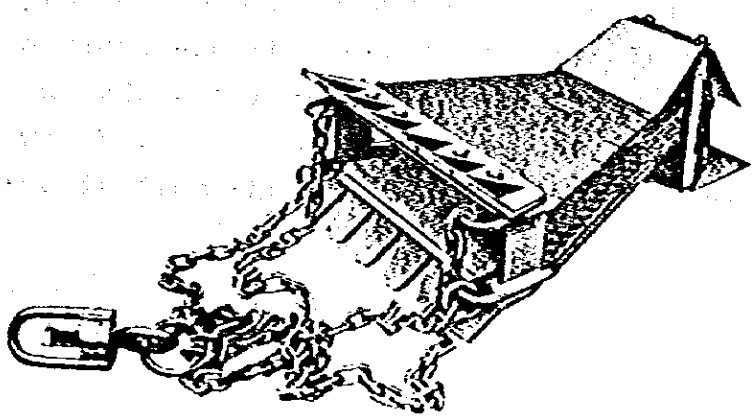
Fig. 4.11 VIBROCORER DEVICE



Piston Corer



Smith-McIntyre Sampler



Dredger

Fig. 4.12 BOTTOM SAMPLING DEVICES

(6) Current

The mooring method of current meters used for the current survey conducted in the shallow sea areas of Indonesia and Sri Lanka and the Great Passage are shown in Fig. 4.13. In the shallow sea areas of Indonesia, current meters were moored 5 m below the sea surface and 5 m above the seabed at a survey station of water depth of 26 m. Adopted mooring method for the current meters are two ways; one being the suspension method that a current meter is suspended from the middle buoy out of three, those are moored in the surface layer with two anchors, down to 5 m below the sea surface, and the other being the rising method that a current meter connected to a weight of 40 kg submerged onto the seabed in installed 5 m above the seabed by buoyancy of submerged buoys. The weight and anchor form a mooring system connected to one line when they are connected to each other with a rope.

In the shallow sea area of Sri Lanka, current meters were installed 5 m below the sea surface and 5 m above the seabed at an observation station where the water depth was 23.5 m. The mooring method is that two current meters are moored to the rising system mentioned above.

The current meter to be installed 5 m below the sea surface is moored at a correct water depth by calculating back to a water depth beforehand measured, and adjusting a rope length between a float and the current meter. In this mooring system, an underwater acoustic release is positioned just above a weight. The current meter was recovered by separating it from the mooring system with this release.

In the Great Passage sea area, the current survey was conducted at three observation stations. The water depth at these three stations is about 1,500 m, and measuring layers are 10 m and 15 m above the seabed. The mooring system is based on the rising system, and the mooring system excepting a weight is recovered to a survey ship at completion of the survey by actuating the acoustic release positioned just above the weight.

This method theoretically requires no surface layer buoy, but a surface layer buoy is added to the mooring system so that the mooring system can be recovered from the buoy in case the acoustic release does not operate by any possibility. However, the acoustic releases used during the route survey all operated satisfactorily.

1) Aanderaa Current Meter Model 4, Model 5 (Fig. 4.15)

   The Anaderaa Current Meter is a current meter of magnetic tape recording type which is able to measure the current direction, current velocity, water temperature and electric conductivity. Measuring ranges of these items are as follows.

   Current direction : 0 ∿ 360°

   Current velocity : 2.5 ∿ 250 cm/sec

   Water temperature : -0.34 ∿ 32.17°C

   Electric conductivity: 0 ∿ 70 mmho/cm

   A measuring interval is selectable to 0.5 ∿ 30 minutes. A specially designed 9 V battery is used for a power supply, which allows this current meter to be usable for the time of 10,000 intervals. The pressure withstanding depth of Model 4 is 2,000 m and that of Model 5 is 6,000 m.

2) Underwater Automatic Release (manufactured by EG&G Sea-Link Systems)

This release is indispensable for recovering a current meter installed in the rising system which is the optimum current meter mooring system using submerged buoys. It releases an anchor weight by a supersonic command, thus making a measuring device surface automatically.

- EG&G Sea-Link Digital Acoustic Command System (Specifications)

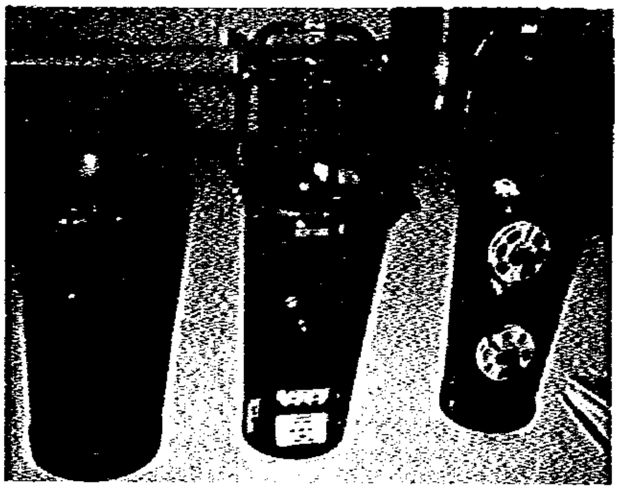
  Shipboard Unit (Model 701)

  - Size: 48 x 18 x 13 (cm)
  - Weight: 16 kg
  - Transponder Interrogate Frequencies: 9 & 11 kc

  Underwater Dacs Release/Trasponder (Model 723A)

  - Operating Depth: 6,000 m
  - Reply Frequencies: 8 frequencies
  - Size: dia 6.6 x L 43.0 (inches)
  - Weight: 31.8 kg
  - Operating Temperature: -10°C ~ +60°C

Current Meter which connected by rope with Buoy and Acoustic Releaser, installed in the sea.



Inside of Current Meter

Fig. 4.14 AANDERAA CURRENT METER

Releaser (EG&G)

Fig. 4.15 DEVICES FOR CURRENT METER

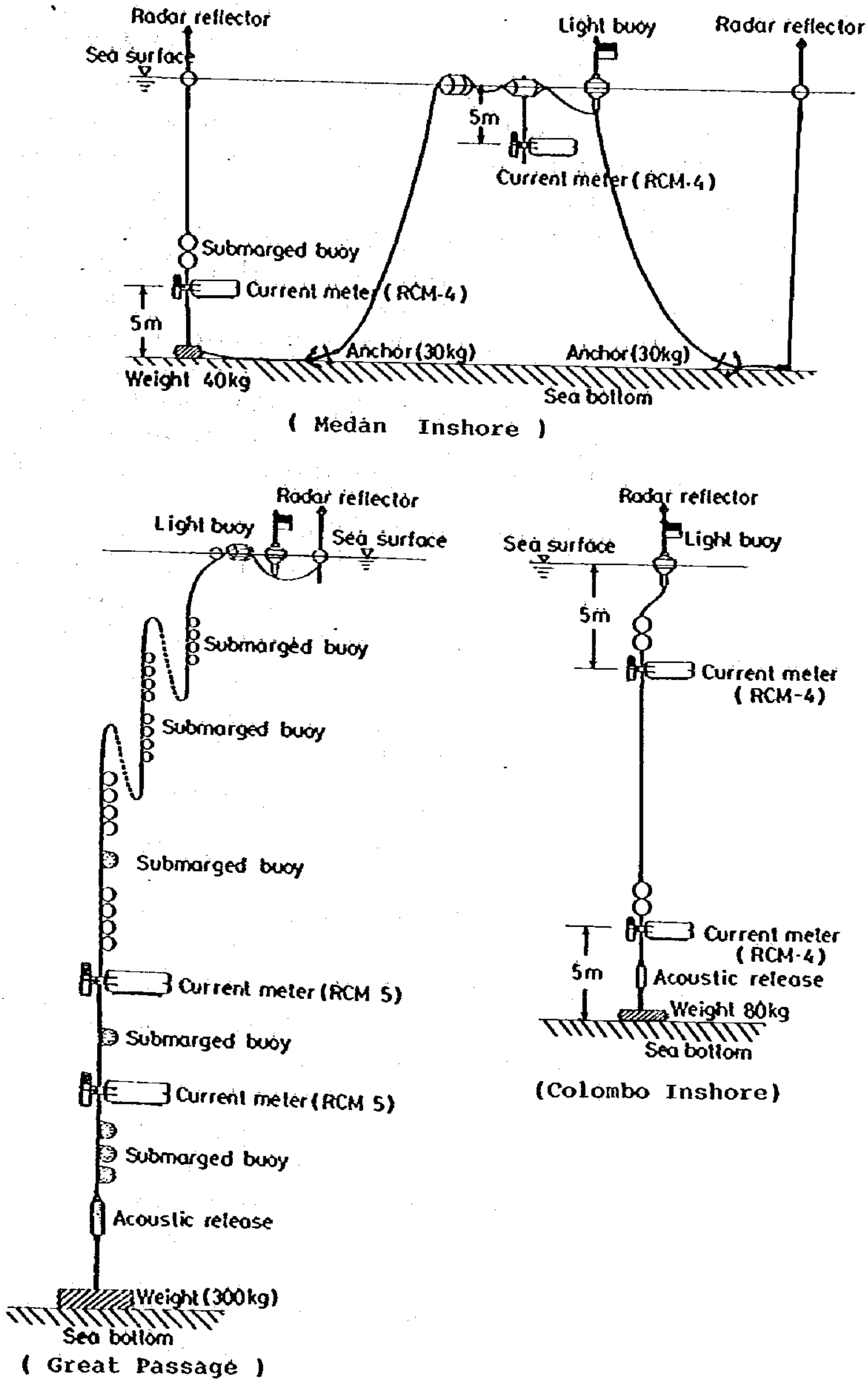


Fig. 4.13 MOORING METHOD OF CURRENT METER

(7) Temperature Measurement

The thermometry was conducted at 94 observation stations. The submersible electric thermograph ET-5 and reversing thermometer were used at 75 stations out of 94, and the XBT etc. was used at other 19 stations. Although slightly vary with sea areas, the water depths of survey layers are 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, 15.0, 20.0, 30.0, 40.0 m and 1.0 m above the seabed, in a total of 12 layers, in shallow sea areas of less than 50 m.

In sea areas deeper than 50 m, the water depths are 0.5, 10.0, 20.0, 30.0, 50.0, middle of the water depths and 5 or 10 m above the seabed, in a total of 7 layers.

The submersible electric thermograph ET-5 was used at the water depth of up to 50 m, and the reversing thermometer was used for temperature measurement in two layers deeper than 50 m. The water depth of stations where the XBT used was 1,800 m or less.

1) Nansen Bottle, Reversing Thermometer

i) Nansen Bottle

The Nansen bottle is a cylindrical water sampler which is opened and closed by valves,and a reversing thermometer can be attached to it. When operating it, it is perpendicularly attached to a wire, the wire is paid out down to a measuring water depth, and the Nansen bottle is turned up-side down by a messenger after the bottle has reached a measuring layer. As soon as the bottle is inverted, its open valve closes. The messenger is a metal weight which is of such design that a hole matching the wire diameter is drilled in the center of the messenger, the messenger falls down to the position of the Nansen bottle along the wire, and turns the Nansen bottle up-side down by applying an impact to a tripping device of the Nansen bottle.

ii) Reversing Thermometer

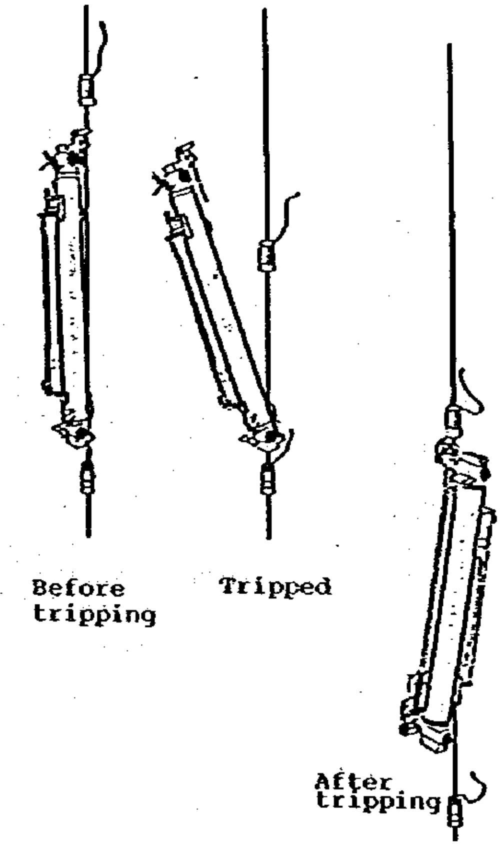
In a normal upright state the reversing thermometer records a water temperature of a place where it is installed. When it is reversed, a reading of a mercurial column at that time is recorded and kept. Protected and unprotected types are used, and the pressure imposed on the reversed thermometer is given from the water temperature difference between these two types, and the water depth whereat the water temperature is measured can be calculated.

2) XBT (Expendable Bathythermograph)

The XBT automatically measures and records a vertical temperature distribution in the sea by throwing a water temperature measuring probe into the sea from a ship sailing or at anchor. The XBT used for the route survey is able to measure the water temperature up to the water depth of 1,800 m. Its water temperature measuring range is -2°C ∿ 34°C.

3) Electric Thermograph ET-5 (for Shallow Water)

The water temperature of a measuring layer can be read by suspending a sensor of the ET-5 from a ship down to the measuring layer. The cord length of the ET-5 used for the route survey is 50 m and, accordingly, the ET-5 is able to measure the water temperature up to the water depth of 50 m. A water temperature measuring range of the ET-5 is -5 ∿ 40°C, and a water temperature response speed of the sensor is 2 ∿ 3 seconds.



Reversing thermometer attached with Nansen bottle in operation

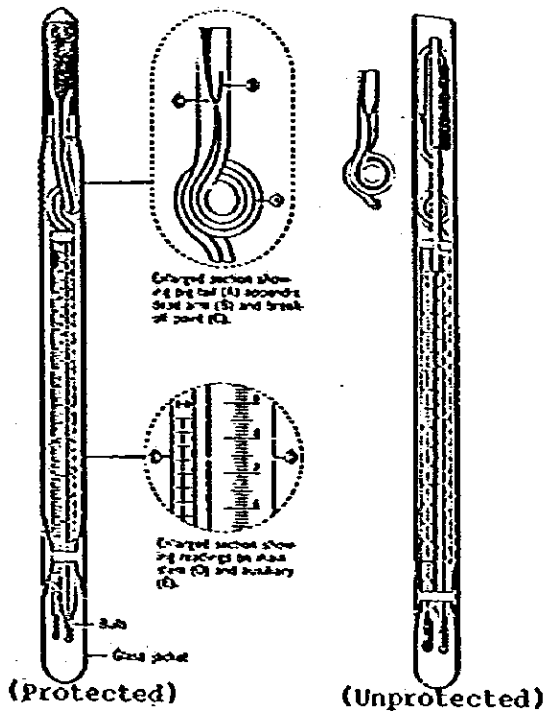
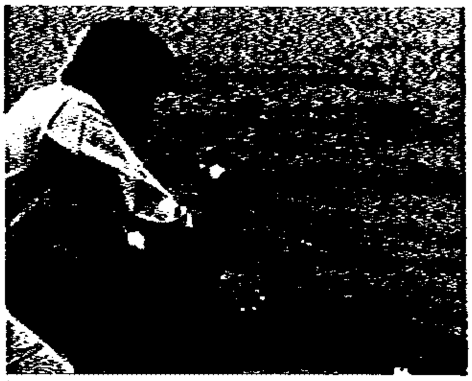
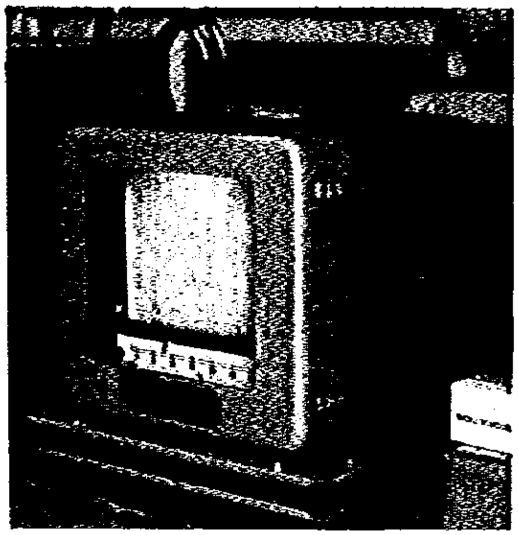


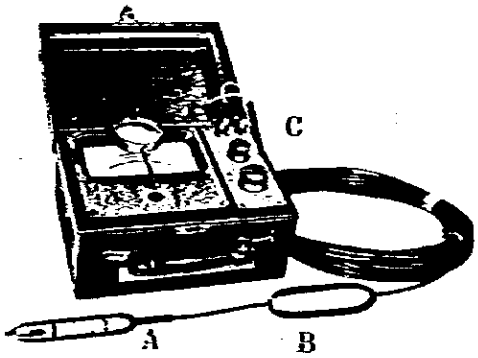
Fig. 4.16 REVERSING THERMOMETER



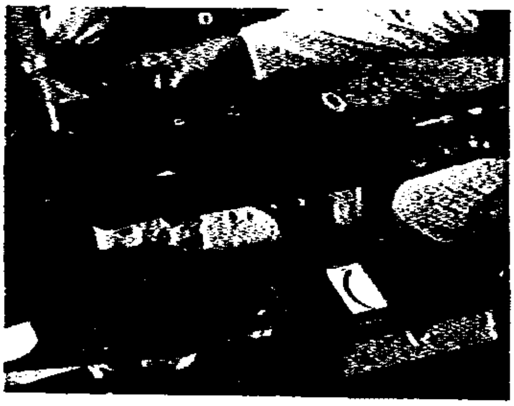
XBT launcher. Sensor probe is pushed out into the water. Sensor is connected by electric wire with Recorder



Recorder of XBT



Electric thermometer (ET-5)
A: Sensor B: Weight
C: Indicator



ET - 5 in operation on-deck

Fig. 4.17 THERMOMETER

(8) Seabed Photographing

Cameras used for the route survey are two types of cameras; a deep sea camera (Benthos, USA) and underwater camera (Nikon, Japan) (see Fig. 4.18). Photographs of the seabed were taken at a total of 12 points; one point in the Bengal Fan, 4 points of the 90°E Ridge, 5 points in the Great Passage, 1 point in the Sumatra Shelf Basin, and 1 point in the Sunda Shelf.

A diver took photographs of the seabed with the underwater camera at 5 points in the Colombo approach, but photographs could be taken only at 2 points, because the transparency of the water near the seabed surface was extremely low. The deep sea camera is a standard 35 mm deep sea camera system consisting of a camera, flashgun and pinger.

The flashgun illuminates the seabed with flash of a xenon tube, and supplies a shutter pulse and driving power for taking up a film to the camera. The camera consists of a film take-up, shutter, lens and data chamber. At each time when taking a photograph, power is supplied from the flashgun to the film driving motor, and a film is taken up by one frame.

The photographing distance and depth of focus are set by a knob on the lens shutter mount. A date, hour, minute and second of taking a photography, and the station No. are displayed.

The pinger emits a 12 kHz acoustic pulse, and the distance between the pinger and the seabed is found by recording a direct acoustic wave from the pinger and an acoustic wave reflected from the seabed with a receiver mounted aboard a survey ship, and measuring an interval between these two records.

Specifications of the deep sea camera are as follows.

Camera

Standard number of films of taking photographs	: 800 photos.
Film length	: 30.5 mm (100 ft)
Dimensions of case	
Length	: 64.3 cm
Diameter	: 12.5 cm
Weight	
In air	: 21.0 kg
In water	: 16.0 kg
Shutter speed	: 1/50 sec. ∿ 2/5 sec.
Power	: DC 28 ±5 V, 1 A; supplied from flashgun Model 382.

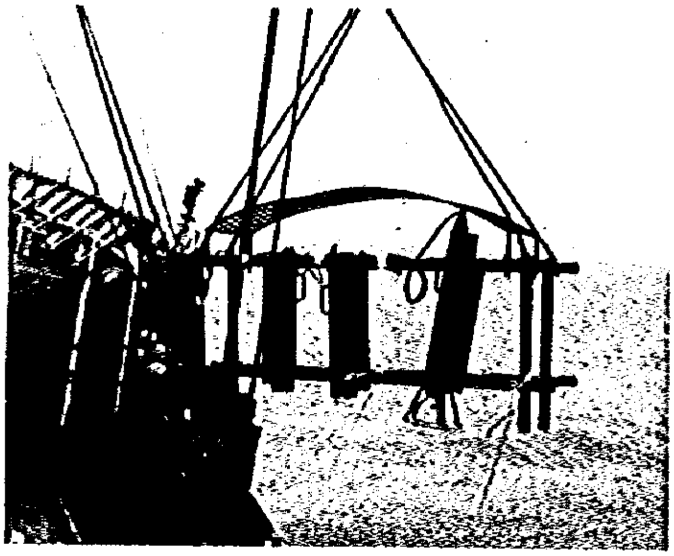
Flashgun

Flash bulb input	: 100 W/sec.
Number of flashing:	3,200 times when fully charged
Flash time	: 1/1000 sec.
Dimensions of case	
Total length	: 90.5 cm
Maximum diameter	: 21.0 cm
Weight	: 31 kg in air

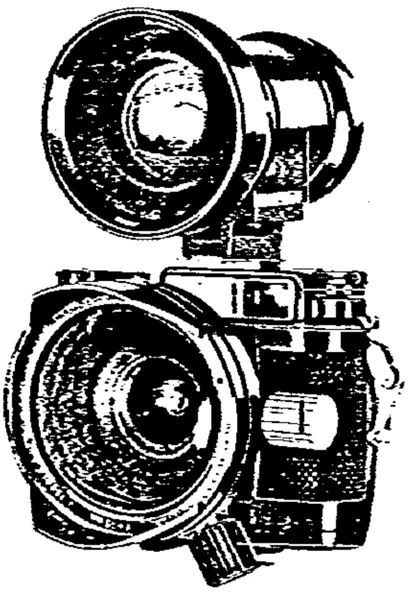
The underwater camera consists of an outer case, mechanical section and lens. The photographs were taken by divers.

Specifications of the underwater camera are as follows.

Film	:	35 mm film
Picture size	:	24 x 36 mm
Standard lens	:	15 mm, F 3.7
Range scale	:	$\infty \sim 0.3$ m
Picture angle	:	94°



Deep Sea Camera (Left: Pinger, Center: Camera, Right: Flash)



Underwater Camera

Fig. 4.18 CAMERAS FOR UNDERWATER PHOTOGRPHING

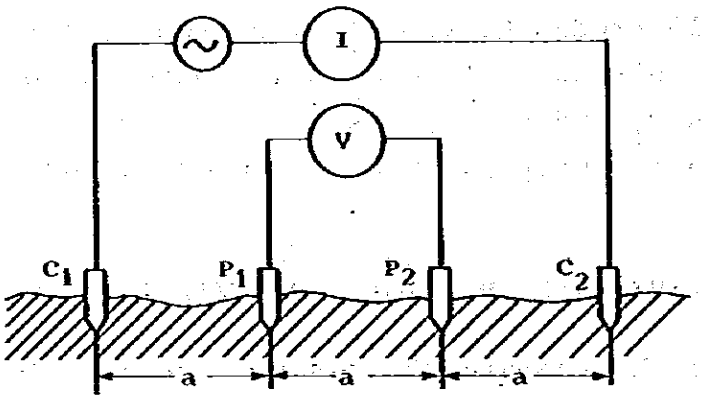
(9) Earth Resistivity (Geological Search by Wenner's Method)

There are several methods of measuring earth resistivities (specific earth resistances), most of which are variations of the method originally conceived by Wenner. In Wenner's four driven-rod electrode method, four electrical contacts are made with the ground by driving into the ground the metal spikes, called electrodes, C_1 P_1, P_2 and C_2 placed in a straight line at equal intervals of a (m). Between the current electrodes C_1 and C_2, a current I (A) is passed and the resulting voltage drop (V) between the potential electrodes P_1 and P_2 is measured. If the ground has a uniform resistivity ρ, an equation of measurement is attained:

$$\rho = 2\pi aV/I = 2\pi aR \ (\Omega \cdot m) \qquad R = V/I \ (\Omega)$$

where R is the resistance measured between the potential electrodes. The above equations are called Wenner's formula, which proved to be very practical in case the depth of driven electrodes is within 1/20 of the electrode interval separation a. Therefore, earth resistivity ρ can be calculated from the measured value of R.

The earth resistivity ρ in the Wenner's formula is constant irrespective of the electrode separation distance if the ground has a uniform structure. However, the ground is generally composed of more than one layer involving rocks of differing resistivity. Therefore, the resistivity calculated from the above formula will not refer to any specific rock or layer but will be a mean value of the individual resistivities of distributed rocks and layers. Such a measured value is called "apparent resistivity" which varies according to the electrode separation a and the position of the electrode system. By obtaining the relations between a and ρ with respect to a particular ground, it is possible to roughly conjecture geological structure, layer formation and location of underground water supplies. Standard and auxiliary curves showing the relation between a and ρ are available, and by placing upon them an a-ρ curve made from actual measurement, the approximate resistivity and depth of each layer involved may easily be obtained on the curve. The resistivity thus obtained is generally taken as a guide for elucidating the nature of the layer.



L-10 Type Specific Earth Resistance Tester M55401

(Yokogawa electric Works Ltd. Japan)

Specifications

Method of Measurement	: Wenner's four-electrode method
Operating Principle	: AC potentiometric system (free o polarization, and capable of direct reading of specific earth resistance)
Method of Power Supply	: Hand drive of generator
Measuring Range	: 0 - 0.3 / 3 / 30 / 300 Ω
Measuring Dial Scale	: 0 - 30 Ω, 1 Ω / div.
Multiplier Dial	: X0.01, X0.1, X1, X10

Accuracy :	±3% of indicated value in the scale range of 10 -30 Ω
	±1% of full scale value in the scale of less than 10 Ω
Output Voltage	: 350 V at more than 150 rpm
Measuring Frequency	: more than 65 Hz/s
Accessories	: 5 pcs. of earth spikes / as electrode with landwires

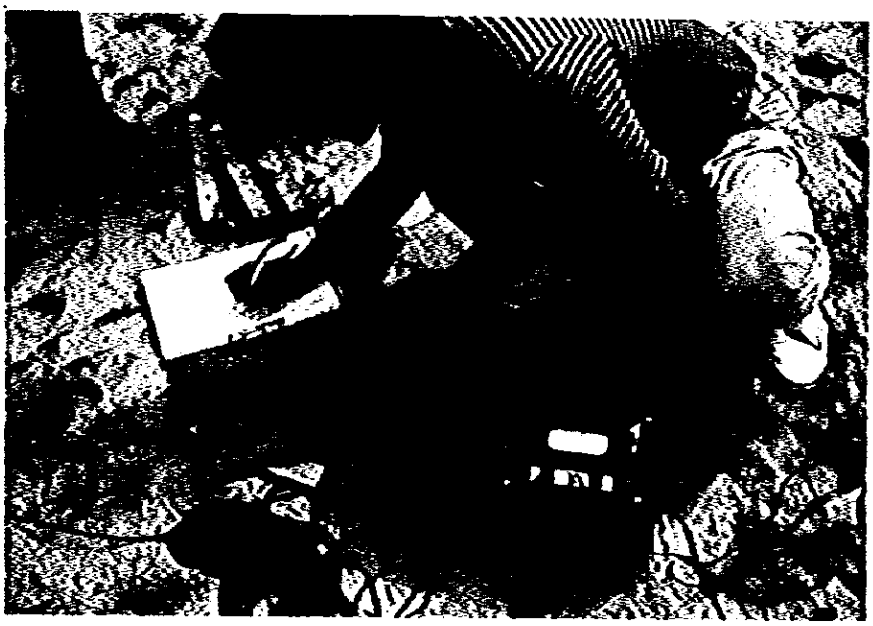


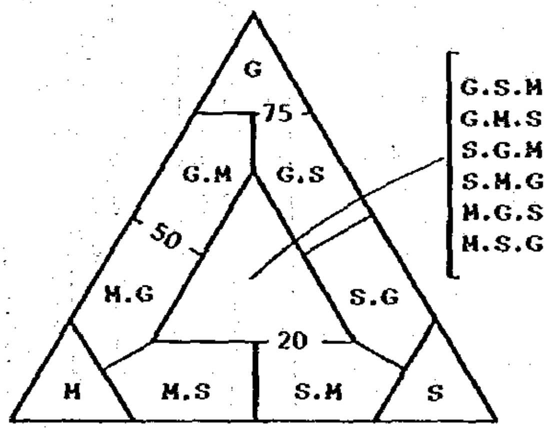
Fig. 4.19 Specific Earth Resistance Tester

Appendix 5

Mechanical Analysis of Bottom Samples

Bottom samples were analyzed in conformity with JIS (Japanese Industrial Standards) A-1204. The analysis results are given in Tables 5.1.

Classification of bottom materials was made according to a triangular diagram shown below.



G:	Gravel	SM:	muddy Sand
S:	Sand	MS:	sandy Mud
M:	Silt and Clay	fS:	fine Sand
		cS:	coarse Sand

Table 5.1 RESULTS OF MECHANICAL ANALYSIS (1/3)

No	Sampling in depth (m)	Area	Bottom Material	Mechanical Composition (%)			
				Clay	Silt	Sand	Gravel
M-1		S. S	f. S	2		98	0
M-2		〃	S. M	18	15	67	0
M-3		〃	S	8	6	85	1
M-4		〃	M. S	30	28	42	0
M-5		〃	f. S	10	7	83	0
M-6		〃	f. S	7	7	86	0
M-7		〃	S. M	24	17	58	1
M-8		〃	f. S	10	4	86	0
V-1	0 ~0.2	〃	S. M	14	16	65	5
	0.5 ~0.7		M	29	60	11	0
	1.0 ~1.2		M	35	63	2	0
P-1	0 ~0.2	〃	M	29	26	42	3
	0.3 ~0.5		M. S	60	23	17	0
	0.75~0.95		M	48	31	21	0
V-2	0 ~0.2	〃	S. M	12	23	60	5
	0.8 ~1.0		M	26	62	12	0
P-16	0 ~0.2	〃	S. M	14	32	52	0
	0.35~0.55		M	65	33	2	0
V-3	0 ~0.2	〃	f. S	10	14	73	4
	0.2 ~0.4		M. S	29	30	40	1
	0.8 ~1.0		M	56	41	2	1
P-2	0 ~0.2	〃	S. M	12	31	55	2
	0.5 ~0.68		M	10	83	7	0
P-3	0 ~0.05	〃	S. M	11	23	64	2
	0.25~0.37		M	60	39	1	0
P-4	0 ~0.2	〃	f. S	14	23	60	3
	0.3 ~0.48		M	61	36	3	0
P-5	0 ~0.2	〃	M. S	3	57	40	0
P-6	0 ~0.2	〃	f. S	6	8	86	0
P-7	0 ~0.2	〃	f. S	6	7	87	0
P-8	0 ~0.12	〃	S. M	7	18	75	0
	0 ~1.0	〃	M	58	36	6	0
P-9	0 ~0.05	〃	S. M	5	39	52	4

Table 5.1 RESULTS OF MECHANICAL ANALYSIS (2/3)

No	Sampling in depth (m)	Area	Bottom Material	Mechanical Composition (%)			
				Clay	Silt	Sand	Gravel
	0.2 ~0.43	S. S	M	62	34	4	0
P-10	0 ~0.11	〃	S. M	47	16	36	1
	0.11~0.22	〃	M. S	4	33	63	0
P-11	0 ~0.7	〃	M. S	15	52	33	0
P-12	0 ~0.15	〃	f. S	6	10	84	0
	0.5 ~0.7		M. S	14	46	38	2
P-13	0 ~0.2	S. B	M	76	22	2	0
	0.8 ~1.0		M	70	29	1	0
P-14	0 ~0.2	〃	M	73	26	1	0
	0.8 ~1.0		M	82	16	2	0
P-15	0 ~0.2	〃	M	79	18	3	0
	1.0 ~1.2		M	55	44	1	0
P-46		〃	M	55	44	1	0
P-42	0 ~0.29	G.	f. S	10	15	75	0
P-38	0 ~0.2	〃	M	39	37	24	0
	0.8 ~1.0		M. S	36	37	27	0
P-35	0 ~0.21	N.	M	66	33	1	0
P-34	0 ~0.2	〃	M	78	20	2	0
P-33	0 ~0.2	90' B	M	66	32	2	0
	0.7 ~0.92		M	75	21	4	0
P-32	0 ~0.2	〃	M	46	52	2	0
P-30	0 ~0.2	〃	M	55	31	14	0
P-27	0 ~0.2	〃	M	57	31	12	0
	0.6 ~0.8		M	69	23	8	0
P-25	0 ~0.35	〃	M	65	24	11	0
P-24	0 ~0.2	B.	M	69	25	6	0
	0.5 ~0.7		M	79	17	4	0
P-22		〃	M	81	16	3	0
P-17		C. C	M	30	48	21	1
V-5	0 ~0.2	C. S	f. S	7		90	3
	1.0 ~1.2		S	4	7	78	11
V-4	0 ~0.2	〃	f. S	5		94	1
	1.0 ~1.2		f. S	8		90	2

Table 5.1 RESULTS OF MECHANICAL ANAYSIS (3/3)

No	Sampling in depth (m)	Area	Bottom Material	Mechanical Composition (%)			
				Clay	Silt	Sand	Gravel
M-9		C. S	c. S	—	—	97	3
M-10		〃	c. S	—	—	94	6
M-11		〃	c. S	—	—	98	2
M-12		〃	c. S	—	—	99	1
M-13		〃	c. S	—	—	99	0
M-14		〃	c. S	—	—	98	0
M-15		〃	f. S	—	—	94	0

S. ……Sunda Shelf
S. B. …Sumatra Basin
G. ……Great Passage
N. ……Nicobar Fan
90° B…90° E Ridge
B. ……Bengal Fan
C. C. …Colombo Continental Slope
C. ………Colombo Continental Shelf

Appendix 6

Sounding Records of Submarine Canyons

With respect to the study on submarine canyons in the Bay of Bengal, a report by Curray et al. (1971) is available. In this report it is shown in detail that submarine canyons spread over the seabed reticulately. As a result of the route survey, it was found that the proposed cable route crosses submarine canyons at ten points. The locations of these ten points satisfactorily coincide with the survey results of Curray et al. (1971). (Fig. 6.1)

Profile records of these submarine canyons (recorded by the Raytheon 3.5 kHz Subbottom Profiler) are shown in Fig. 6.2 ~ 6.4. The width and depth of these submarine canyons are given in Table 6.1.

When conducting the route survey, we tried to collect data for checking whether turbidity currents are still flowing through the submarine canyons, and whether such currents give damage to a cable. For this purpose, a bottom material sampling and seabed photographing were made in the submarine canyon No.8, and a bottom material sampling was made in the largest submarine canyon No. 2.

As a result of analyzing sampled bottom materials, it was found that the material of the submarine canyon bed in extremely fine soft clay, and large-grain sediments indicating the existence of a strong current were not found at all. The photographs of submarine canyon beds (Photo No.1) show no ripple marks or the like indicating the existence of a fast current.

A definite evidence of the existence of currents flowing near the proposed cable route was not obtained as mentioned above, and even though such currents are present, it seems that such a fast current as to give damage to a cable is scarcely present.

Table 6.1 Submarine canyons on the proposed cable route

No.	Location	Width Between Shoulders (m)	Bottom Width (m)	Depth (m)	Development of Natural Levee
1	A/C 21 → A/C 22 158 km	3,100	1,800	22	Yes
2	A/C 21 → A/C 22 298 km	14,400 4,700	12,000 3,500	30 140	Yes
3	A/C 21 → A/C 22 414 km	1,500	-	12	Almost none
4	A/C 21 → A/C 23 48 km	1,800	-	10	Almost none
5	A/C 22 → A/C 23 169 km	3,200	-	5-10	Yes
6	A/C 22 → A/C 23 200 km	2,600 900	2,400 700	10 45	Yes
7	A/C 22 → A/C 23 259 km	3,000	1,700	40	None
8	A/C 22 → A/C 23 310 km	2,300	-	32	Yes
9	A/C 22 → A/C 23 395 km	650	-	10	None
10	A/C 23 → A/C 24 17 km	1,400	-	10	None

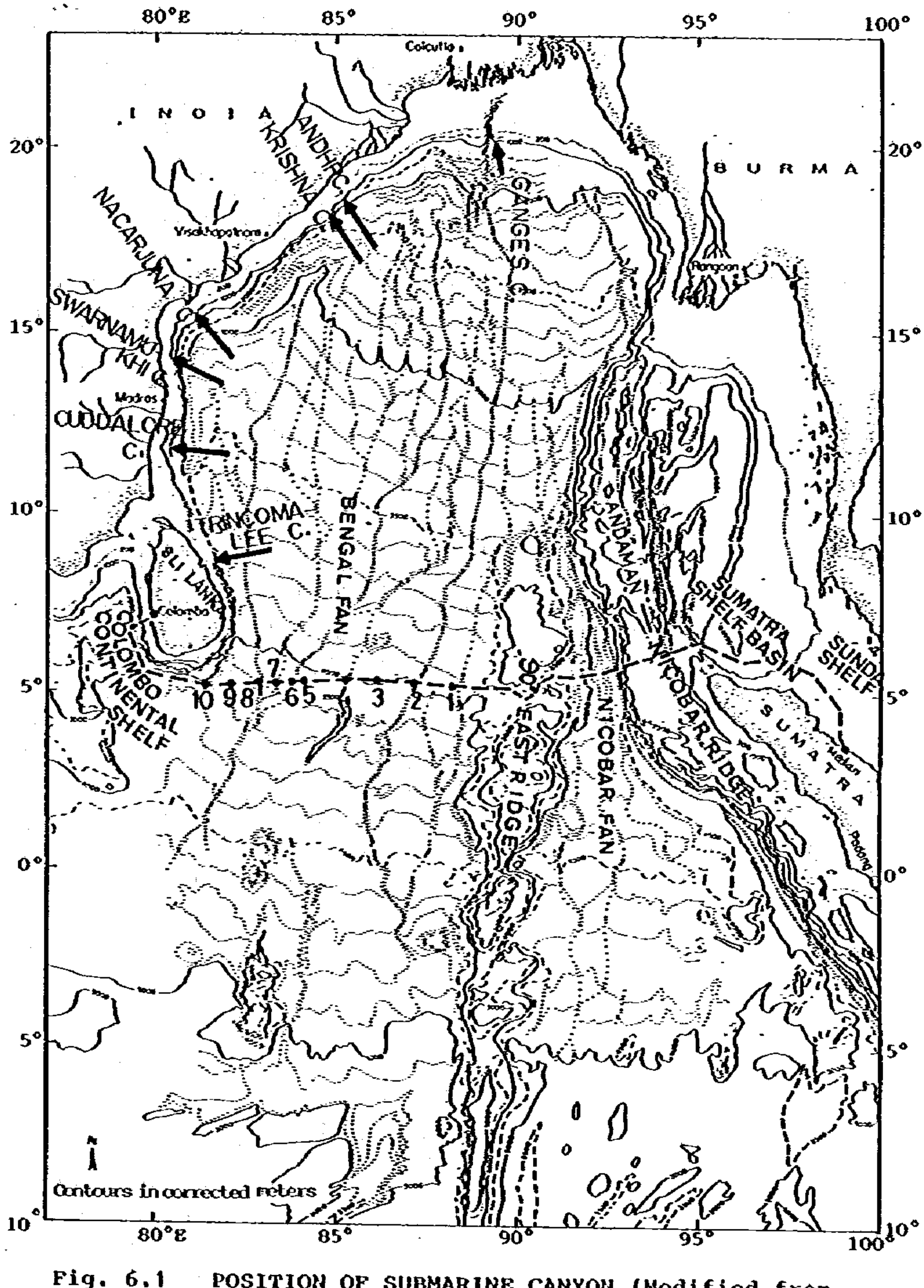
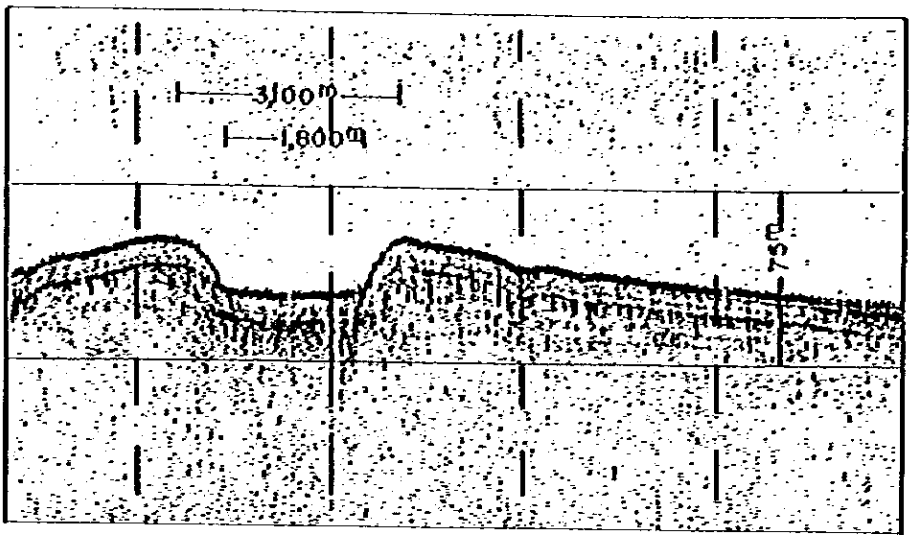
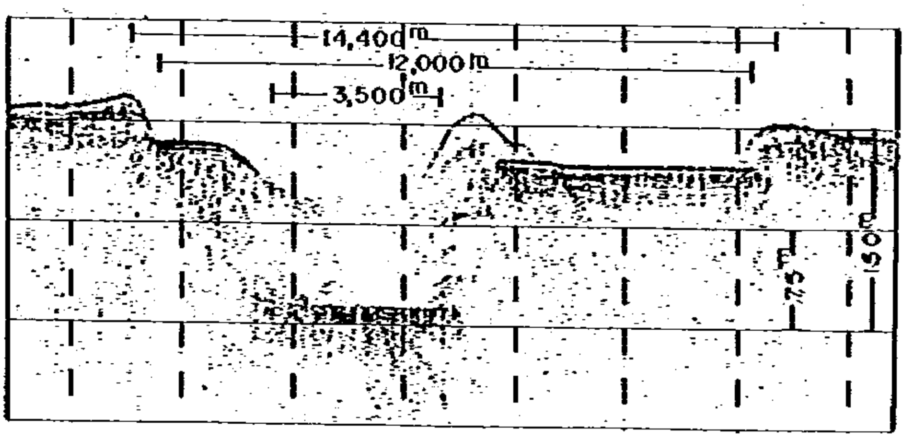


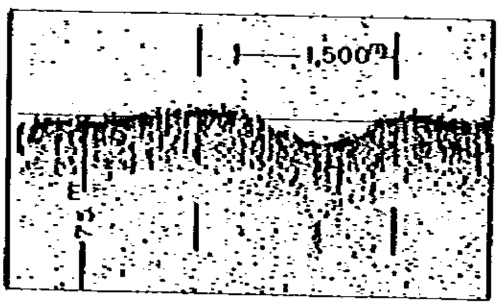
Fig. 6.1 POSITION OF SUBMARINE CANYON (Modified from Curray, 1971)



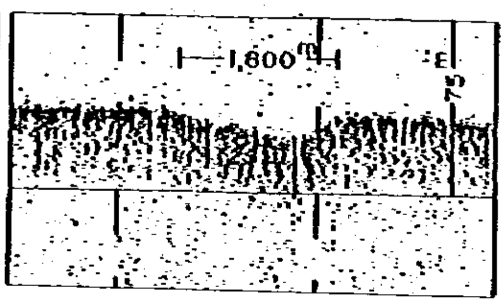
Submarine Canyon No.1



Submarine Canyon No,2

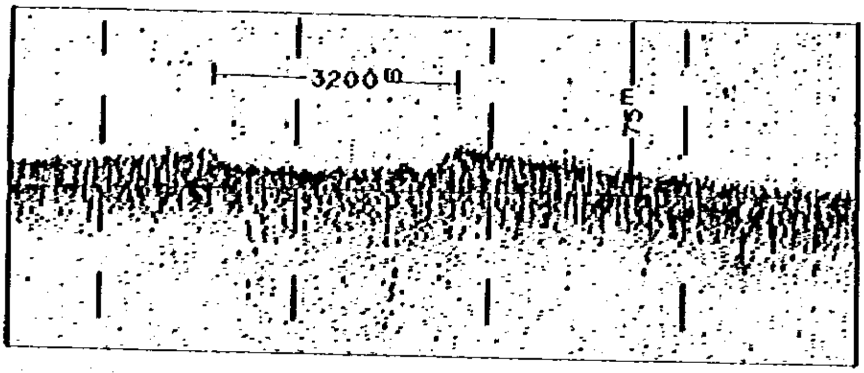


Submarine Canyon No.3

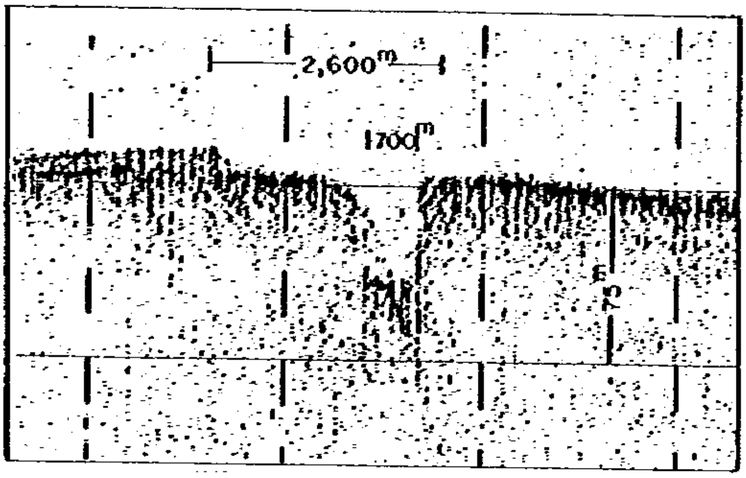


Submarine Canyon No.4

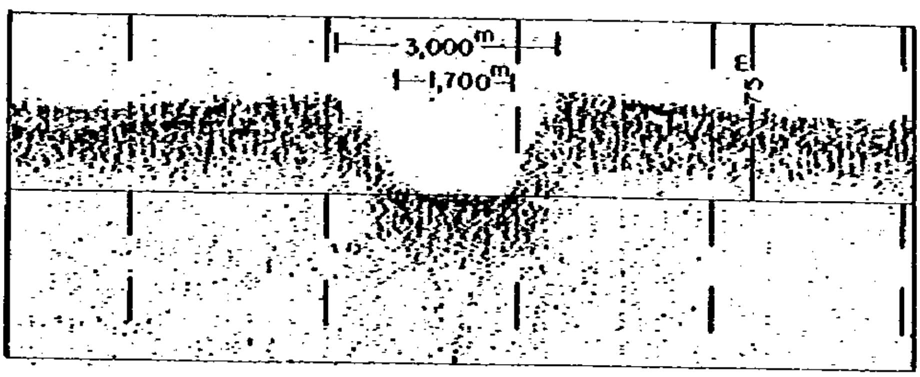
Fig. 6.2 PROFILE RECORDS OF SUBMARINE CANYONS (Recorded by the Raytheon 3.5 kc Subbottom Profiler)



Submarine Canyon No.5

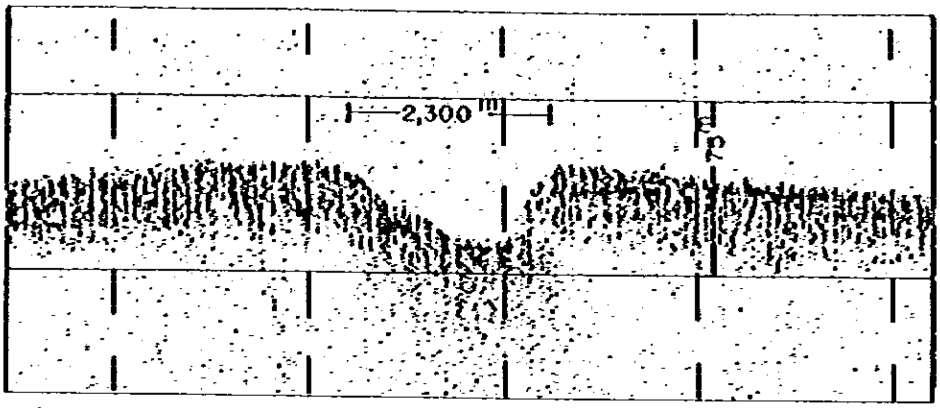


Submarine Canyon No.6

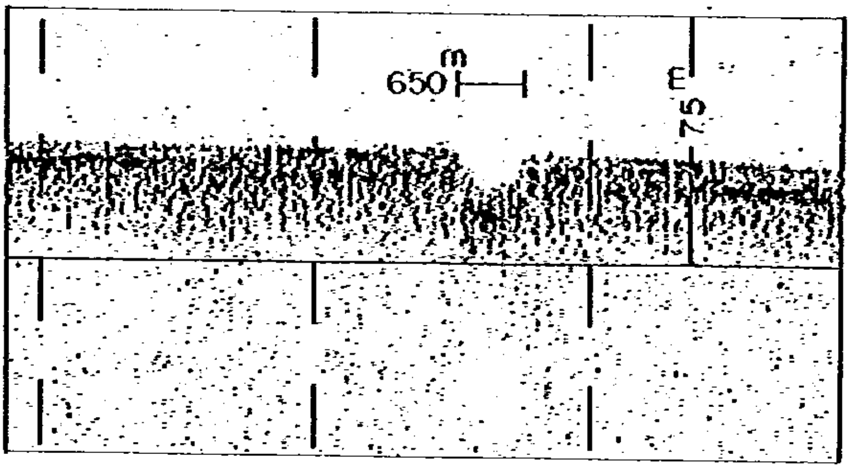


Submarine Canyon No.7

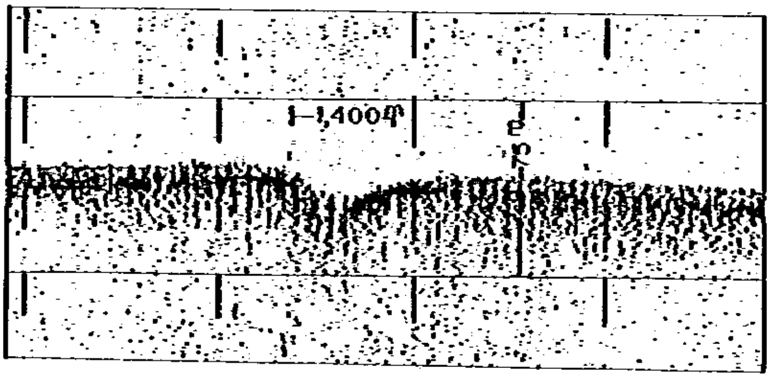
Fig. 6.3 PROFILE RECORDS OF SUBMARINE CANYONS (Recorded by the Raytheon 3.5 kc Subbottom Profiler)



Submarine Canyon No.8



Submarine Canyon No.9



Submarine Canyon No.10

Fig. 6.4 PROFILE RECORDS OF SUBMARINE CANYONS (Recorded by the Raytheon 3.5 kc Subbottom Profiler)