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U. S. NAVAL TECHNICAL MISSION TO JAPAN
CARE OF FLEET POST OFFICE
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14 December 1945.

RESTRICTED

From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Japanese Sonar and Asdic.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, covering Target E-10 of Fascicle E-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Lieut. E. E. Schwalm, USNR, Lieut. A. A. Lang, USNR, J. W. Lealy, CRE, USN, Lt. Comdr. T. V. Lavarack, RNVR, and Lt.(jg) S. H. Kadish, USNR, interpreter and translator.

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JAPANESE SONAR AND ASDIC

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945
FASCICLE E-1, TARGET E-10

DECEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ELECTRONICS TARGETS

JAPANESE SONAR AND ASDIC

The Japanese devoted many years prior to entry into the war to research and development of sonar equipment, notably hydrophones. The emphasis which was placed on sonar devices, both offensive and defensive weapons, is clearly shown by the lavish and often unnecessary amount of spaces allocated to them in the otherwise cramped quarters of Japanese ships. At sea it was customary to man the hydrophone set continuously and to operate the echoranging set at least fifteen minutes in every hour. The reliance placed on sonar apparatus even in the last months of the war is exemplified by the memorandum, dated April 1945, included as an appendix to the report.

Sonar would appear to represent one of the few fields in which generous use was made of German assistance. The influence of captured British equipment is much in evidence, notably in the adoption of the streamlined sound dome and the chemical recorder. The eventual shortage of chemically prepared paper restricted the use of the latter, but it is interesting to note that little attempt was made, in any event, to use the attack computation instruments fitted, and that they were omitted from later models.

The total lack of any advanced attack technique, and of specially designed attack instruments, is surprising in view of attention paid to the development of the detection devices themselves.

During the war a mass-production type of both hydrophone and echo-ranging equipment was evolved, each based on German designs, with the latter being virtually a direct copy. In addition, certain special application sets were developed, some previous to the war, and paramount among these was the successful underwater radio reception equipment using ultra-long waves. Operational messages were being passed by this system immediately prior to the attack on Pearl Harbor.

Anti-sonar measures were confined principally to the development of a sound-absorbing paint which was in operational use on all submarines at the end of the war. Considerable attention was given to methods for reducing "own ship's noise" both as an aid to listening devices and in reducing the chances of detection by enemy equipment.

Research carried out by the Army in underwater sound, with special reference to harbor defense, appeared to have been largely independent, as were Hydrographic Department surveys having specific reference to sonar water conditions.

TABLE OF CONTENTS

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INTRODUCTION

The major portion of the data for this investigation was obtained from the designers of both hydrophone and echo-ranging apparatus, and from subsequent inspection of typical installations and interrogation of personnel in charge of their operation and maintenance.

Additional information has been forthcoming from the superficial examination of various documents that have been discovered; those which are relevant to the subject matter of any part are listed at the end of that part. These documents have not been translated, but will be available, if required for reference, at the Washington Document Center.

REFERENCES

Activites and Targets Investigated:

Acoustic Department of Second Naval Technical Institute Located at NUMAZU.

Third Section (acoustic research) of Seventh Military Laboratory located at ITO.

Kure Naval Yard.

Yokosuka Naval Yard.

Japanese Personnel Interrogated:

Rear-Admiral T. MIYAZAWA, IJN, - Chief of Naval acoustical research in general.

Captain T. KUYAMA, IJN, - In charge of research at NUMAZU in Under water Listening Devices.

Civilian Technician G. SAITO - Echo-ranging Devices (NUMAZU).

Lt. Colonel J. ICHIKAWA, IJA, - In charge of Ito Laboratories.

Major T. YAMANAKA, IJA, - Senior Scientist on underwater sound at Ito Laboratories.

Comdr. J. OHNO, IJN, - Electronics Maintenance Officer at KURE.

Comdr. H. YAMANAKA, IJN, - Sonar Engineer at KURE.

Captain I. MATSUMOTO, IJN, - In charge of sound-absorption techniques at KURE.

THE REPORT

Part I

HYDROPHONE EQUIPMENTS

A. TYPES

Many types of hydrophone equipment had been produced in the past, but those now in use fall into four main classifications: The Types 93 and "O", with which Japan entered the war; the Type 4 series with Rochelle Salt units on the German system and first produced in 1944; the Type 3, developed during the war for use in merchant ships; and the "Simple" series, designed for small craft. A description of each type in use is as follows:

1. Type 93 (Figure 1) - Equipped with 16 units in two elliptical arrays, manually operated compensator with bearing repeator on bridge.

2. Type "O" (Figure 1) - Substantially similar, but with 30 units in double ellipse array.

3. Type 4, Model 1 (Figures 2 and 3) - Uses 80 Rochelle Salt units in complex circle arrays.

4. Type 4, Model 2 (Figures 2 and 3) - Represents identical equipment, but only 40 units fitted and connected. Designed for submarines.

5. Type 3, Series (Figure 2) - Installed in merchant ships, three models being available with 12, 15 or 24 units in simple circle array. Type 1 and 2 represent the only equipments of any type fitted with remote electrical control of compensator. The phasing panel is unique in also incorporating a loudspeaker.

6. "Simple" Series - KANISHIKI - The only type to use an external sound dome, in which are assembled 12 units in a single circle.

7. "Simple" Series - JUJIGATA - Battery-operated and readily portable. Four units arranged in a simple cross. Extensively used in fishing boats.

8. "Simple" Series - TANSHIKI - Constitutes a simple battery receiver and single moving coil hydrophone unit lowered over the side of fishing craft.

B. BEARING DETERMINATION SYSTEM

With the exception of two models in the "Simple" series which use four or less units, all types depend on electrical phasing of a multiple unit array to provide bearing indication.

Sound waves arriving at the position of a multiple unit array will cause the individual e.m.f's generated to be displaced in phase according to the relative position of each unit to the wave fronts of the incoming sound. If, by use of delay networks, these e.m.f's are shifted into phase, the particular combination necessary will correspond to the direction from which the sound emanated, any change in this direction necessitating a different combination. These combinations are achieved by the use of a complex switching device consisting of a number of fixed contact-bars set parallel to each other, over which is rotated a circular plate in which are mounted a number of carbon

LEGEND*			
1	HYDROPHONE ARRAY	2	WATERTIGHT JUNCTION BOX
3	HYDROPHONE SWITCH BOX	4	COMPENSATOR (PHASING) PANEL
5	AMPLIFIER	6	BAND PASS FILTER
7	HEADPHONES	8	LOUDSPEAKER
9	BEARING REPEATER	10	REMOTE BEARING CONTROL
11	POWER TRANSFORMER	12	POWER RECTIFIER
13	POWER RESISTOR	14	POWER FILTER
15	BATTERY CHARGING PANEL	16/A	6 V/50V BATTERIES (Not shown)

*Legend also applies to Figure 2

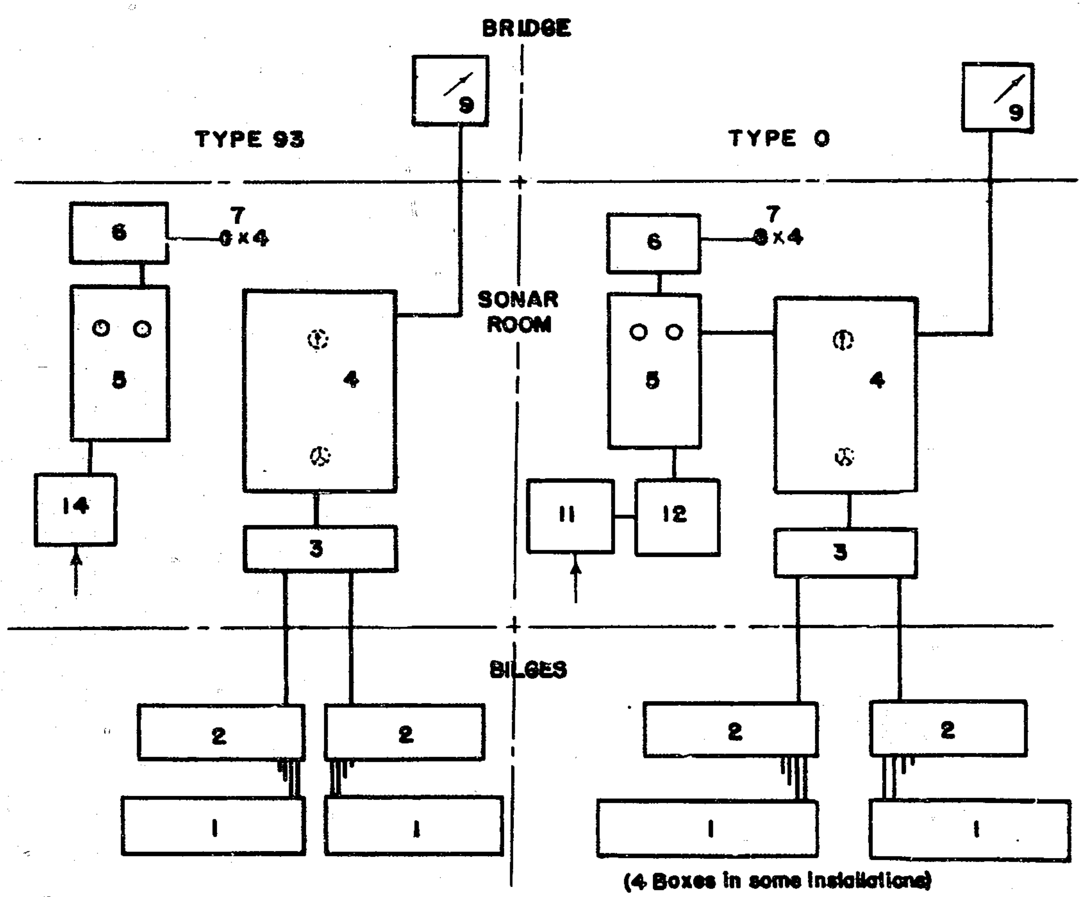


Figure 1

BLOCK DIAGRAMS OF TYPE 93 AND TYPE O HYDROPHONES

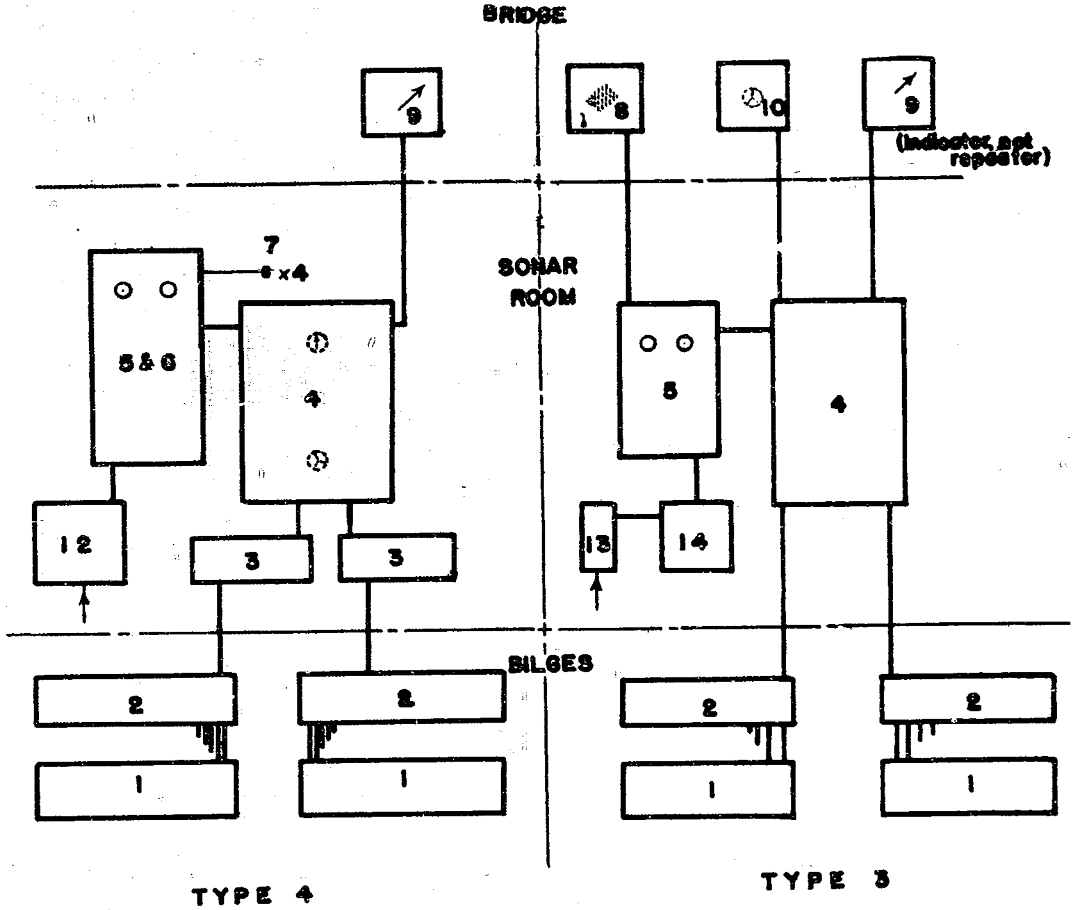


Figure 2

BLOCK DIAGRAMS OF TYPE 4 AND TYPE 3 HYDROPHONES

(See legend on Figure 1)

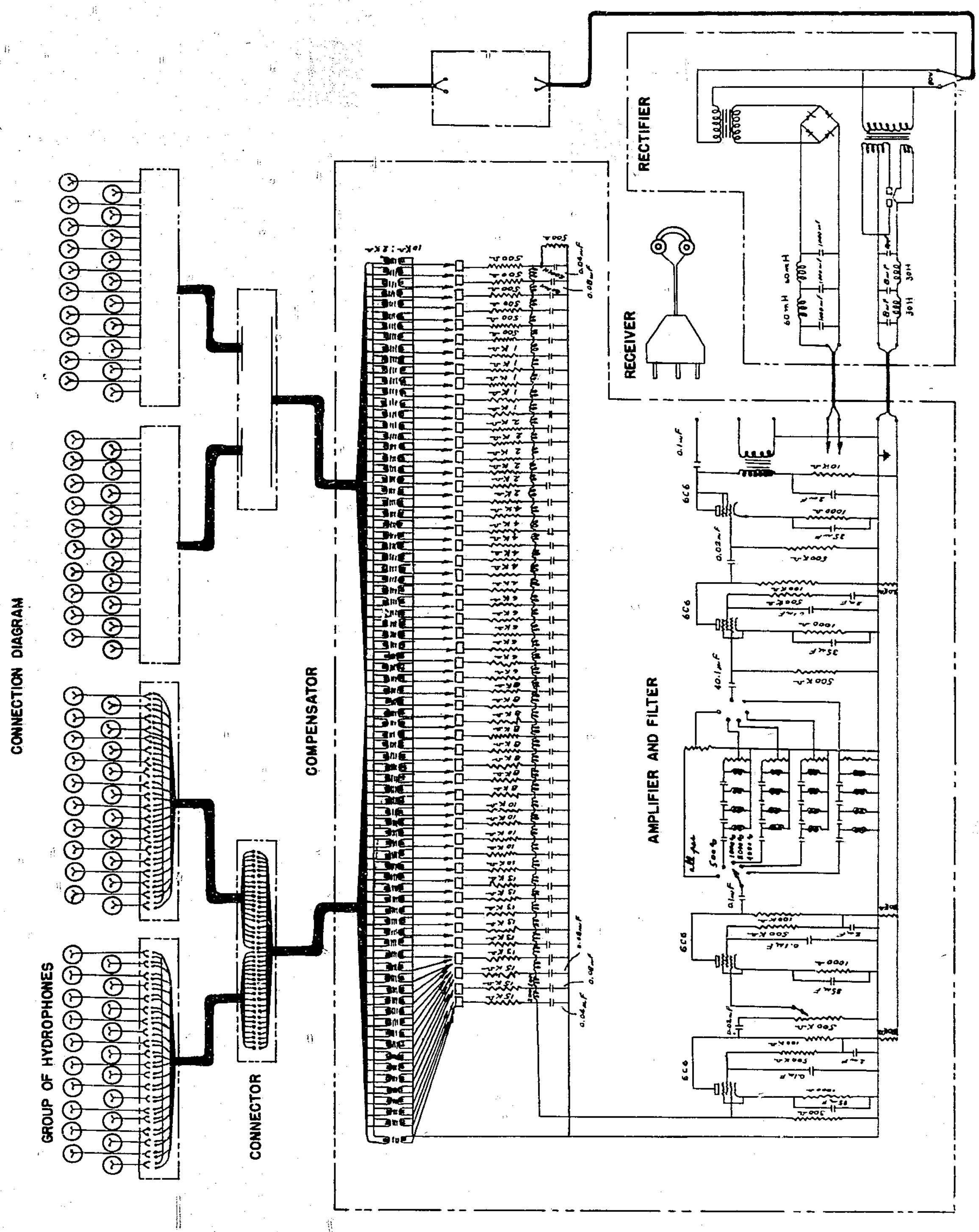


Figure 3
TYPE 4 HYDROPHONE SET

brushes. In this manner, the position of the switch necessary to correct phase displacement is readily converted into bearing angle.

C. MAXIMUM RANGES ACHIEVED

The results achieved with the Type 4, the most efficient equipment in use, was stated to be 1000 meters for a slow moving submerged submarine, and 6000 meters for a torpedo, the ship proceeding at 12 knots in either case. Relevant technical data is set forth in Tables I and II. Additional information may be obtained from reference to the seized documents ND21-6215, ND22-3010, and ND22-3011, which will be available at WDC. (See Enclosure A)

Table I

PRODUCTION DATA HYDROPHONE EQUIPMENT

Type	Model	Research		Quantity		Gross Weight (Kg)	Remarks
		Start	Finish	Made	Fitted		
93		1930	1935	600	500	1000	Battleships, Destroyers
0		1936	1938	80	60	1800	Battleships, Destroyers
4	1	1943	1944	100	20	1600	Destroyers
4	2	1944	1945	20	2	800	Submarines
3	1	1942	1943	1000	300	300	Merchant Ships
3	2	1942	1943	200	20	400	
3	3	1942	1943	1000	100	300	
"Simple"	KANI-SHIKI	1942	1943	100	80	500	Small Craft

Part II

RANGING EQUIPMENTS

Echo-ranging equipments fall into three main categories: the Type 93 series, with which Japan entered the war; the Type 3 series, which is the direct adaption of the German 'S' Set; and the semi-portable "Simple" series, developed during the war for use in small craft.

A. TYPE 93 SERIES

The manufacture of this series ceased in July 1944, when the Type 3 was introduced on a mass production basis. Existing sets remained in use, many being later converted to Type 3. Research was commenced in 1931 and the first model was produced two years later.

1. Transmitting Panel - All transmitters were based on the Hartley oscillator circuit, the output varying from 1.7 to 2.5 kw according to the model. Pulse repetition was automatic at 2, 4, or 8 second intervals with alternative lengths of 50, 100 or 200 milliseconds.

2. Projector - The same unit was used for transmission and reception, and was retractable within a circular section trunk which could then be sealed off with a sluice valve. All models except one had quartz projectors; the exception being Model 6 fitted with magneto-striction type said to have increased the range at 12 knots (the highest normal operating speed) from 1500 to 2000 meters. The raise-lower system was electro-hydraulic, the

Table II

TABLE OF UNDERWATER SOUND LISTENING DEVICES

Part I - Hydrophones

Model	Ships Fitted	Arrangement						Type					
		No.	Pattern	Dimensions (m)	Accuracy of Angle (approx.)	Background Noise (approx.)	Where Located	Principle	Membrane Dia. (mm)	Weight (kg)	Sensibility (db)*	Freq. Range (~)	When to Depth Charge**
93	BB A/S Boat Sub Merchant	16	Ellipse	Major Axis 3	5°	50%	Side inst.	Moving Coil type	145	18	35	500 - 2500	35 Meters
0	BB Merchant	30	Double Ellipse	Major Axis 4	3°	30%	Side inst.	Moving Coil type	145	18	35	500 - 2500	35 Meters
97	CD (non ship)	13	Single Circ.	Dia. 3	5°	50%	Sea Bottom	Moving Coil type	145	18	35	500 - 2500	35 Meters
1	CD (non ship)	10	Single Circ.	Dia. 1	10°	50%	Sea Bottom	Moving Coil type	105	20	35	500 - 3500	
Simple Type	Small Boat Special Service	12	Single Circ.	Dia. 0.6	30°	50%	Stream Lined Dome Inst.	Rochelle Salt Type	100	6	40	800 - 4000	20 Meters
4	DD	80	Complex Circ.	Max. Dia. 3 (2 L.)(1 S.)	3°	15%	Bottom Inst.	Rochelle Salt Type	100	6	40	800 - 4000	20 Meters
4 T. 2	Sub	40	Triple Elip.	Major Axis	10°	10%	Side Inst.	Rochelle Salt Type	100	6	40	800 - 4000	20 Meters
3 T. 1	Merchant	12	Single Circ.	Dia. 1.5	10°	40%	Tank Inst.	Carbon Type	45	0.9	55	200 - 1500	
3 T. 2	Merchant	24	Single Circ.	Dia. 3.0	5°	30%	Tank Inst.	Carbon Type	45	0.9	55	200 - 1500	
3 T. 3	Merchant	15	Single Circ.	Dia. 1.4	20°	30%	Tank Inst.	Carbon Type	45	0.9	55	200 - 1500	

* 0 db = 1 μv/bar

** (T.N.T. 100kg)

Table II

TABLE OF UNDERWATER SOUND LISTENING DEVICES

Part II - Listening Devices

Model	Ships Fitted	Compensator										
		Control System	Retardation Net							Microphone Brush Span	Equal. Resist. (K Ω)	Bearing Repeater Device
			Type	Ret Time (μS)	Element No.	L. (mH)	C. (μF)	M. (mH)	ZO (Ω)			
93	BB A/S Boat Submarine Merchant	Contact Bar Grating	T	2000	50	80	0.02	6.64	2000	1/15	2-15.5	have
0	BB Merchant	Contact Bar Grating	T	2700	90	20	0.06		1000	1/13.6	0.5-7	have
97	CD (non ship)	Contact Bar Grating	T	2000	50	80	0.02	6.64	2000	1/15	2~11.5	no
1	CD (non ship)	Contact Bar Grating	T	666	34	80	0.02		2000	1/10		no
Simple Type	Small Boat Special Service	Circular Contact Bar	T	400	12	10	0.02		500			no
4	DD	Contact Bar Grating	T	2000	50	40	0.04		500		0.5-15	have
4 T. 2	Sub	Contact Bar Grating	T	1200	30	40	0.04		500	1/12.5	0.5-18	no
3 T. 1	Merchant	Automatic Relay Switch	T	1000								no
3 T. 2	Merchant	Automatic Relay Switch	T	2000								no
3 T. 3	Merchant	Contact Bar Grating	T	960	24	80	0.02		2000			no

Table II

TABLE OF UNDERWATER SOUND LISTENING DEVICES

Part III - Listening Devices (cont.) and Other Apparatus

Model	Ships Fitted	Listening Device									Other Apparatus	
		Amplifier			Filter (H.P.)		Receiver		Electric Source		Connection Box	Switch
		Type	Valve in Use (m)	Amplification (db)	Cut off Freq. (~) A.P.	Cut off Freq. (~) L.P.	Type	No.	Kind (V)	Rectifier		
93	BB A/S Boat Sub Merchant	3-stage Resistance Coup.	UZ 606 X 3 (UZ77)	85 - 90	500. 700 1200. 1700	700. 900 1200. 3000	Moving Iron	4	D.C. 100 D.C. 220 (for) (Ω)		2	1
0	BB Merchant	4-stage Resistance Coup.	UZ 6301 X 1 UZ 606 X 3	90 - 95 100	500. 700 1200. 1500	700. 900 1500. 3000	Moving Iron	4	A.C. 100	Plate K X 80 Fil. Selen	4	1
97	CD (non ship)	3-stage	UZ 606 X 1 UZ 89 X 1	95	550. 770 1000. 1200 1500.	900. 1400 1700. 2000	Moving Iron	4	D.C. 200 D.C. 6	Secondary Battery	Sulphurite Connection	1
1	CD (non ship)	3-stage	UZ 606 X 1 UZ 89 X 1	95	1000. 2200		Moving Iron	4	D.C. 200 D.C. 6	Secondary Battery	Sulphurite Connection	1
Simple Type	Small Boat Special Service	3-stage	UZ 606 X 3	90	500. 1000 1500.		Moving Iron	4	D.C. 100		1	
4	DD	4-stage	UZ 606 X 4	90 - 95 100	500. 1000 2000. 4000		Moving Iron Moving Coil	2 2	A.C. 50 D.C. 200	Plate X - 80 Fil. Selen	2	2
4 T. 2	Sub.	4-stage	UZ 606 X 4	90 100	500. 1000 2000. 4000		Moving Iron Moving Coil	2 2	D.C. 50 D.C. 200	Plate X - 80 Fil. Selen	1	1
3 T. 1	Merchant	3-stage	12 ZRI X 1 12 ZPI X 2	60			Moving Iron		D.C. 100 D.C. 4.5		1	
3 T. 2	Merchant	3-stage	12 ZRI X 1 12 ZPI X 2	60			Moving Iron		D.C. 100 D.C. 4.5		2	
3 T. 3	Merchant	3-stage	U X 111BX1	20	700.		Moving Iron		D.C. 22.5 D.C. 1.5 4.5			

same system being used for the training, the control valves for which were remotely operated from the Sonar Room through a mechanical rod arrangement.

3. Sound Dome - Domes of British design were later fitted to all models, but were non-retractable.

4. Receiver - A conventional straight heterodyne amplifier was used in all models, tunable over 16-31 kc, and with a gain of 120 db.

5. Range Indication - A simple form of instrument was fitted on which the range was indicated by a pointer traversing a circular scale, in conjunction with echo response in the headphones. Available ranges were 1500, 3000. and 6000 meters.

6. Attack Instruments - No special instruments were incorporated, bridge instruments being indicated on block diagram contained in Figure 4.

B. TYPE 3 SERIES

Development of this series commenced in 1942, following the arrival of German technicians with complete plans and specifications of the equivalent German model. With the exception of Model 6, completed in March 1945, all models were produced in the previous year and a total of 800 sets were eventually manufactured. Schematic diagrams of Models 2, 3, and 4, mainly installed in destroyers, merchant ships, and submarines respectively, are contained in Enclosures (A), (B), and (C).

1. Transmitting Panel - Usual oscillator circuits were employed, a high-frequency generator being later developed for Model 2, as an alternative, in April 1945. Output capacities varied from 250 watts to 2.5 kw according to the model. Pulsing was controlled automatically from the range indicators, alternative length being available, except in Model 4.

2. Projector - Magneto-striction projectors were used for all models. Model 1 incorporated two separate 14.5 kc projectors set at a 60° angle to each other and a separate 13 kc projector with independent control and reception gear. Other models utilized the split-type projector consisting of two separate magneto-striction units. The units were mounted side by side and used together for transmission, and independently for reception. Frequencies varied from 13 to 20 kc according to the model. All units were polarized from an exciter panel and filter junction box. Manual training by a mechanical system was employed for all models except Model 4, which was fitted with an electrical system, and Model 2, which was alternative.

3. Sound Dome - Sound domes after the British pattern were fitted to Models 1, 2 and 3, the dome for Model 1 being retractable in conjunction with an electro-mechanical system, and the other two models, non-retractable.

4. Receiver - Double channel straight-heterodyne amplifiers of approximately 120 db gain, utilized for all models except Model 1, incorporated 3 projectors. Band-pass tuning was used only on Model 1 and early Model 2 sets.

5. Recorder - Chemical recorders are fitted only in the case of Model 1 as standard, in which two are provided. These represent an almost identical copy of the British type A/S 14, the separate drives required being taken from a common control box situated beneath. Use has also been made of the British Type A/S 3, incorporating self-contained drive, but it is not standard. (Figure 5 illustrates two recorders of the first type.)

6. Range and Bearing Indication - The principles on which bearing indication is obtained are as follows:

When an echo is received by the twin elements of the projector, the e.m.f generated by each is vectorially added and subtracted, the two resultant e.m.f's being then amplified and shifted into phase by the phaseshifter circuits. When applied to the plates of a C.R. Tube, an image is produced and the relation between visual angle of the image (ϕ) and the angle (θ) subtended by the direction of the object and the normal to the surface of the projector, is given by the formula:

$$\phi = \frac{\pi d}{\lambda}\theta$$

Where d = the distance between the centers of the twin units
λ = the wave-length transmitted

Range indication is given either by electrostatic sweep of the C.R. tube screen or by a mechanical system comprising an oscillating mirror and scale. The latter system was standard in German prototypes and the method by which an illuminated scale is observed through a semi-transparent mirror produces very little strain on the operator. Two or more ranges are available except in Model 4 which has a 4000 meter range only. In models 5 and 6, the scale is made logarithmic in place of linear.

7. Attack Instruments - No attack instruments are fitted and those normally used with British type recorders are omitted from Japanese designs. A second C.R. tube is fitted on the bridge in some installations.

8. Calibration Device - In the Model 4, a small 20 RC projector and associated oscillator transmitting equipment is installed for calibration purposes. The projector is fitted 3 to 10 meters forward of the main projector according to the class of submarine.

C. "SIMPLE" SERIES

Development was commenced in 1942 and completed the same year. The set was designed to be semi-portable, easily installed, battery-operated and suitable for small craft.

1. Transmitting Panel - The condenser-discharge method is used, the condenser being permanently in series with a limiting resistance, connected to a 2000 v. DC rotary-convertor and directly across the projector on discharge. Pulsing is automatic from the range recorder.

2. Amplifier - A magneto-striction 14.5 kc amplifier is attached to a shaft which may either pierce the hull in the usual manner or be suspended from the side of the craft. Training is achieved by a chain and rod system in Model 1 and by a flexible shaft drive in later models.

3. Receiver - A straight heterodyne receiver supplied from a separate power panel is used with band-pass tuning and gain of 120 db.

4. Recorder - A chemical type recorder was used, based on the British Type A/S 3, with alternative ranges of 1000 and 2500 meters.

Technical data with respect to all types and models is contained in Table III.

Additional information relating to echo-ranging equipments and an account of the state of research at the outbreak of the World War are contained in the following documents which will be available from WDC: ND21-6212, ND21-6239, ND22-3010, ND22-3011, ND22-3013, and ND22-3014. (See Enclosure A)

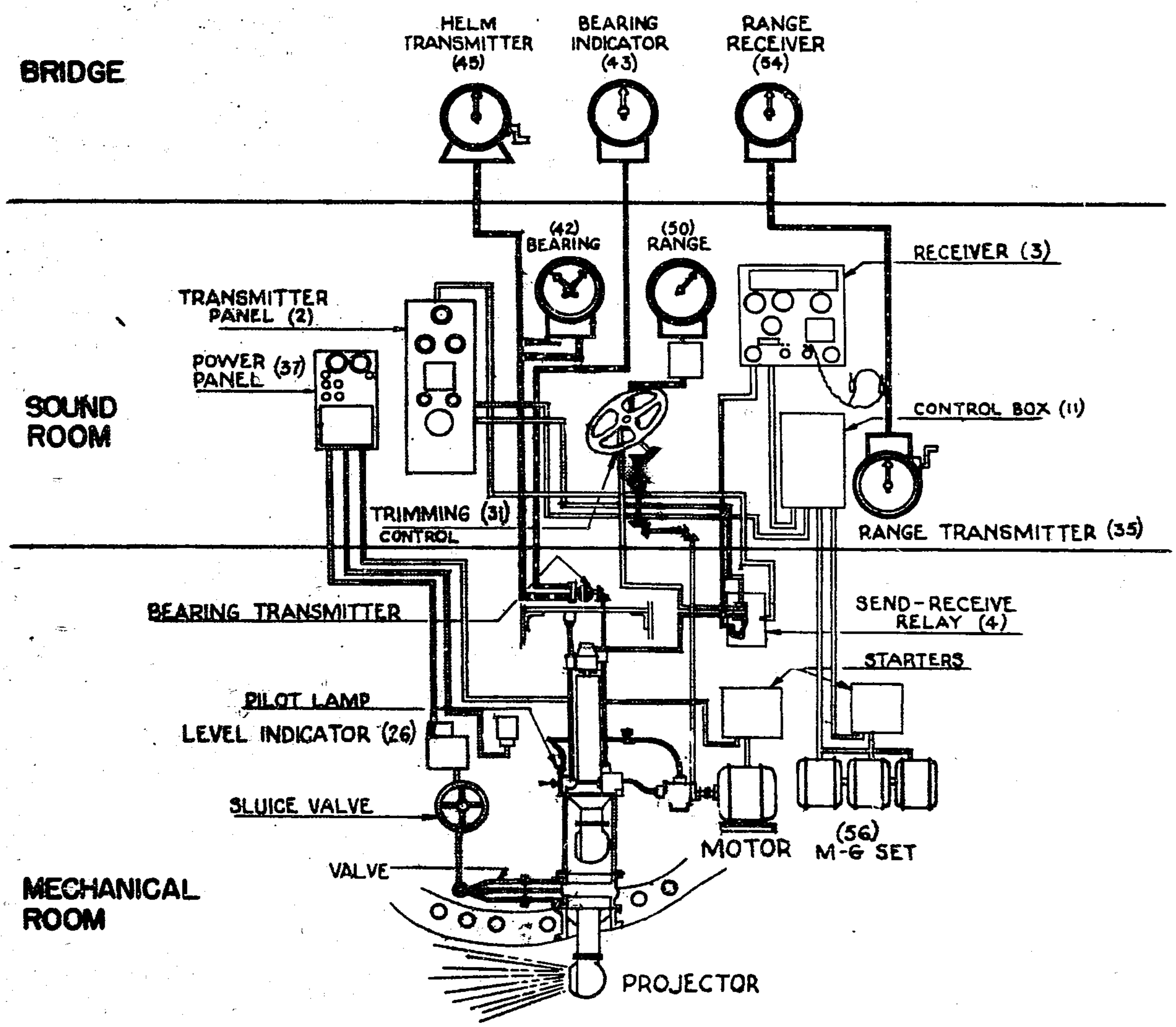


Figure 4
TYPE 93 SONAR INSTALLATION

Figure 5

TYPE 4 - MODEL 1 ECHO-RANGING SET

Table III

ECHO-RANGING EQUIPMENTS

Part I - Production Data

Type	Model	Research		Quantity		Gross Wt (kg x 1000)	Remarks
		Start	Finish	Made	Fitted		
3	1	1-44	10-44	40	36	4.5	Battelships, Destroyers
	2	3-44	4-44	350	285	1.5	Destroyers
	3	1-44	10-44	380	250	1.5	Merchant Ships
	4	9-43	7-44	30	26	1.2	Submarines
	5	3-44	7-44	10	0	0.4	A/S Vessels (Small craft)
	6	1-45	3-45	1	0	0.5	A/S Vessels (Small craft)
93	1	4-31	3-33	130	120	2.0	Destroyers (AC)
	3	5-41	4-42	30	20	2.0	Destroyers (DC)
	4	4-39	10-40	40	40	1.8	Submarines
	5	11-43	9-43	50	35	2.0	Coast Defence Ships
Simple	1	1-42	11-42	240	190	0.5	Small Craft
	2	3-43	10-43	30	24	0.5	Small Craft
	3	3-43	12-43	360	295	0.5	Small Craft

Table III

ECHO-RANGING EQUIPMENT

Part II - Technical Data

Type	Model	Frequency (KC)	Projector		Transmitter		Sound Dome	Elevation System	Training System	Range Indicator				Bearing	
			Q or MS*	No.	Type	KW				Type	No.	Sweep System	Ranges (m x 1000)	Accuracy (±)	Discrimination
3	1	13 & 14.5	MS	3	Oscillator	2.5	Retractable	Electro Mechanical	Electric or Manual	Recorders & CR Tubes	2	Electric	1, 3, & 6	2°	5°
	2	13 or 16	Twin MS	1	Oscillator or HF Generator	1.2	Fixed		Electric or Manual	CR Tubes	2	Electric	1, 3, & 6	2°	5°
	3	16	Twin MS	1	Oscillator	1.0	Fixed		Electric or Manual	CR Tubes	1	Mechanical	3 & 6	2°	5°
	4	20	Twin MS	1	Oscillator	1.0		Electric or Manual	Electric	CR Tubes	2	Mechanical	4	1°	5°
	5	16	Twin MS	1	Oscillator	0.20		Manual	Manual	CR Tubes	1	Electric	0.4 & 1.6	2°	5°
	6	14.5	Twin MS	1	Oscillator	0.25		Manual	Manual	CR Tubes	1	Electric	1.5 & 3	2°	5°
93	1	17.5	Q	1	Oscillator	1.7	Fixed	Electro Hydraulic	Electro Hydraulic	Indicator & Headphones	1		1.5, 3, & 6	3°	10°
	3	17.5	Q	1	Oscillator	2.0	Fixed	Electro Hydraulic	Electro Hydraulic	Indicator & Headphones	1		1.5, 3, & 6	3°	10°
	4	17.5	Q	1	Oscillator	2.5	Fixed	Electro Hydraulic	Electro Hydraulic	Indicator & Headphones	1		1.5, 3, & 6	3°	10°
	5	16 or 19	MS	1	Oscillator	1.7	Fixed	Electro Hydraulic	Electro Hydraulic	Indicator & Headphones	1		1.5, 3, & 6	3°	10°
Simple	1	14.5	MS	1	Condenser Discharge	0.25		Manual	Manual	Recorder	1		1 & 2.5	4°	10°
	2	14.5	MS	1	Condenser Discharge	0.25		Manual	Manual	Recorder	1		1 & 2.5	4°	10°
	3	14.5	MS	1	Condenser Discharge	0.25		Manual	Manual	Recorder	1		1 & 2.5	4°	10°

*Q - Quartz
MS - Magneto-strictionted

LEGEND			
1	6V BATTERY	2	24V BATTERY
3	SWITCH BOX	4	TRANSMITTER PANEL
5	PROJECTOR JUNCTION BOX	6	PROJECTOR
7	AMPLIFIER	8	RECORDER
9	HEADPHONES	10	SUPPLY PANEL FOR AMPLIFIER
11	TRAINING UNIT	12	FLEXIBLE SHAFT DRIVE

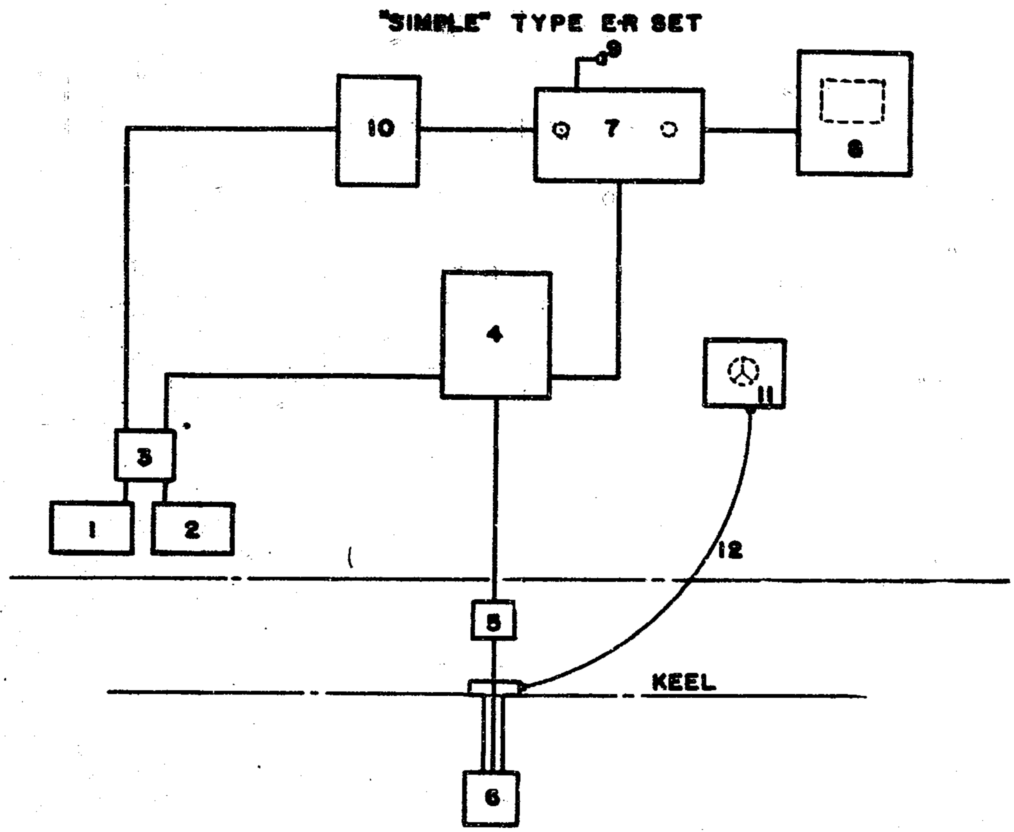


Figure 6
SIMPLE TYPE ECHO-RANGING SET

Part III

HYDROPHONE UNITS, ARRAYS, ECHO-RANGING PROJECTORS AND SOUND DOMES

Research in the design of hydrophone units and unit arrays had received far more attention than that given to echo-ranging projectors. This is exemplified by the amount of information contained in various documents found. The most significant alternation in projectors was the change to magneto-striction types from quartz and, as a corollary, the adoption of the streamlined sound-dome.

A. HYDROPHONE UNITS

Research carried out between 1930 and 1935 established the use of the moving-coil type in place of the carbon types almost universally used earlier. It is however, interesting that the latter type was adopted for the Type 3 Merchant Ship equipments introduced during the war. In 1943 an extensive investigation was made, with the aid of a German technician into the piezo-electric effect of X-45 degree cut Rochelle Salt crystals and their use in hydrophones.

The number of patterns of each type that was developed considerably exceeds those actually placed into production. Susceptibility to the effects of depth charge explosions occasioned some trouble and also lack of watertightness. Some units were cased entirely in thick rubber which was stated to have certain advantages. To combat the shortage of nonferrous metals, plastic bodies were produced but proved impossible to render permanently watertight.

1. Carbon Hydrophones - The type incorporated in the Type 3 sets has a relatively low frequency response of 200 - 1500 cycles but is of simple construction, small and light in weight, with high sensitivity.

2. Moving-Coil Hydrophones - Both permanent-magnet and energized-field types have been developed but that now used as standard, designated P 3, is of the former type. Its construction and characteristics are given in Figure 7 and 8, and certain additional details in Table IV. It consists essentially of a large circular magnet set in a massive manganese bronze body, the moving element being in the form of a single layer coil on a thin circular form.

3. Rochelle Salt Hydrophones - The first production type developed was the KR - 10, subsequently superseded by the RO - 11 which, although less sensitive, had improved frequency response. The construction of both types and their characteristics are given in Figures 8, 9, and 10 and additional information in Table IV. Each type has a built-in micro-transformer for impedance matching purposes, thus permitting the units to be located some distance from the phasing control network without deleterious effects due to line losses. Both types are assembled into stainless steel cases with 2mm manganese bronze diaphrams.

The main difference between the two patterns is the manner in which the crystal block is formed and inserted; KR-10 has two solid pieces of crystal while RO-11 has two sections of three crystals each, compressed in a fibre holder.

Due to the greater ease of production and improved characteristics over the moving-coil and carbon types, further research was carried out to investigate the possibilities of using other piezo-electric crystals, notably quartz, tourmaline, and the strontium salt of formic acid, which although possessing greater theoretical sensitivity, up to 20%, proved unsatisfactory in practice.

B. HYDROPHONE UNIT ARRAYS

To obtain bearings of extreme accuracy, elaborate unit arrays become necessary, together with the use of a great number of units to obtain the least possible interference from own ship's noise.

1. Typical Arrays - Arrays of hydrophones in common use are illustrated in Table V, together with values of interference levels experienced with each arrangement. Elliptical instead of circular basic arrays are used in certain models. Triangular and figure-of-eight arrays offer little advantage while the simple fore and aft linear array suffers from lack of differentiation of whether the sound source is to port or starboard.

2. Interference Due to Background Noise - This subject received much investigation but was found to be exceedingly complicated to analyze and varied considerably from ship to ship. The results of certain measurements are expressed in Figures 11 and 12 where the sound pressure in decibels of the interference near the hydrophone unit is plotted against speed. The most convenient method of reducing the interference level with relation to incoming signal strength has been to increase the number of units in the array (see Figure 13).

3. Hydrophone Position - Four methods are in use as follows:

(1) Side installation
(2) Bottom installation
(3) Tank installation
(4) Streamlined cover installation

Each of these is illustrated in Figure 14.

It has been found essential to investigate carefully the most appropiate method and the actual position in which the array is installed, to insure minimum noise from disturbed water in the vicinity.

C. ECHO-RANGING PROJECTORS

Until the introduction of the Model 3 echo-ranging set, quartz projectors had been used exclusively. The change to magneto-striction appears to have been governed solely by the fact that the Model 3 was a direct adaption of the German prototype, although it was stated that considerable trouble had been experienced with fracture of the quartz due, it was thought, to electrical overloading.

1. Quartz Projectors - The earlier projectors were extremely massive and cumbersome, especially when designed for the lower frequencies. The projector of the Type 91 set, operating at 9 kc, was fully 30 inches in diameter and of considerable weight. It was used in conjunction with a 5 kw oscillator with 7000 volts applied to the plates. Projectors for the Type 93 series incorporated solid (as opposed to strip) "sandwiches" of quartz and were assembled into cast-iron bodies of spherical shape, the general appearance being that shown as part of Figure 4. The plates were stated to be of mild-steel with which pitting troubles had been experienced and protecting paints were lavishly applied. Trouble had also been experienced with seepage of water into the body with consequent breakdown. The process of changing the projector when the ship was waterborne was possible, in the Type 93, by virtue of the sluice valve at the base of the trunk, but it was a long and tedious job. No facilities existed for a projector to be stripped for superficial examination.

2. Magneto-striction Projectors - This type of projector had been in use for some years, in circular form with toroidal windings, for fathometer equipment, (Part VI), and the communication set described in Part VII.

The projector incorporated in the Type 3 echo-ranging equipment follows the German design and consists of two identical independent units assembled side by side within a rectangular cast-iron body, approximately 16" high by 9" square. The area of the exposed face of the unit is determined by the wave length used with the width equivalent to $\frac{1}{2}\lambda$ and the length 3λ, where λ equals the wave length in use. The units are made up of 4mm stampings similar to those for a four-limbed transformer, the windings being wound by hand on the two inner limbs. The horizontal acoustic angle is stated to be 30° and electro-acoustic effeciency 30%, the electrical input being 2kw at 3800volts with polarization from a 20 volt. 8 ampere DC source.

Of particular interest is the development of a ferrous alloy to combat the shortage of nickel ordinarily used for magneto-striction devices. The result of an investigation into alternative materials was published in August 1943 and from which an iron-aluminum alloy, constituting between 12.7% and 12.9% aluminum, was adapted. Comparative figures obtained were as follows:

At Optimum Polarization Current

	Nickel	AL-Fe Alloy
Electro-mechanical ratio	91.2	89
Mechanical-acoustic ratio	50.8	57.4
Electro-acoustic ratio	46.4	46.4
Resonant frequency, kc	24.4	23.9

It was stated that experiments carried out using separate projector for transmitting and receiving had shown increases in range and that further investigation was being planned.

D. SOUND DOMES

The use of sound domes was first adopted following the capture of the British equipment at Singapore. Consistant with usual policy, no attempt was made to make improvements in the design and only physical modifications were made for purposes of adapting it to existing sets. Types in use are shown in Figure 15. Stainless steel sheet, 1mm thick, was universally used.

Early domes were designed to be free-flooding but severe water-noise was experienced and the system was abandoned. To investigate the effects of corrosion and pitting of the projector faces by the action of salt water in the dome, various chemical fluids were tried, including glycerine, but finally fresh water was used exclusively. It was stated, however, that this became contaminated by sea water after a short period.

No special raise-lower gear comparable with the British type was designed for the retractable domes. Raise-lower equipment is illustrated in Figures 24, 31, and 32 included in Part V. Satisfactory operation was claimed, but it was stated that two or three days were required in which to change the projector.

Additional information is available from the following documents which will be obtainable from WDC (see Enclosure A): ND21-6152, ND21-6209, ND21-6214, ND21-6241, ND21-6242, ND21-6243, ND21-6245, ND21-6248, ND21-6265, and ND21-6285.

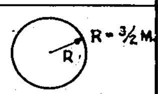
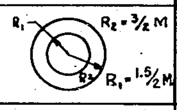
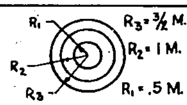
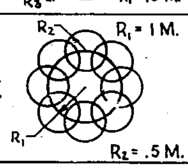
Table IV

HYDROPHONE UNITS - TECHNICAL DATA

		Model		
		P-3	KR-10	RO-11
Type		Moving Coil	Piezo Electric Rochelle Salt Shear	Compression
Weight (kg)		18	6	6
Material of the Body		Ni-Bronze	Stainless Steel	
Membrane	Material	Ni-Bronze	Ni-Bronze	Ni-Bronze
	Diameter (mm)	145	100	100
	Thickness (mm)	4	2	2
Crystal	Cut		X - cut parallel to the Axis	X - 45°
	Size (mm)		49 x 20 x 3	31 x 24 x 2
	No. of Crystal		1	6
Sensibility (db)		35	40	40
Effective Range for Depth Charging (m) TNT 100kg		35	20	20
Frequency Range		500 - 2500	800 - 4000	500 - 6000
Note		Having a permanent magnet	Having a proof device	

Table V

HYDROPHONE ARRAYS - TECHNICAL DATA

ARRANGEMENT OF HYDROPHONES	BACKGROUND LEVEL (%)			
	NOISE	PURE TONE		
		500 ~	1000 ~	4000 ~
SIMPLE CIRCLE 	40%	40%	40%	40%
DOUBLE CIRCLE 	25 - 35%	15 - 20%	25 - 35%	35 - 40%
TRIPLE CIRCLE 	8 - 12%	5 - 8%	10 - 15%	30 - 40%
COMPLEX CIRCLE 	10 - 15%	8 - 10%	10 - 15%	30 - 40%

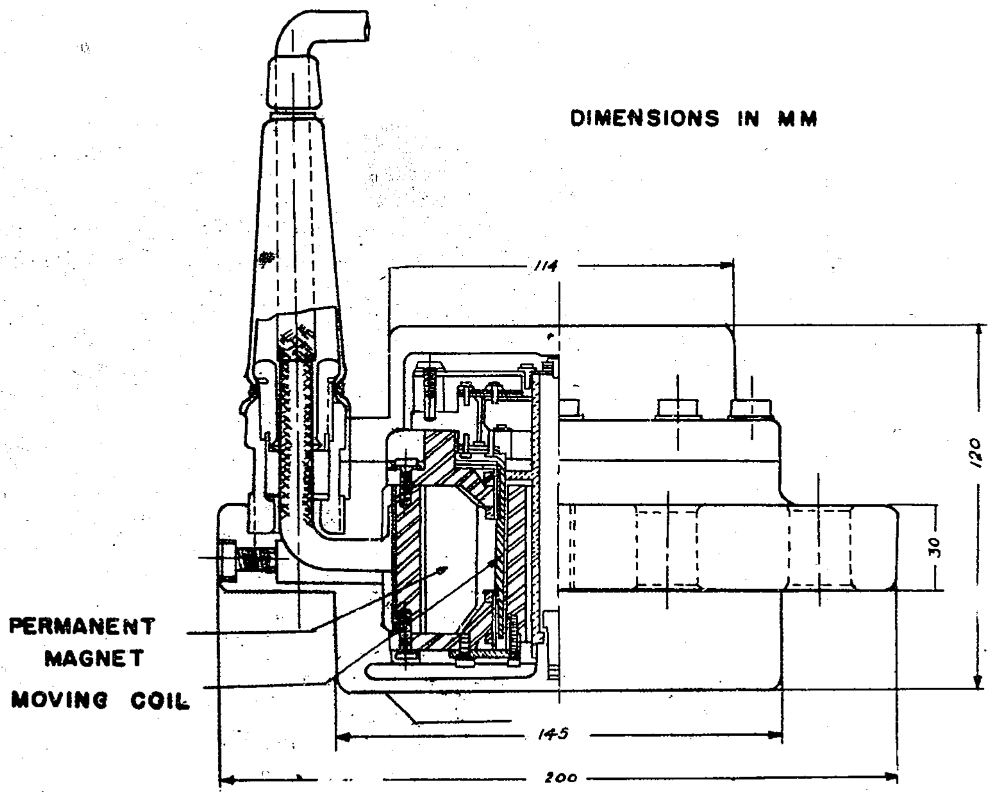


Figure 7
HYDROPHONE UNIT TYPE P-3

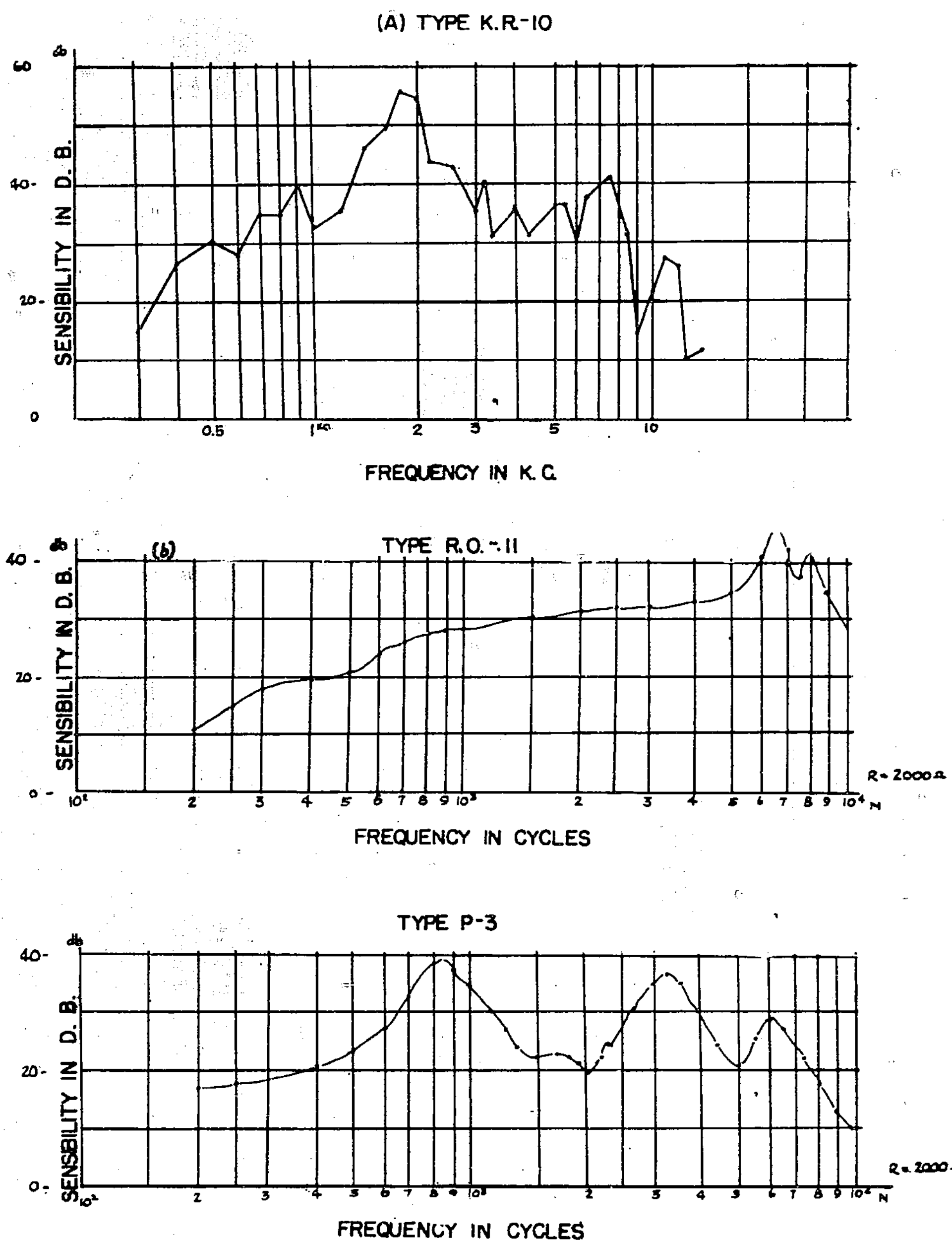
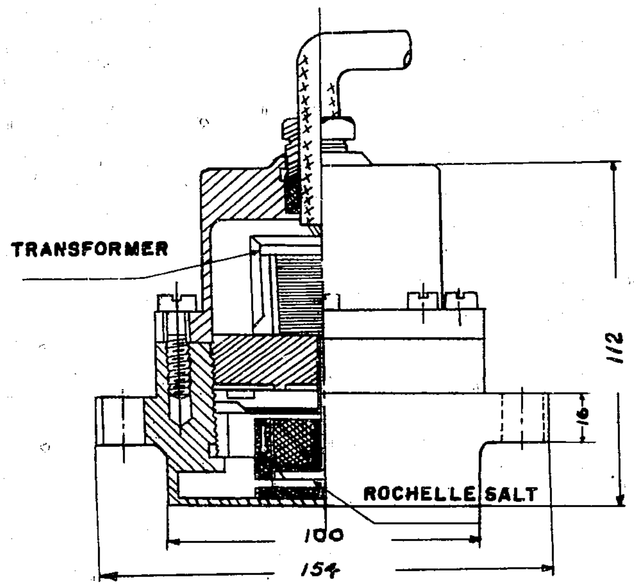
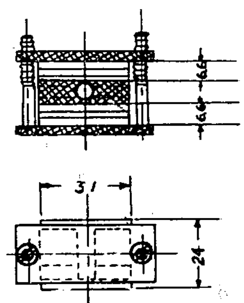


Figure 8

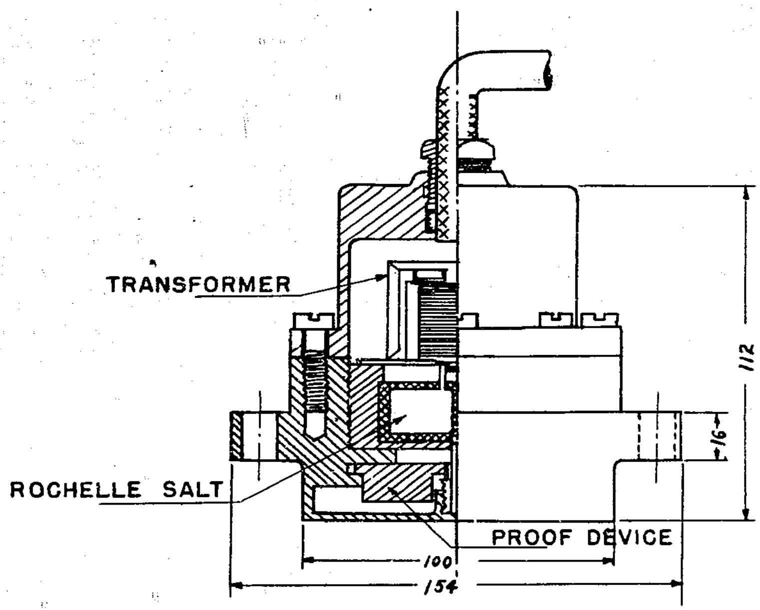
HYDROPHONE UNITS TYPES KR-10, RO-11, AND P-3

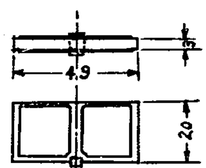




DIMENSIONS IN MM

Figure 9
HYDROPHONE UNIT TYPE RO-11





ELEMENT OF ROCHELLE SALT

DIMENSIONS IN MM

Figure 10
HYDROPHONE UNIT TYPE KR-10

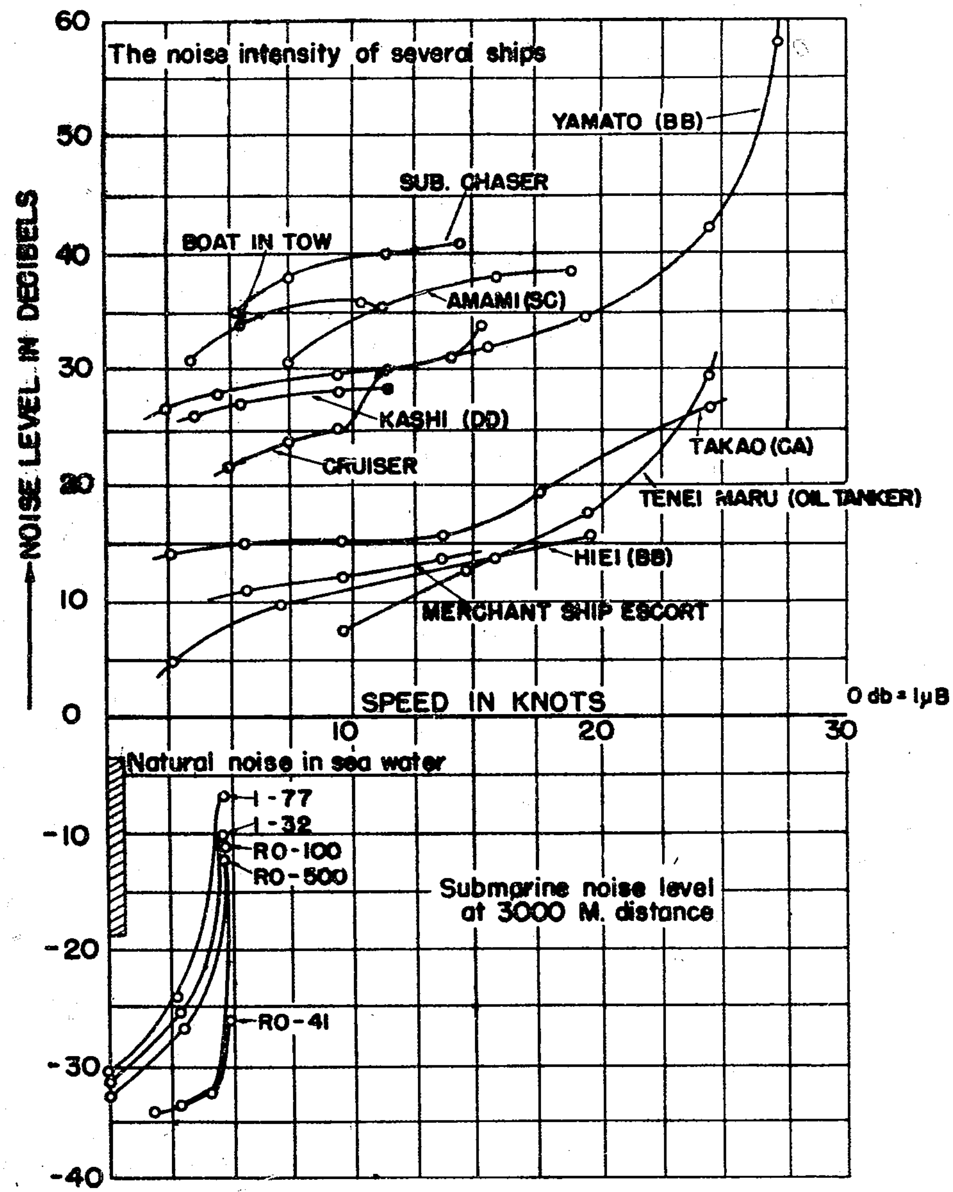


Figure 11

NOISE LEVELS OF SHIPS UNDERWAY - WARSHIPS

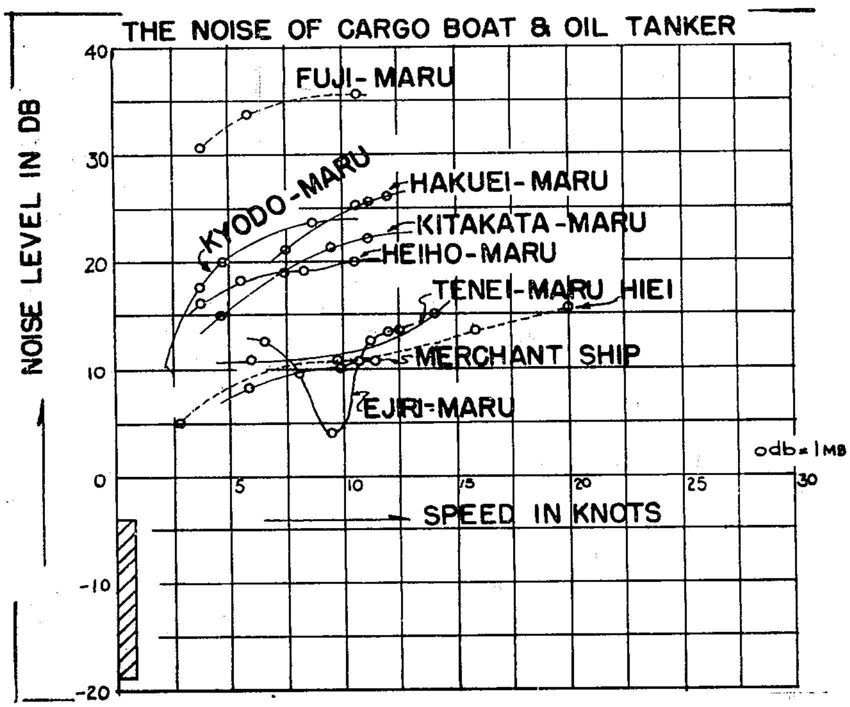


Figure 12

NOISE LEVELS OF SHIPS UNDERWAY - MERCHANT SHIPS

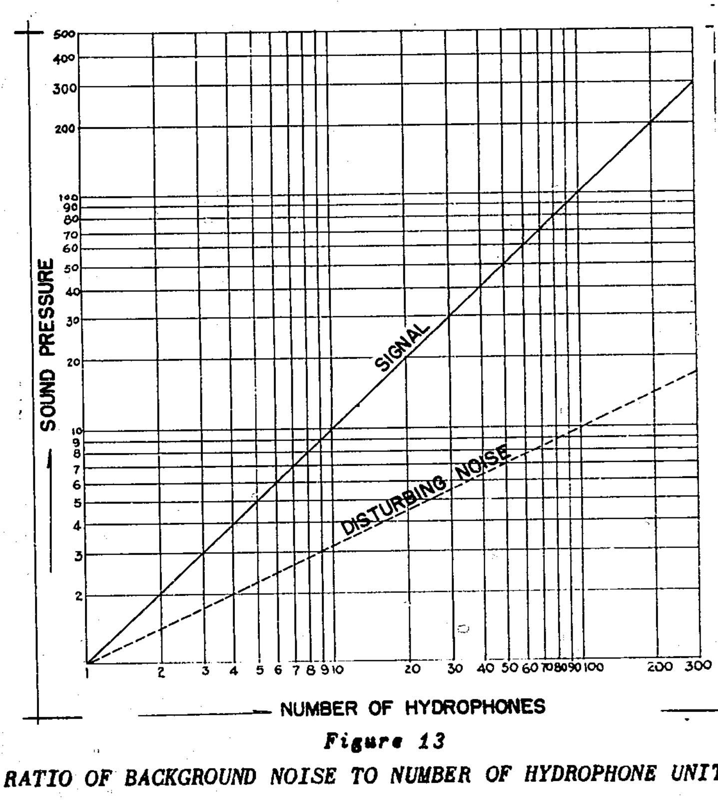


Figure 13

RATIO OF BACKGROUND NOISE TO NUMBER OF HYDROPHONE UNITS

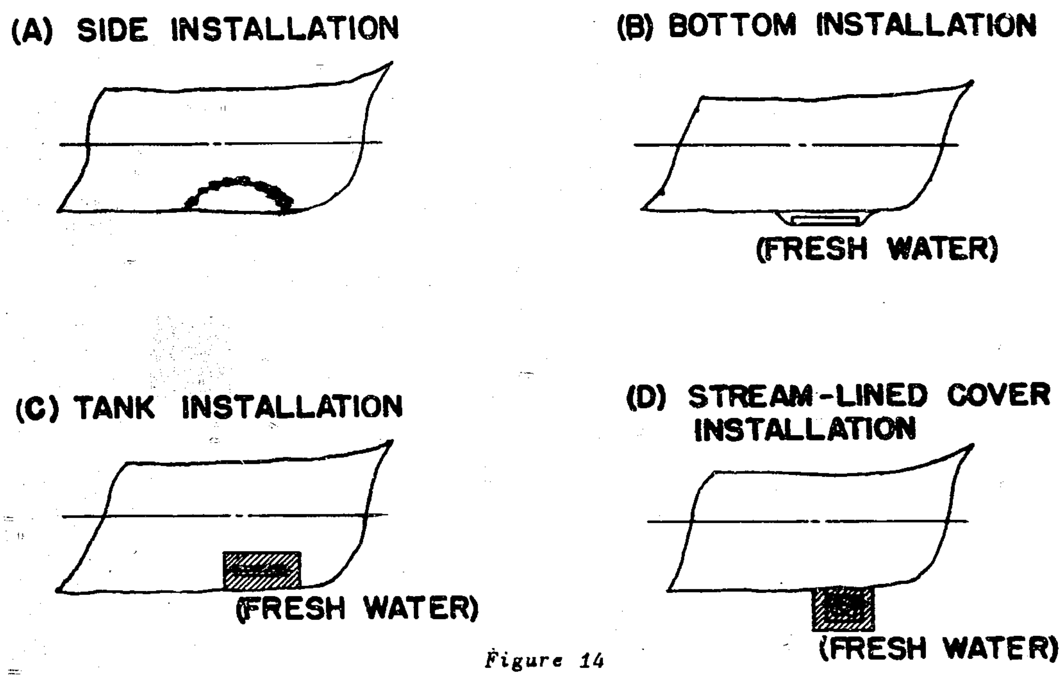


Figure 14

METHODS OF INSTALLING HYDROPHONES

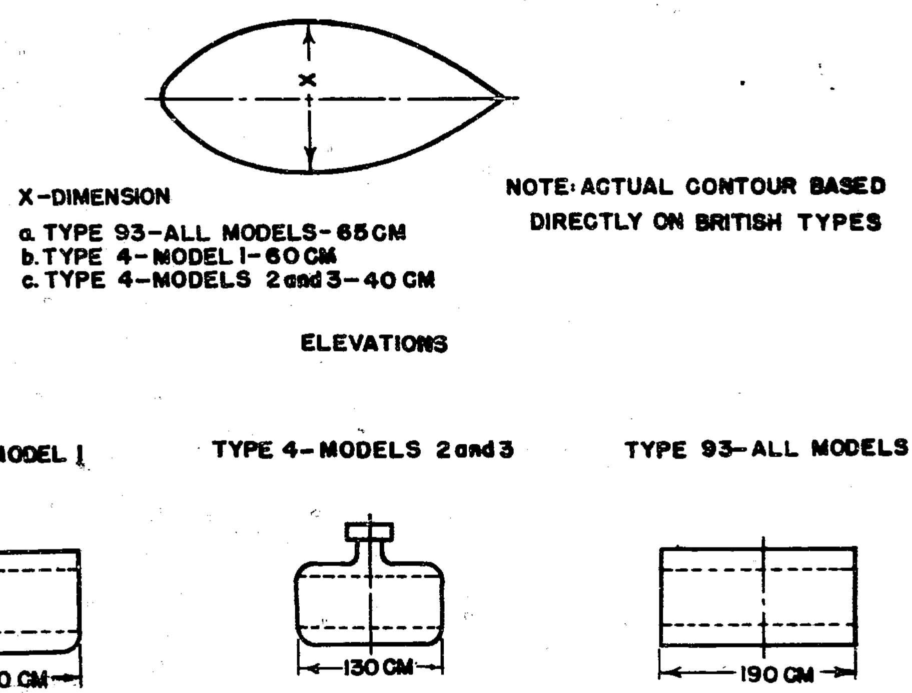


Figure 15

SOUND DOMES AS FITTED TO VARIOUS ECHO-RANGING SETS

Part IV

EQUIPMENT MANUFACTURE

The general appearance of hydrophone and sonar equipments is generally good, especially the earlier sets. Due consideration had been given to accessibility and many ingenious devices adopted to achieve this on multi-hydrophone equipments. The equipment generally is of massive construction, liberal use being made of light alloy castings, although the quality of electronic components in amplifiers, etc, is often poor by comparison. The packing of spares and of tools is particularly good, well-made wood boxes fitted with compartments and trays being employed. Each individual component and tool is allotted a separate compartment lined with felt or corrugated cardboard in the case of electronic components. No moisture-proofing measures were taken even in the case of spare armatures and field-coils.

The principal manufacturers of sound equipment were:

Sumitomo TSUSHIN KOGYO
Tokyo Shibaura DENKI
Hidachi SEISAKUSHO
Oki DENKI
Aichi TOKEI, NAGOYA
Tokyo KEIKI SEISAKUSHO

The production program for 1945 (April to August) is listed in Table VI. This information is extracted from the seized document ND21-6238 which will be available at WDC (see Enclosure A).

Part V

TYPICAL SONAR INSTALLATIONS

Two typical sonar installations are briefly described and illustrated with photographs. One installation was in an aircraft-carrier (KATSURAGI, CV), and presumably used as a defensive weapon. The other was in a destroyer (TERUTSUKI, DD), where the emphasis would be on attack. The amount of space allocated to the sonar installations represents an indication of the great reliance placed on these instruments.

The two installations described were poorly carried out according to U.S. and British standards. The compartments were lined with wood to facilitate wiring and the fire risk accepted. The bonding of cables was inefficient, and in very few cases were they protected from chafing when passed through bulkheads. The general appearance was one of a job done in a hurry and never completed, but it was evident that it was not so regarded by the Japanese. Ample room was provided for maintanance purposes.

Table VI

UNDERWATER SOUND EQUIPMENT, INSTALLATION SCHEDULE

APRIL - AUGUST, 1945

Set	No. not installed	No. available in store	No. to be installed		No. Manufactured			Ships Fitted
			No. of Ships	No. in reserve (20%)	No. left from 1944	1945 Schedule	Total	
Type 3, Mod 1	26		111	115	117		117	Battleships, etc.
Type 3, Mod 2	159		594	714	632	100	732	Destroyers, etc.
Type 3, Mod 3	39		690	1225	833	300	1133	Merchant Ships
Type 3, Mod 4	14		100	100	36	64	100	Submarines
Type 3, Mod 6			316	680	0	700	700	Special Craft
Type 93	170		0		110	0		Warships, Submarines
Portable Set	339		0		141	0	141	Small Boats
Special "SV"			49	60		60	60	Defense Merchant Ships
Special "RA"			300	300		300	300	Motor Launches
Special "RK-1"			50	50		50	50	Destroyer Escorts
Type 4, Mod 1	23	0	144	173	130		130	Warships, Destroyers, Merchant Ships
Type 4, Mod 2		0	670	804	0	300	300	Small Craft, Submarines
Type Zero	16	0	30	30	42	240	282	Warships, Merchant Ships
Type 93	361	112	119	123	285	100	385	Warships, Submarines
Simple Type	319	40	177	212	203	240	443	Small Boats
Cross Type	23	70	167	200	357	0	357	Special Picket Boats
Type 3, Mod 1	312		1229	1475	524	0	524	Merchant Ships
Type 3, Mod 2	104	358			215	0	215	Merchant Ships
Type 3, Mod 3	82		17	21	100	0	100	Merchant Ships
Type 97		2	80	80	80	0		Harbor Defense Set

A. INSTALLATION IN KATSURAGI (CV)

The equipment consisted of the following:

One - Type 3, Model 1, Echo-ranging Set
Two - Type 0, Hydrophone Sets

The echo-ranging and hydrophone instruments were all mounted on the forward bulkhead, outboard and inboard respectively, of the Sonar Room, which by comparison with the Radar Room, was very spacious. The transmitting power supply panels for the echo-ranging set were located just off the passageway and immediately aft of the operating space. The lower sound room, housing the directing gear, and the machinery were in bad condition, but this was attributed mainly to lack of maintenance since the surrender. (See Figures 16 and 18 to 24)

B. INSTALLATION IN TERUTSUKI (DD)

The equipment consisted of the following:

One - Type 3, Model 1, Echo-ranging Set
One - Type 4, Model 1, Hydrophone Set

The sonar equipment was located on the starboard side of the main deck in a compartment which was more than adequate in size. Communication with the bridge was established both by telephone and voice tube. The transmitting and power supply panels were situated in a small compartment just forward of the operating space. The lower sound room was in good condition and the raise-lower mechanism was reported to have given little trouble. The equipment was manned continuously at sea and the echo-ranging set operated at least fifteen minutes in each hour. No special attack instruments were fitted, but there was a repeat range and bearing indicator, for the echo-ranging set, located on the bridge. (See Figures 17 and 25 to 32)

Information concerning the types of equipment normally fitted to different classes of vessel, may be obtained from the seized document ND22-3015 which will be available from WDC (See Enclosure A).

Figure 16
TYPE O H.P. SETS IN KATSURAGI (CV) CLASS

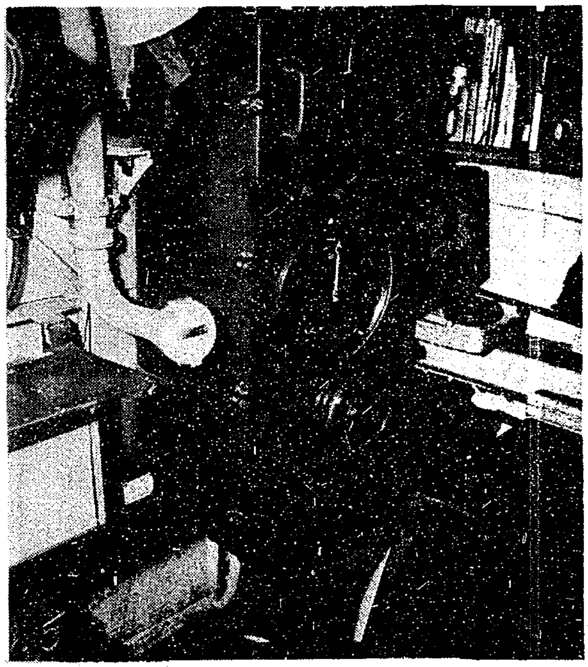


Figure 17
TYPE 4 MODEL 1 H.P. SET IN TERUTSUKI (DD) CLASS

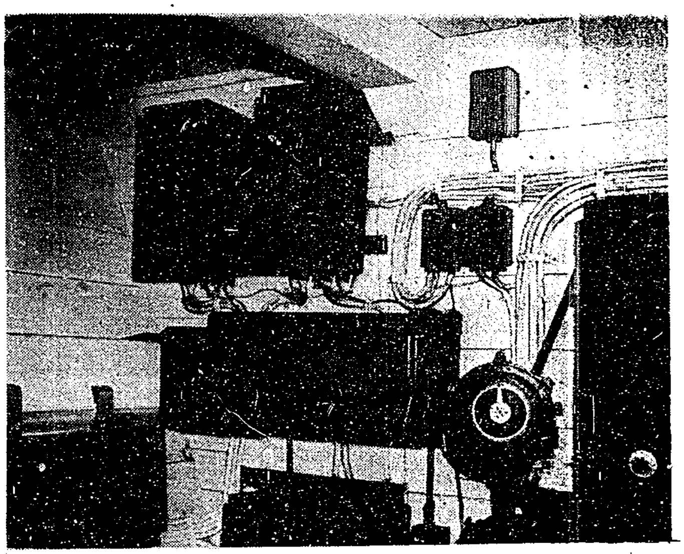


Figure 18
TYPE 3 MODEL 1 ECHO-RANGING SET IN KATSURAGI (CV) CLASS
(Chemical Recorders are marked '1' and Recorder Amplifiers, '5'.)

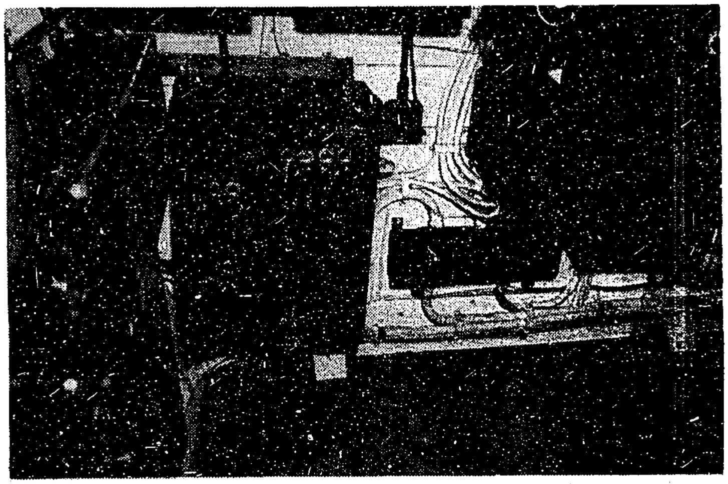


Figure 19
TYPE 3 MODEL 1 ECHO-RANGING SET IN KATSURAGI (CV) CLASS
(Recorder Control and Driving Panel marked '4'.)

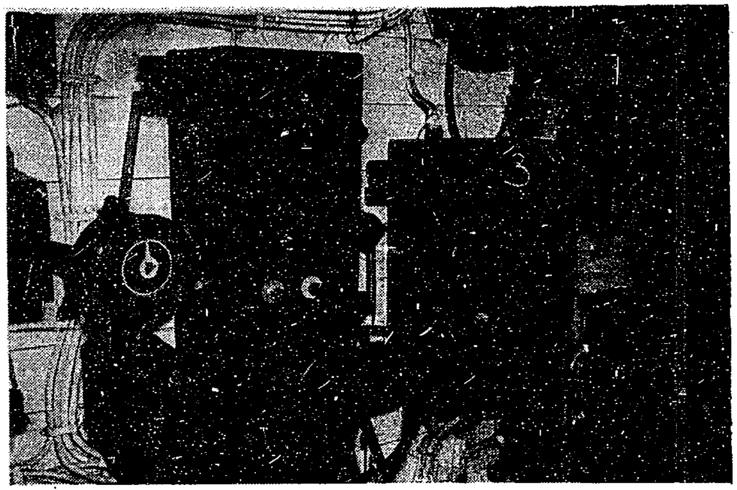


Figure 20
TYPE 3 MODEL 1 ECHO-RANGING SET IN KATSURAGI (CV) CLASS
(C.R. Tube Indicator is marked '2'; Receiver, '3'; and Training (Selsyn) Control, '6'.)

Figure 21
POWER SUPPLY PANELS OF TYPE 3 MODEL 1 ECHO-RANGING SET IN KATSURAGI (CV) CLASS

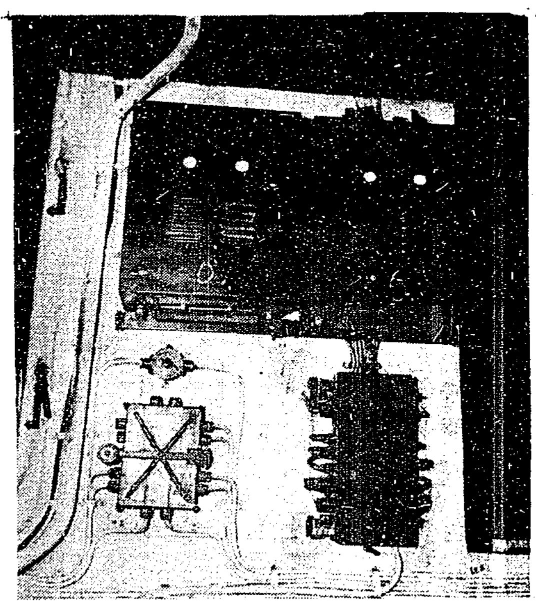


Figure 22
TYPE 3 MODEL 1 ECHO-RANGING SET IN KATSURAGI (CV) CLASS
(13 kc Transmitting Panel is marked '9' and 14.5 kc Transmitting Panel, '10'.)

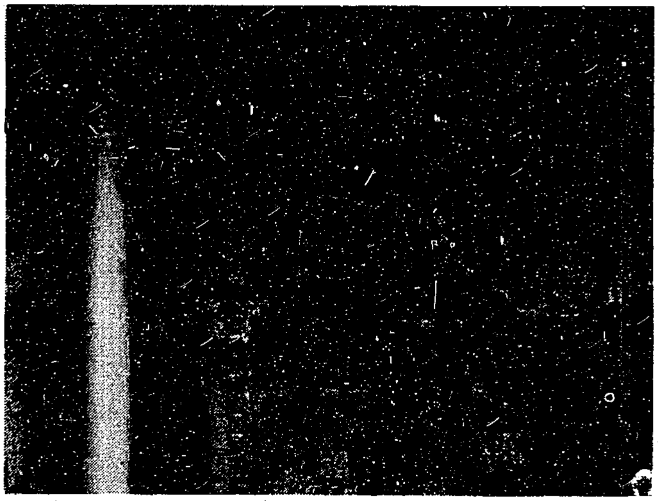


Figure 23
RAISE-LOWER MECHANISM OF TYPE 3 MODEL 1 ECHO-RANGING SET IN KATSURAGI (CV) CLASS

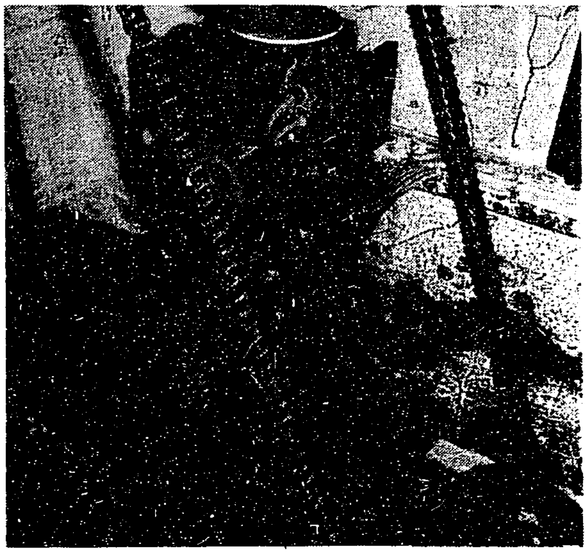


Figure 24
TRAINING MECHANISM (SELSYN) OF TYPE 3 MODEL 1 ECHO-RANGING SET IN KATSURAGI (CV) CLASS

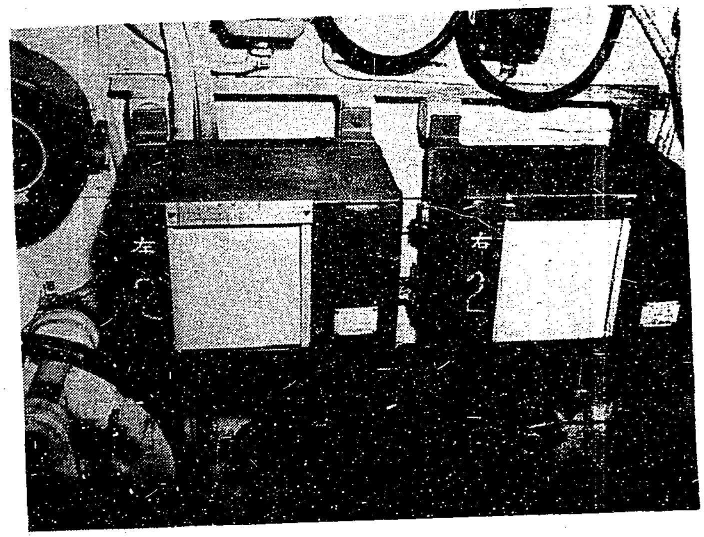


Figure 25
CHEMICAL RECORDERS OF TYPE 3 MODEL 1
ECHO-RANGING SET IN TERUTSUKI (DD) CLASS

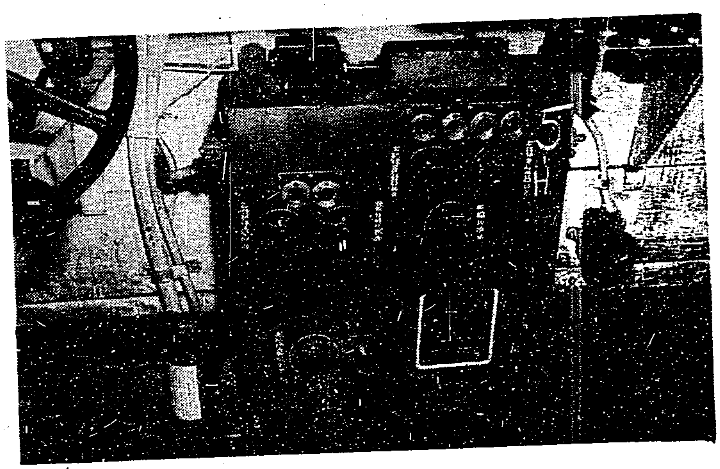


Figure 26
RECORDER CONTROL AND DRIVING PANEL OF TYPE 3 MODEL 1
ECHO-RANGING SET IN TERUTSUKI (DD) CLASS

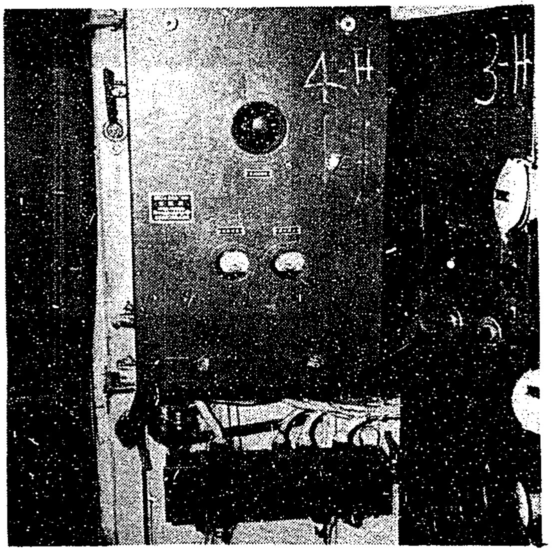


Figure 27

TYPE 3 MODEL 1 ECHO-RANGING SET IN TERUTSUKI (DD) CLASS
(C.R. Tube Indicator, marked '3H', Receiver, '4H'.)

Figure 28

TYPE 3 MODEL 1 ECHO-RANGING SET IN TERUTSUKI (DD) CLASS
COMPARTMENT CONTAINING POLARIZER PANELS AND ASSOCIATED EQUIPMENT

Figure 29
TYPE 3 MODEL 1 ECHO-RANGING SET IN TERUTSUKI (DD) CLASS
M.G. SETS AND CONTROL BOXES

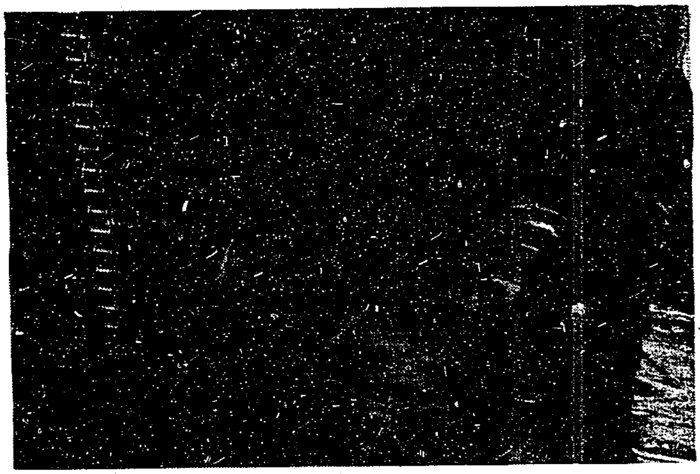


Figure 30
RAISE-LOWER MECHANISM (1) OF TYPE 3 MODEL 1
ECHO-RANGING SET IN TERUTSUKI (DD) CLASS

Figure 31

RAISE-LOWER MECHANISM (2) OF TYPE 3 MODEL 1 ECHO-RANGING SET IN TERUTSUKI (DD) CLASS

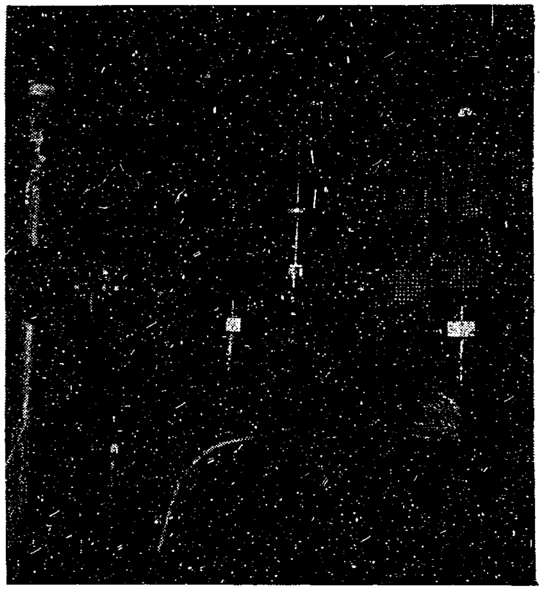


Figure 32

TRAINING SYSTEM (MECHANICAL) OF TYPE 3 MODEL 1 ECHO-RANGING SET IN TERUTSUKI (DD) CLASS

Part VI

FATHOMETERS

Commercial-type fathometers were of conventional design. One model examined, known as "Type 356" and manufactured by Tokyo Keiki Seisakusho Ltd., was dependent on the obsolescent "Fessenden" principle and utilized the revolving flashing-tube system for depth indication. The equipment in general use in the Navy, bears the designation "Type 99", and is stated to have given most satisfactory results. A report on research into sound propagation with reference to fathometers was prepared in March, 1941 and describes in detail the experiments carried out. These consisted essentially of measuring the attenuation of the transmitted wave that reflected from the sea-bed, and in turn reflected from the surface. This measurement was accomplished by the use of an omni-directional search receiver suspended in the sound beam.

The Type 99 Fathometer, superceding the Type 90 with revolving flashing-tube indicator, is equipped with a chemical recorder and is designed for operation from a 100 volt DC supply.

A. TRANSMITTER PANEL

The transmitter panel incorporates a 100/2000 volt rotary convertor, across the output of which is a permanently connected 4 mf condenser charging through a 100 kilohm resistance. The transmitter contactor is energized automatically from the recorder, and when operated, discharges this condenser across the transmitter unit. The contactor is fitted with a mechanically tuned bow spring armature, similar to that used in the British Admiralty echo-sounding set (a commercial model which was available before the war). The reason for its use in the British set is entirely different, and its employment in this instance by the Japanese was not entirely clear.

B. TRANSMITTER AND RECEIVER UNITS

The transmitter and receiver units are situated adjacent to each other and are of the magneto-striction type, assembled within double-skin metal reflectors in a manner similar to that incorporated in the British Admiralty equipment. Details of the units, which are identical, are as follows:

Stampings	nickel (later Al-Fe Alloy)
Internal diameter	10cm
External diameter	18cm
Total depth	12cm
No. of turns	24
Frequency	14.5 kc

C. "FLASHING" UNIT

Since polarization of neither transmitter nor receiver units was adopted, periodical "flashing" of the receiver was necessary to ensure maximum sensitivity. This was achieved by manual switching in a simple device which temporarily disconnected the receiver unit from the amplifier and connected it across an 8-volt battery in series with a choke, resistance, and ammeter. In the normal position the receiver unit was connected directly to the amplifier in series with a 2 mf condenser.

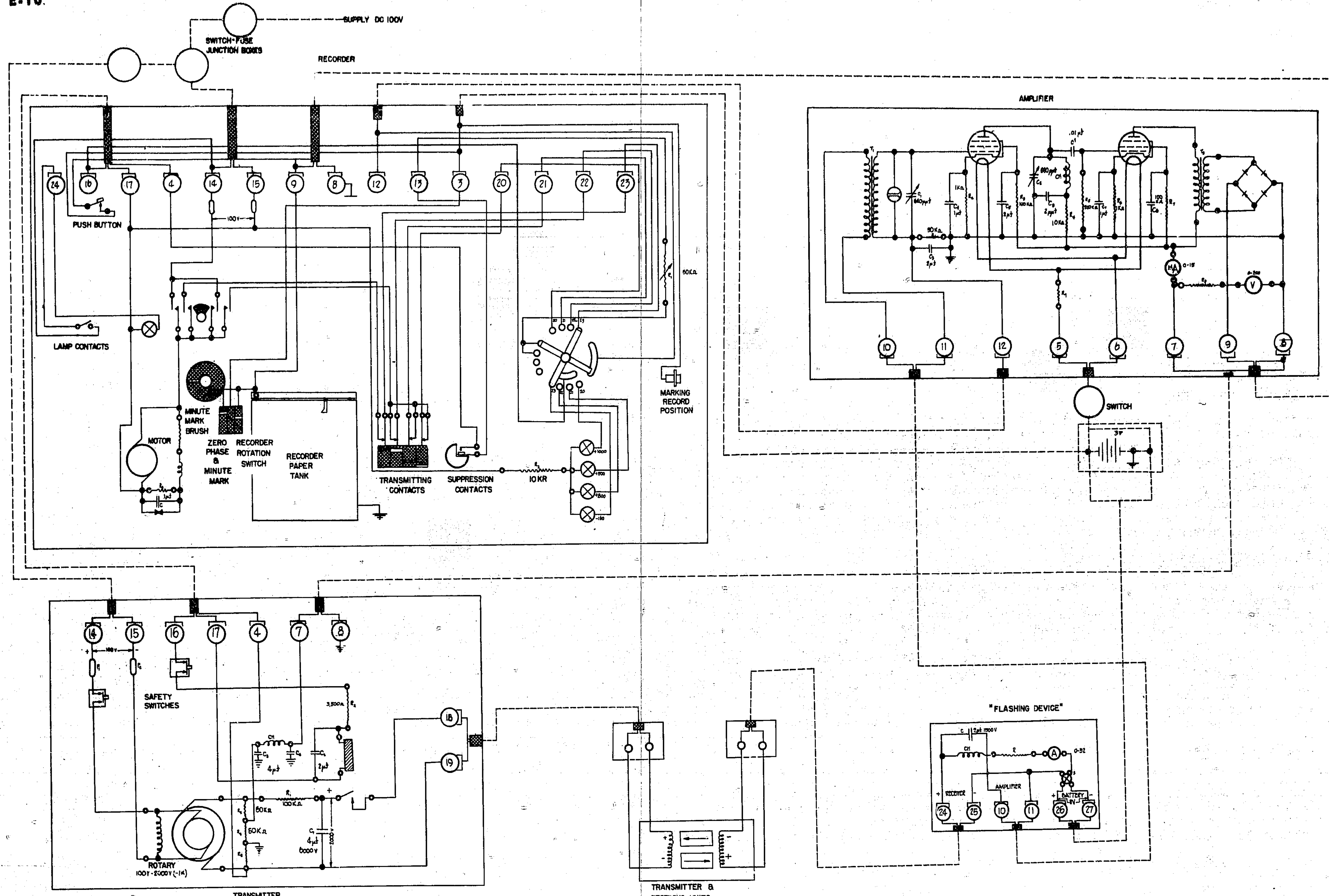


Figure 33
TYPE 99 FATHOMETER

D. AMPLIFIER

The amplifier is of conventional design incorporating a selenium rectifier output and having a gain of approximately 90 db.

E. RECORDER

The recorder embodies several interesting features. Driving power is supplied by a 1/20 hp electro-mechanically governed motor which is again similar to that incorporated in British Admiralty equipment. The paper-tank and paper-feed are similarly identical but the recording stylus mechanism is unique. A drum is mounted above the tank. Inside the drum is machined a left- and right-hand female helical groove, each with pitch of ½ turn. The stylus is traversed by means of these two grooves and thus makes one complete traverse back and forth in one revolution of the drum. When returning to the zero position, the stylus is tilted out of contact with the paper so that no record is registered in this direction. Also driven by the motor are four transmitting cams, any one of which may be switched into the circuit, and by virtue of their relative displacement enable four depth ranges to be obtained. The action of selecting any one, by manual switching, causes a corresponding pilot light to be illuminated, and also, in the first two positions, switches in a set of suppression contacts, the action of which is to reduce the amplifier sensitivity during a brief period after transmission. A further set of contacts causes timing marks to be registered on the record at definite intervals. No change-speed device is included to extend the possible ranges, the maximum range being 2000 meters.

F. REMARKS

A schematic circuit and photographs of the equipment are included in Figures 33, 34 and 35. During trials the set is stated to have recorded up to 6000 meters in summer and 10,000 meters in winter.

Details of research carried out are available in the seized document ND21-6150 which will be available at WDC (see Enclosure A).

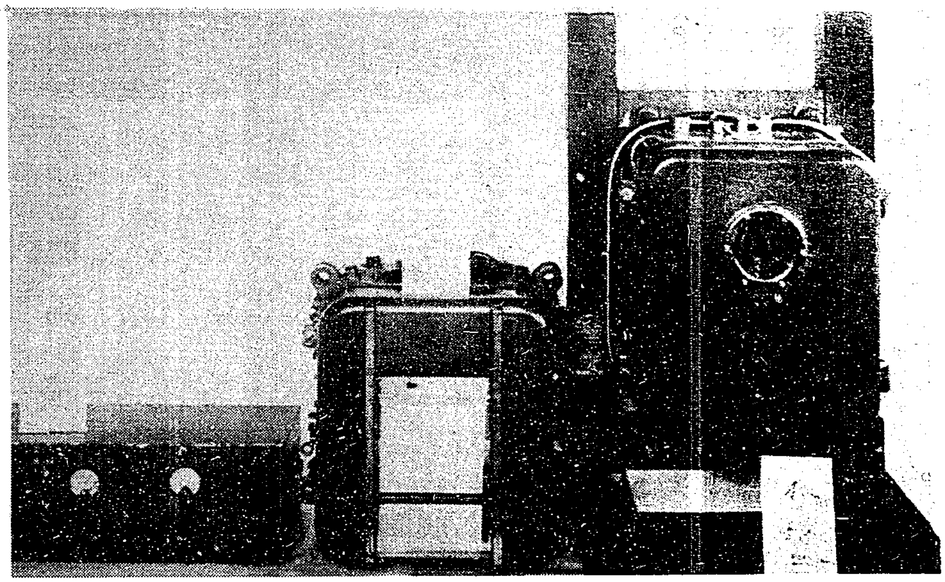


Figure 34

TYPE 99 FATHOMETER

RECEIVER, CONTACTOR PANEL, AND RECORDER

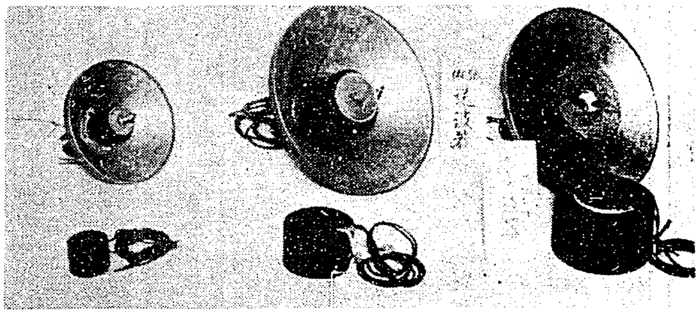


Figure 35

TYPE 99 FATHOMETER, MODIFIED FOR RESEARCH PURPOSES

(Note: Frequency of Production Model - 14.5 kc)

Part VII

SPECIAL EQUIPMENT DEVELOPED FOR SPECIFIC PURPOSES

Six types of equipment were discovered, which, by virtue of being designed to meet specific requirements, are of interest. These comprised:

Mine Detection Device, relying on the echo-ranging principle.
"Dip Angle" device for determining depth of submarines and also for mine-detection.
"Intercept Indicator" for intercepting sonar transmissions at great distances.
Underwater communication by use of sound waves
Sono-buoys
Hydrophone detection on ultra-low frequencies.

A. MINE DETECTION DEVICE

The Mine Detection Device was developed from standard naval fathometer equipment by the third Section of the Seventh Military Laboratory at ITO. The reason for its being made a military commitment it was stated, was due to pressure of work at the naval research stations. It was known as "Tanreiki".

A standard 14.5 kc fathometer magneto-striction transmitter unit and reflector were mounted in a torpedo-shaped body, approximately 120cm long, with sharply tapered tail and domed celluloid sound window at the forward end. This body was mounted on a stremlined strut arranged for suspension from the side of a small craft. The sound beam was thus projected in an approximately horizontal direction; no separate receiver unit was utilized.

The transmitter panel was convertional, incorporating a rotary-convertor, output 2000 volts DC, directly charging a 10 mf condenser through a 30 kilohm resistance and discharging across the transmitter unit upon transmission.

The incoming signal was amplified, rectified, and recorded by a chemical recorder. The amplifier and recorder were contained in one case presenting a very compact arrangement and intended to be comparatively portable. The amplifier was particularly neat in its construction and could be withdrawn from the recorder case, to provide accessibility, in a matter of seconds. The recorder was of the usual design, but utilized extra wide paper (about 25cm) and a unique recording system. Immediately above the tank was fitted a drum with a male helical thread of one turn arranged to just make contact with the paper.

As the drum revolved, contact with the paper moved from left to right, one turn being equivalent to a complete traverse. As soon as contact with the paper had reached the extreme right, contact was established again at the left-hand end resulting in no dead period which is while the stylus pen is returning, common with the usual chemical recorder.

The equipment was stated to be successful and was placed in production in 1943. It could be arranged for either battery or power operation. (See Figure 36)

B. "DIP ANGLE" DEVICE

The "Dip Angle" Device is a special adaption of the "phase-difference" principle of the Type 4 Sonar. It is designed to operate in conjunction with a standard Type 4, Model 3 Sonar Set. By projecting a sound beam at an angle to the horizontal, it was supposed to be capable of determining the depth of an enemy submarine by analysis of the image produced on a CR tube. The indication was termed the dip-angle of the target and a mechanical arrangement was mounted at the front of the CR tube for computation. It was stated that the apparatus had not proved satisfactory, mainly due to the time element involved. It was still in the development stage. The schematic circuit, and the manner in which the projectors were arranged, is illustrated in Figure 39.

C. "INTERCEPT INDICATOR"

The "Intercept Indicator" was developed with the object of providing submarines with a means of intercepting Sonar transmissions at great distances.

Four magneto-striction units were mounted in the form of a cross within a streamlined sound dome, such that their combined response areas included all bearings. By use of a CR tube, an image would be obtained when a transmission was intercepted, the particular form of the image giving an approximate indication of the bearing. The amplifier had a gain of about 120 db and covered a frequency band from 13 to 25 kc. The principle of operation is outlined in Figure 37.

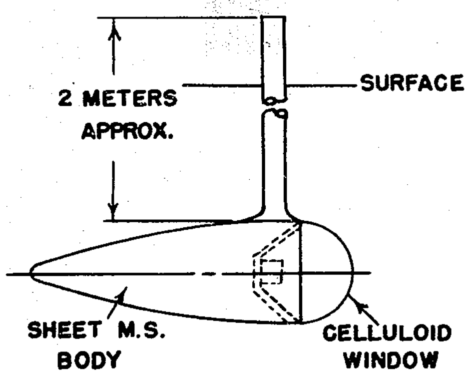
During trials, a bearing accuracy of approximately ± 20°, and a maximum range of only 10,000 meters was obtained. The initial development work was completed shortly before the end of the war and only one set of gear installed, that being in RO-68. An improved model, using a circular sweep on the CR tube, was being considered.

D. UNDERWATER COMMUNICATION EQUIPMENT

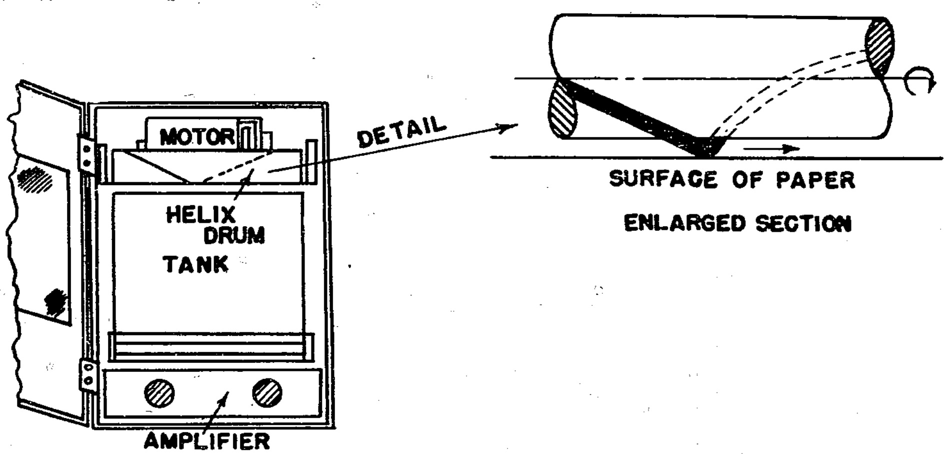
Two types of underwater communication equipment were discovered.

1. The German "Periphone" equipment was used experimentally and from this was developed a communication set referred to as "Multiple underwater signal equipment". Three moving-coil units were mounted, one above the other, in a sword-like casing which was retractable although not rotable. A frequency of 3 kc was used, supplied by a motor-alternator generating at 1.5 kc and feeding through a doubler circuit. Under ideal conditions, ranges of 50,000 meters were obtained (deteriorating to 10,000 under poor conditions) the transmission and response being omni-directional. The experiments were carried out at KURE but were suspended.

2. Between 1937 and 1940, a voice communication equipment was developed for use by submarines to avoid the time element involved by Morse signalling methods. A carrier frequency of 10 kc was used, with a single sideband operation (side band, 1 kc wide), 200 watt output, Class 'A' amplification, and 50% modulation. Magneto-striction units were utilized, the same unit being employed for both transmission and reception. Details of the manner in which a spheroid-type reflector was used with these units is shown in Figure 30. This design was arrived at by trial and error, and it was found desirable to keep the resonant cavity as small as practicable.

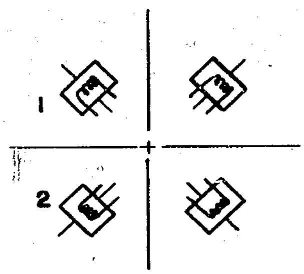


UNDERWATER EQUIPMENT

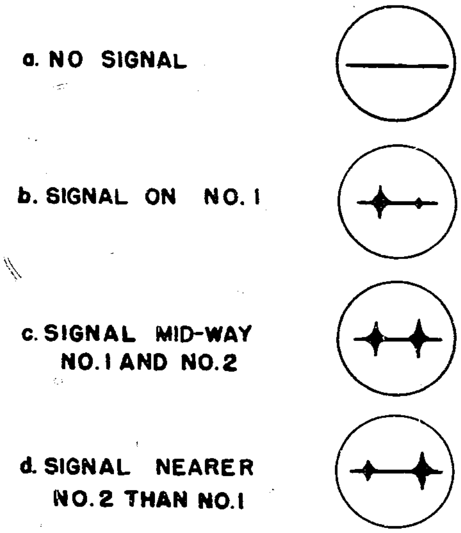


GENERAL LAYOUT OF
RECORDER—AMPLIFIER

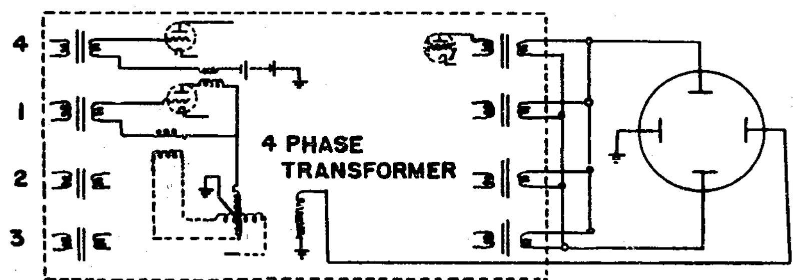
Figure 36
TANREIKI MINE DETECTOR



ARRANGMENT OF HYDROPHONES



TYPICAL CRT IMAGES



DEFLECTION CIRCUT

Figure 37
INTERCEPTOR INDICATOR

Experiments showed that communication was reliable up to 10-15,000 meters. The equipment was not installed in submarines and was never used operationally in the war mainly because of the large amount of space it occupied.

E. Research into Sono buoys was projected but never progressed beyond the drawing-board due to other commitments.

F. HYDROPHONE DETECTION ON ULTRA-LOW FREQUENCIES

An investigation was commenced in August, 1944 into the practibility of hydrophone detection of submarines on ultra-low frequencies of several cycles per second. The principle in view was that a submarine would emanate, in addition to noise in the usual region of several thousand cycles per second, very low frequency pressure waves which, by virtue of correspondingly low attenuation, might be propagated for several hundred miles, especially in an ocean current.

Preliminery experiments were made with a moving-coil hydrophone with an electro-magnetic oscillograph as a recorder. The hydrophone was suspended above the sea-bed to give velocity response and then laid on the sea-bed for pressure response. As a result of these experiments, some measurements were obtained from a 100-ton ship but were considered unsatisfactory and inconclusive until some form of electrical or acoustic filter could be designed. Subsequently, it was hoped to devise a method of fixing the approximate position of the submarine after detection, but meanwhile the research was temporarily abandoned.

The investigation was instituted by the Research Department of the Second Military Laboratory as a harbour defense commitment, the experiments being carried out by the Geophysical Laboratory of Kyoto Imperial University.

No documents were discovered referring to any of the equipment described in this article.

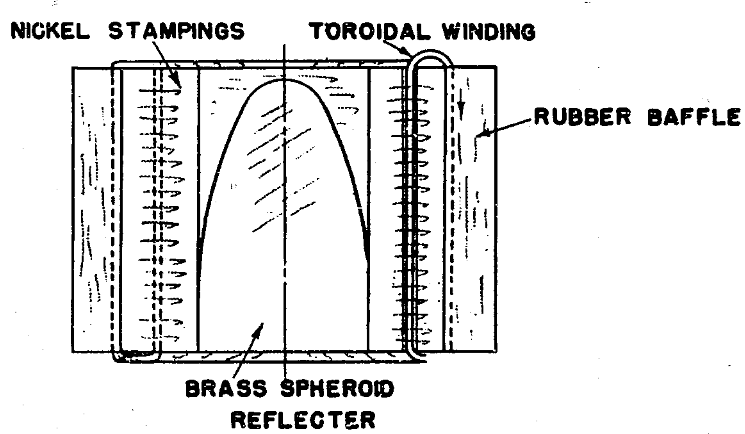
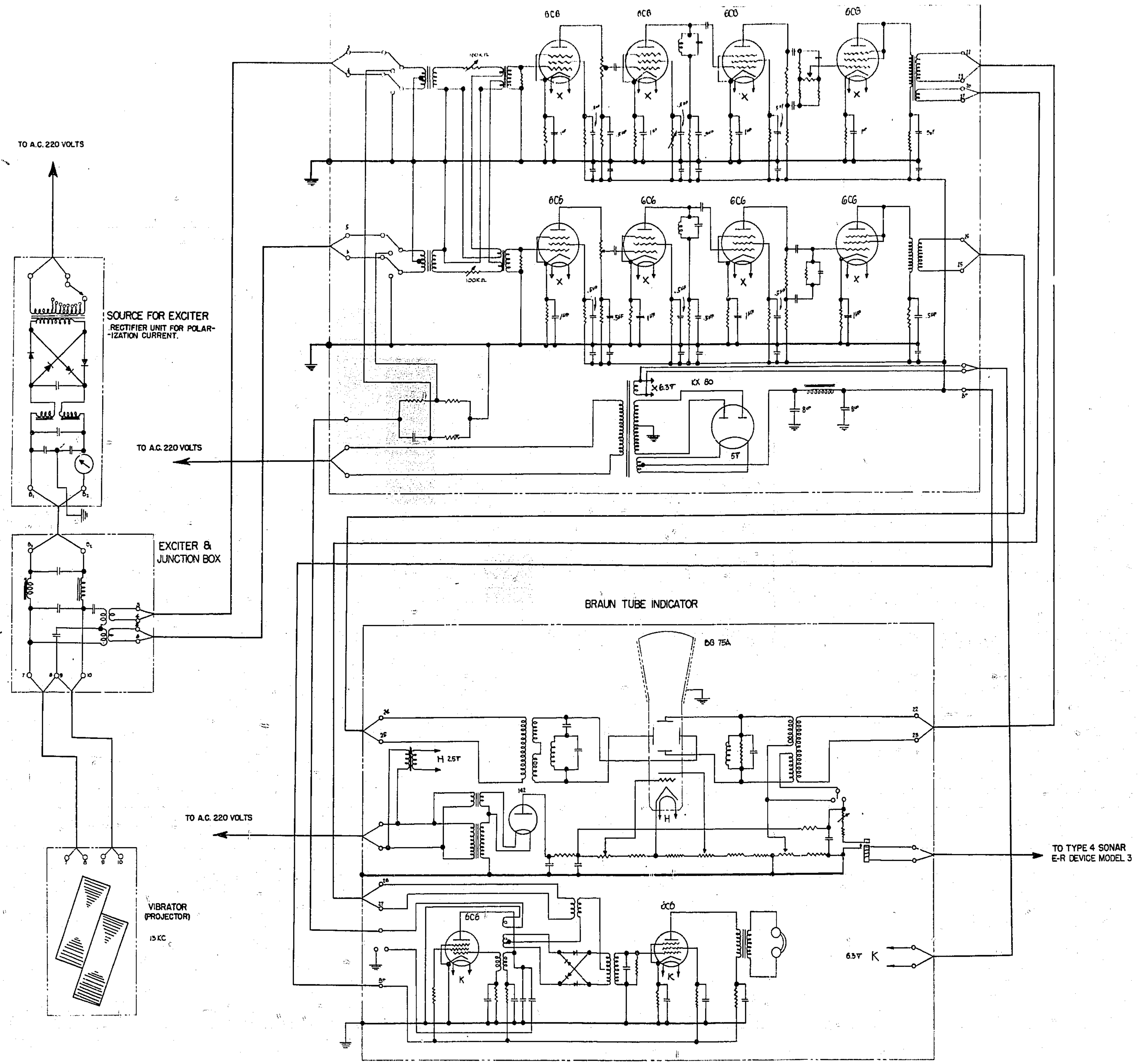


Figure 38
MAGNETO - STRICTION PROJECTOR
FOR UNDERWATER COMMUNICATOR SET

Figure 39

DIP-ANGLE DEVICE



Part VIII

REDUCTION OF "OWN SHIP's NOISE" WITH SPECIAL REFERENCE TO SONAR

Attention was first paid to reduction of own ship's noise in 1940, but it was not until the receipt of some German-made sound absorbing rubber mountings in 1942 that major research was instituted. A report on experiments, with specific application to sonar operation, appeared in August of that year. A later report, in November, 1944, is concerned with the emanation of noise from a submarine underway.

Research carried out by the acoustic department of the Second Naval Technical Institute was directed at the following objectives:

- To reduce the threshold level of sound in sonar operating positions and so enhance the value of listening instruments.
- To reduce the underwater noises radiated from the ship's hull and so lessen the range at which such noises might be intercepted by listening devices.
- Concurrently, to minimize the shock damage sustained in submarines when subjected to depth-charge attack.

The methods adopted consisted primarily of mounting the main engines, auxiliary machinery, connecting pipes, and propeller shafts on vibration and sound-absorbing rubber blocks. Details of such methods and of their applications will be found in NavTechJap Report, "Japanese Naval Vessels - Own Ship's Noise", Index No. S-43. The Sonar Room received individual treatment, felt strips being largely used for sound lagging purposes, although more recently, a sound absorbing enamel with raw rubber base had been successfully developed and stated to be equally effective. In September, 1942, tests were made on a British saddle - type, anti-vibration mounting designed for use with Sonar instruments, and as a result of which, the Japanese manufactured a similar type in various sizes.

Experiments were made with an "A" Class Defense Ship with an approximate displacement of 1000 tons . The threshold noise level in the Sonar Room was stated to have been reduced by 15 to 20 db. This resulted in the detection range of the hydrophone effect of a 100-ton launch being increased from 1500 to 8500 meters. The intensity of noise emitted from the hull when underway was reduced up to 20 db, depending upon ship's speed. The experimental results are shown in Figure 40, in which comparisons are made with other similar ships on which no modifications had been made.

Investigations into the underwater noises propagated by a submarine underway are stated to have been originally carried out to provide reference data for hydrophone equipment. The experiments took the form of measuring the sound intensity in various directions. A ship fitted with hydrophone gear was anchored in position while the submarine proceeded to trace out the track chart shown in Figure 41. During this time, the range and bearing of the submarine, with reference to the ship, would be carefully noted at half-minute intervals. The phasing control of the hydrophone set would be continuously operated to correspond with these bearings, the noise intensity being registered on an automatic recorder. These results were then interpolated in the form of polar diagrams showing intensity of sound at various bearings and different ranges. A typical example is shown in Figure 41. These results were obtained in an experiment with an "RO" type submarine at 4 knots, the recording ship being fitted with Type 4 hydrophone equipment.

Additional information with reference to this subject may be obtained from the seized documents ND21-6244, ND21-6252, and ND21-6253, which will be available at WDC (see Enclosure (A)).

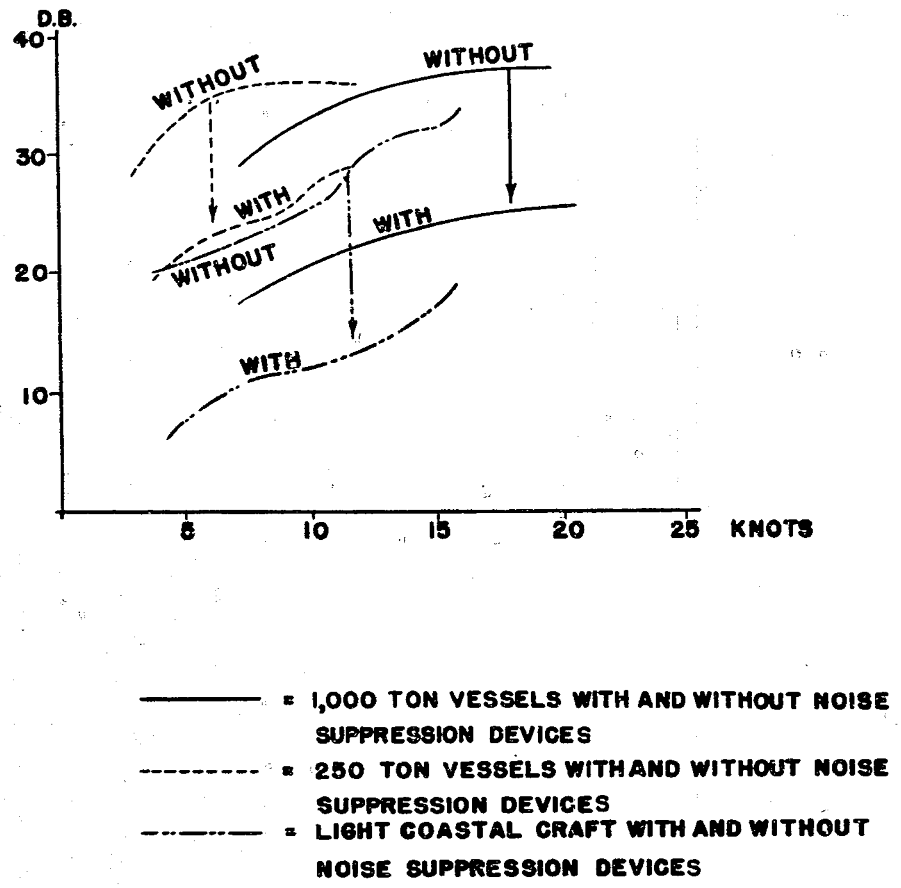


Figure 40

NOISE LEVELS OF SHIPS FITTED AND SHIPS NOT FITTED WITH NOISE SUPPRESSION

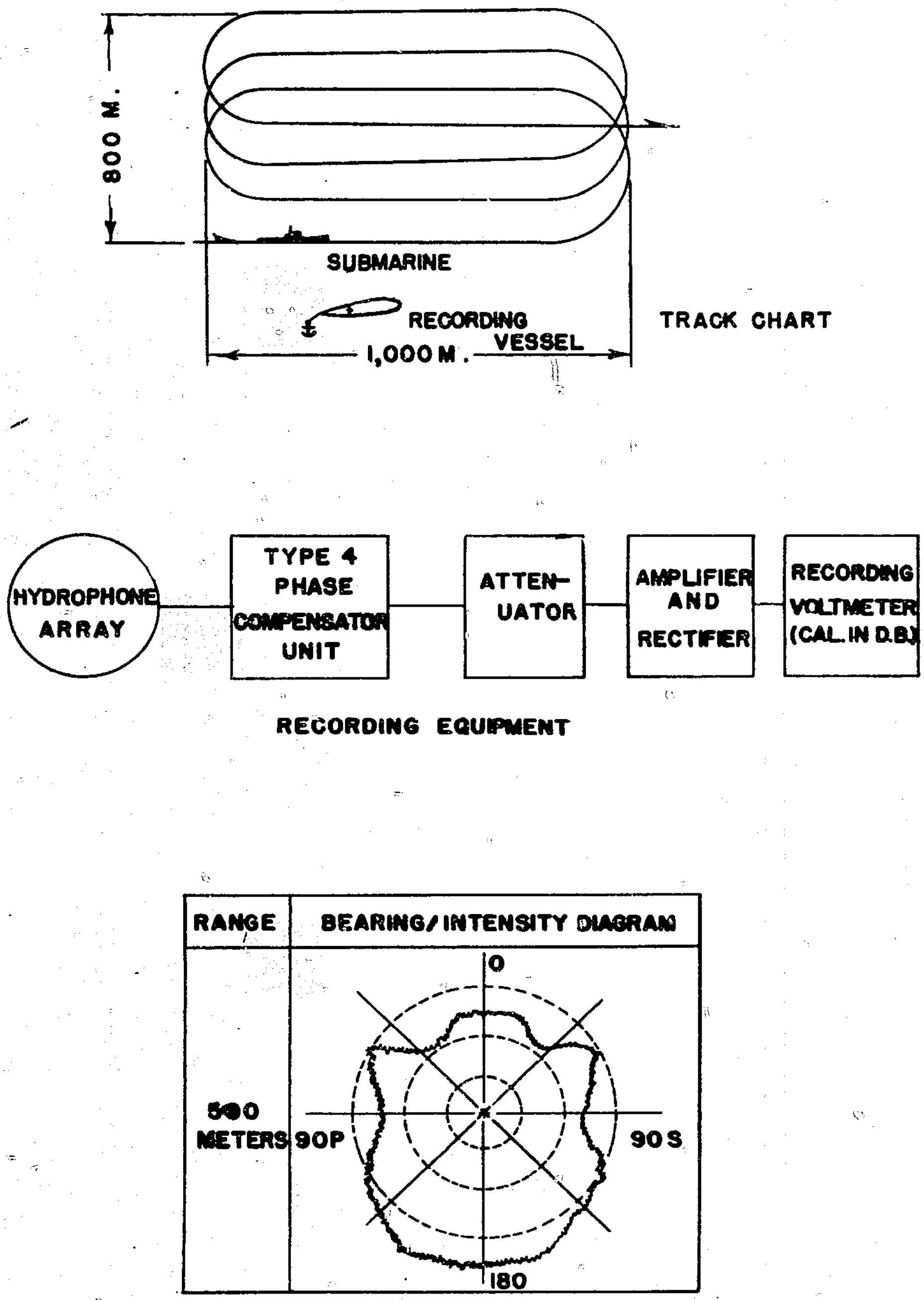


Figure 41
MEASUREMENT OF NOISE LEVEL OF A SUBMARINE

Part IX

DECOY AND OTHER DEVICES EMPLOYED FOR EVASION OF SONAR BEAMS

Research into decoy and similar devices was surprisingly small and only two types were ever produced. The "bubble target" so extensively used by German U-boats was experimented with but was not adopted. Rather, more attention had been given to the application of external sound-absorbing coatings to submarine hulls.

The most popular decoy device was known as a Noise Making Buoy and is roughly illustrated in Figure 42. It consisted of a watertight container containing a battery-driven motor with double shaft extension, the whole device having slightly negative buoyancy. One motor shaft was coupled to a second shaft passing through a watertight gland and fitted with a small propeller, the purpose of which was to give motion to the device in any random direction. The hydrophone effect of the propeller was considerably enhanced by a noise-making mechanism driven by the other shaft extension of the motor. This mechanism consisted essentially of a disc fitted with "teeth" around the periphery which made contact with the inside wall of the drum casing. The device was arranged for release from submarine while submerged and was stated to be realistic in use.

The second device developed consisted of a small streamlined body fitted with a moving-coil hydrophone unit, and it was towed 50 to 100 meters astern. The hydrophone was used as a transmitter and could be energized from any suitable signal generator or by sound film recordings of hydrophone effects. It was unpopular with submarine commanders and was little used operationally.

At the time of the surrender, it was standard practice for sound absorbing coatings to be applied to submarine hulls after every patrol. The material used was applied in plastic form and subsequently "hardened" to a soft fibrous texture about one-half inch in thickness and resembling grey asbestos-fibre lagging material. By its use, the speed of the submarine was reduced approximately 1 knot.

This material was developed in the hope that sound waves would not be reflected if the entire surface of the submarine were covered, in effect, by small air-bubbles. It is claimed that the results of experiments made showed that up to 78% of the sound energy was absorbed. (See NavTechJap Report, "Japanese Anti-Radar Coverings", Index E-06; and "Japanese Naval Vessels-Own Ship's Noise", Index S-43).

Its composition in percentage by weight is as follows:

		Below Waterline	Above Waterline
Base:	Special Latex	21 %	21 %
	Casein	6	6
	Gum Arabic	3	3
Pigment:	Sulphur		0.7
	Vulcanization Accelerator		0.3
	Anti-Weathering Material		0.3
	Portland Cement	16	16
	Silicon Oxide (SiO_2)	30	30
	Calcium Carbonate ($CaCO_3$)	10	8.7
	Iron Oxide Powder (Fe_3O_4)	2	2
	Carbon Black	0.3	0.3
	Mica Powder	0.7	0.7
	Asbestos Powder	11	11

The method of application is to apply two layers the first day (no special undercoating necessary), and two further layers the second, subsequently allowing two days for drying. When sulphur chloride bubbles have formed, a coat of MK2 ships-hull paint is applied. To vulcanize the surface coating above the waterline, a vulcanizing fluid is applied, this fluid comprising a 0.3% sulphur trichloride solution.

The Institute of Physical and Chemical Research was stated to be actively engaged in developing a coating consisting of alternating layers of sponge rubber and metallic strips, but this method never reached the production stage.

No Japanese documents dealing with this subject were discovered.

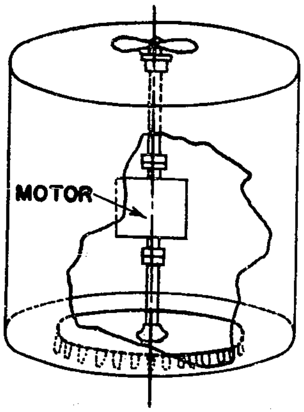


Figure 42

NOISE-MAKING BUOY

Part X

HYDROGRAPHIC INVESTIGATIONS WITH SPECIAL REFERENCE TO SONAR

Although it is evident from research and experimental reports that it was fully appreciated that the efficiency of Sonar operation varied considerally with sea and atmospheric conditions, very little practical use appears to have been made of this knowledge. When tabulating results of open-water trials, sea and air temperatures and the direction and force of the wind and sea were almost invariably recorded. Further, it had been frequently observed that Sonar conditions in Tokyo Bay were excessively poor due to presumed accumulations of minerals, vegetable, and other deposits. No data was obtained and collated in a form of practical value to anti-sub vessels. The only publica- issued by the Hydrographic Department is with reference to Fathometer Surveying (Hydrographic Bulletin Vol, 17, Nos. 10 - 12 (October - December 1938), "Method of Calculationg Velocity and Soundings by Sound Waves in Water").

Temperature gradients were measured for experimental purposes by the acoustic department of the Second Naval Institute at NUMAZU with the aid of a simple invertible thermometer which could be lowered to a required depth and then jerked sharply. This action served to fix the indication. The Third Section of the Seventh Military Laboratory, established for acoustic research at ITO, possessed more elaborate equipment of two types. One instrument was for precision measurements, and constituted two thermocouple elements connected to a bridge circuit of which the galvonometer was calibrated directly in degrees centigrade, the scale reading 2-0-2. The second device consisted, again, of two thermo-couple elements, one of which would be suspended just below the surface. The other element would be lowered from a drum, which , revolving as the cable unwound, caused a small recording drum to rotate, one revolution of this drum being equivalent to the full length of the cable, 50 meters. The two elements were again connected in a bridge circuit, in this instance a rheostat being operated continuously to keep the galvonometer at zero deflection. The rheostat knob was calibrated 30-0-30 degrees centigrade. Its operation caused a corresponding record to be made on the drum, which thus plotted temperature difference (between the two thermo-couple elements) against depth (or distance between them) in meters.

Such observations were taken merely for research purposes. No general measurements were made and, subsequently, indicated on hydrographical charts. However, thermal layers had been plotted for the use of submarine commanders with regard to the maintenance of trim. Also, tables giving temperatures recorded at the surface, and at depths of 10 meters, 25 meters, and 50 meters were available in certain publications. These publications bear numbers in the Series 8105 - 8116 contained in the "Catalogue of Confidential Charts and Books, Annexed Volume No. 1". (See NavTechJap Report, Oceanography in Japan", Index No. X-40(N)).

Consistent with the fact that no hydrographical information was published with specific reference to Sonar operating conditions, no charts were prepared and issued on which known "non-sub" contacts were indicated.

No documents relating to the subject of this article were discovered.

Part XI

RESEARCH INTO PROPAGATION OF SOUND IN WATER

In view of the attention given to the development of underwater listening and echo-ranging devices in pre-war years, remarkably little research appears to have been devoted to the fundamental factors affecting the transmission of sound in seawater. During the war, investigations were carried out by the acoustic department of the Second Naval Technical Institute at NUMAZU and, apparently independently by the Third Section of the Seventh Military Laboratory at ITO. Technical data recorded by both organizations is stated to have been burnt, but from information obtained, in neither case had research proceeded to a highly advanced stage.

At NUMAZU, a careful study had been made of attenuation at various frequencies and under varying conditions, including in particular, the reflectivity ratio and other factors introduced by air-bubble formations. Experiments were carried out with various materials to compare their suitability as "sound windows". As a result of these tests, celluloid had been adopted for certain application where the use of the otherwise universally employed stainless steel sheet presented manufacturing or other difficulties. The orignal use of 1mm stainless steel was, however, determined not as a result of research, but from its incorporation in the captured British-type streamlined sound-dome. The complex fading phenomena occuring during transmission of underwater sound had been observed, and similarly, the disturbing factors introduced by the turbulence resulting from passing ships, but no specific investigations had been carried out. It was stated that observations were about to be commenced when apparatus designed for the purpose was destroyed by the air-raid on NUMAZU in July, 1945.

Research was not commenced at ITO until the establishment of the laboratories in 1943. Experiments were conducted, within a range of 9-20 kc only, by use of a fixed sound source and an observation ship specially fitted out with receiving and recording equipment. The results obtained showed the need for continuous observations, and arrangements were being made at the time of surrender for locating fixed stations for both transmitting and recording apparatus. It was hoped to be able to establish a definite relation between efficiency of transmission and diurnal changes in atmospheric conditions and tides. Both fading and turbulence phenomena had been observed, but had been reserved for future research. A series of air-filled target bodies of various shapes were fabricated of mild-steel sheet and were used for investigating the reflectivity ratios at different orientations. They were fixed up to two meters below a flat-bottomed boat and measurements made while stationery and while in motion. A steel-wire sound-recording machine was installed for making sound records of experiments for future analysis.

Additional information may be obtained from reference to the following documents which will be available at WDC (see Enclosure (A)): ND21-6151, ND-6153, ND21-6056, ND21-6240, and ND21-6266.

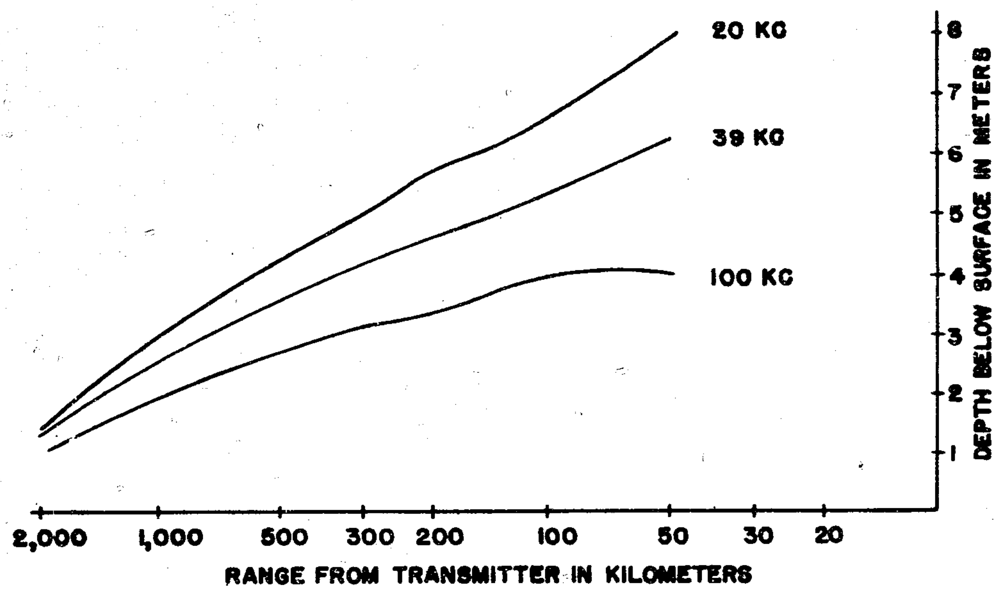
Part XII

UNDERWATER RADIO RECEPTION BY USE OF ULTRA-LONG WAVES

Japanese progress in this field is interesting insofar as they had available at OKAZAKI, a 750 kw ultra-long wave station, whereas to meet a similar demand in Germany, at the instigation of the U-Boat Command, a 500 kw transmitter was erected near Magdeburg. It has been reported that this station, operating at half-power on 20,000 meters was received by U-Boats off the southern tip of South America with the antenna 10 meters below the surface, a result considered barely satisfactory. The interrogation of Japanese personnel has brought to light the fact that not only was this system of communication used but that successful reception was experienced from the Okazaki transmitter at a position off Pearl Harbor, on 7 December, 1941, with the antenna 5 meters below the surface.

The transmitter at OKAZAKI was constructed in 1928 by Telefunken of Germany and was first used, primarily, to communicate with Germany during winter months when short wave reception was poor. It was operated between 7200 and 7400 meters using a high frequency alternator and a unique frequency tripling circuit. The normal receiving station is situated at OZAKI, some 100 miles distant. The antenna consists of sixteen equally-spaced strands supported on insulator-broken steel cables which were stretched between each of four pairs of masts, 250 meters high. These pairs of masts, in turn, were placed in line at intervals of 500 meters in such a way that the eight masts formed a rectangle, 1500 meters long by 300 meters wide. Each of the 3/8" copper antenna wires was approximately 1700 meters long, of which 1500 meters was flat top and 200 meters sloped down to the input junction. The sixteen wires, arranged in sets of eight wires, each parallel to the other on the flat-top for 1500 meters, converged downward from the end masts to two massive spiders, which were in turn connected by porcelain feed-through insulators (ten feet long, two feet thick) to the transmitter output. The antenna was thus apparently a 1/10 wave, 16 wire flat-top, and was beamed on Europe.

Serious consideration to underwater reception appears to have begun in JAPAN during the latter part of 1940. A detailed report of experimental work was published in the first months of the following year. Conventional receivers with D.F. antenna loops, varying from 520 to 1000mm in diameter and 24 to 16 turns respectively, were used during the initial trials and the early part of the war. The type most commonly referred to, and which gave satisfactory results, was known as standard "T"-type, Mark IV. Frequencies ranging from 20kc to 100kc were used for experimental purposes and maximum depths recorded at various ranges. A typical result is reproduced in Figure 43. Similarly,



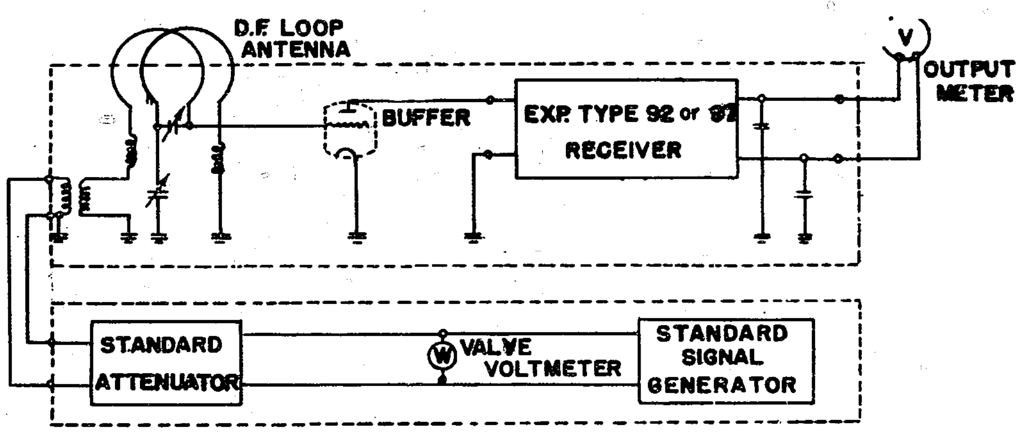


Figure 43
UNDERWATER RECEPTION ON ULTRA-LONG WAVES

attenuation figures in db/meter were recorded at different frequencies. The apparatus employed for these experiments is shown in Figure 43.

The success that attended early trials led to the development of a special receiver and antenna. The former is a very compact unit of conventional design. The new antenna consisted of two loops wound on iron-dust cores and mounted at right angles to each other. The two loops were connected in parallel and sealed in hard rubber for protection against water immersion. It is claimed that this new antenna gave a 10 db gain over the older D.F. loop, and that reliable reception was obtained, well over 2000 miles at antenna depths of 25 meters. The majority of submarines were equipped at the end of the war; the antenna being mounted just forward of the periscope as illustrated in Figure 44.

Attempts were made to convert high-powered transmitters, captured in the South Pacific and Indo-China, for ultra-long wave use, but failed due to inadequate antenna arrays and lack of power.

Additional information is obtainable from the seized documents ND21-6144, ND21-6145/1, ND21-6007, which will be available at WDC (see Enclosure (A)). (New type receivers, complete with antenna will be available at Naval Research Laboratory under NavTechJap Equipment Numbers JE 22-6131 and JE 22-6103).

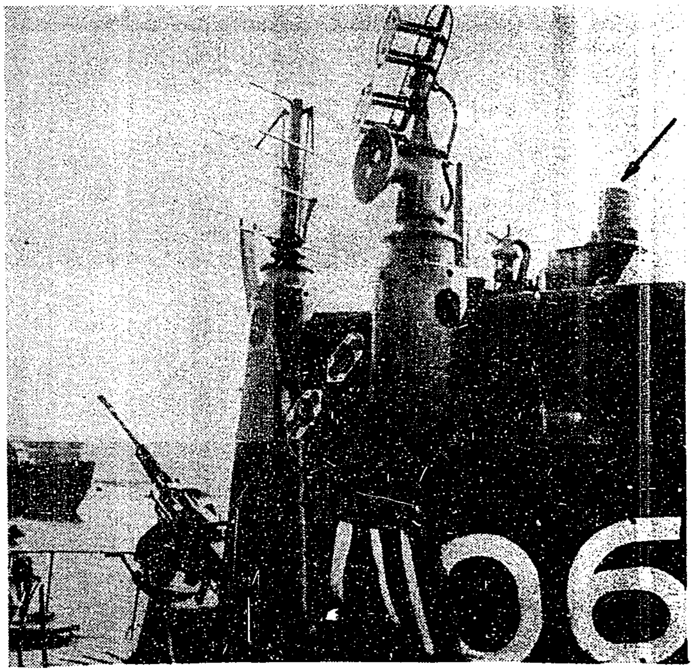


Figure 44
WATERTIGHT ANTENNA FOR UNDERWATER RADIO RECEPTION ON ULTRA LONG WAVES
(Situated Immediately Forward Of Periscope)

APPENDIX

Plans for the Installation of Underwater Sound Equipment.

Issuing Authority: Naval Technical Department
Date: April, 1945
Classification: Military - Very Secret

The following is an extract from Document ATIS No. 3433 (ND21-6238) which, in its complete form, will be available at WDC.

1. Installation Policy

a. In order to ensure unbroken sea communications between Japan, Manchuria, and China, and along Japan's coastal sea routes, particular emphasis is placed upon the maintenance of underwater sound equipment on picket boats, escort ships, and special attack boats (TN: Suicide boats).

b. By virtue of the existing installations on special duty boats in service within the waters of JAPAN proper, special non-navigating boats, merchant ships, and sailing boats, both the offensive and defensive powers of JAPAN are enhanced.

c. In the manufacture and installation of equipment, the chief factors to be raised to a high level are the reduction of breakdowns and the effectiveness of planning.

d. In addition to progress in the installation and research on underwater sound equipment for special attack boats, more extensive work on submarine equipment is similarly necessary.

e. The order of urgency in regard to this equipment is installation, production, and research, in that order.

2. Production Policy

(As indicated in Table VI, Part IV)

3. Installation Practice

(TN - This paragraph outlines the particular phases in the program where greater efficiency is required - e.g. clarification of inspection tests, precise installation, standardization of official tests, more efficient use of technical personnel and operators, and overcoming the difficulties of own ship's noise).

4. Experiments and Research

The particular points in the research program which require emphasis are as follows:

a. Special attack boats' equipment.
b. Elimination of breakdowns in existing equipment installations.
c. Installation methods and elimination of stray noise.
d. Development of other practical equipment.

ENCLOSURE (A)

LIST OF DOCUMENTS FORWARDED TO WDC VIA ATIS

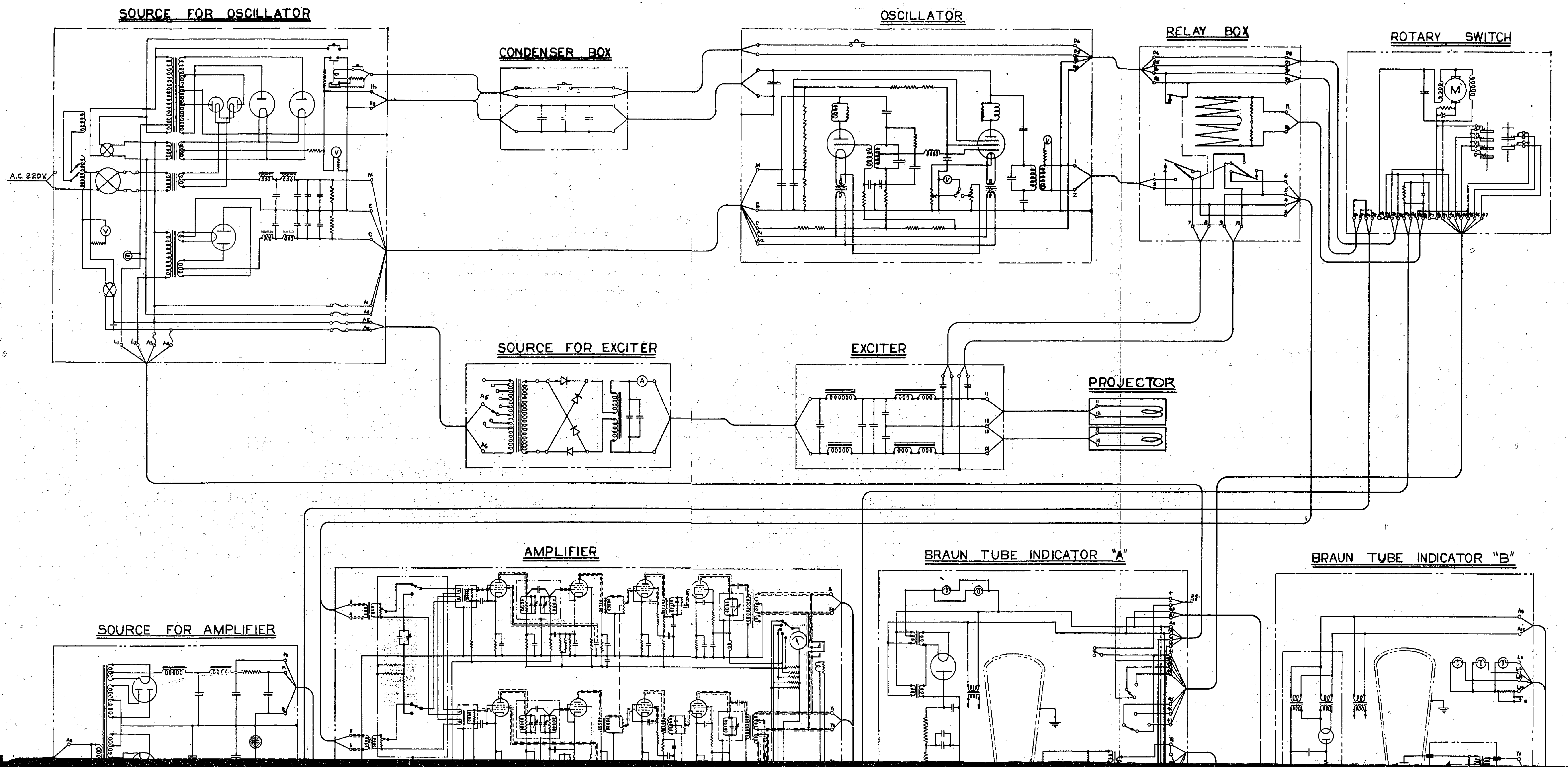
NavTechJap No.	Subject	ATIS No.
	PART I	
ND21-6215	Installation outline: Experimental Model OTSU ("B") Hydrophone.	3432
ND22-3010	List of electronics and Sonar equipment.	4342
ND22-3011	List of radars with characteristics.	4343
	PART II	
ND21-6212	Account of progress in research in echo ranging.	3430
ND21-6239	Test on the high-frequency generator used with temporarily designated Type 3 Model 2 Sonar.	3434
ND22-3010	See above.	4342
ND22-3011	See above.	4343
ND22-3013	Instruction manual: Temporarily designated Type 3 Model 2 Radar.	4345
ND22-3014	Schematic diagram. Temporarily designated Type 3 Model 2 Radar.	4346
	PART III	
ND21-6152	Study of substitute magneto-striction materials: Iron Aluminum alloy, AF alloy.	3426
ND21-6209	Underwater Listening.	3428
ND21-6214	Experiments in adjusting hydrophones.	3431
ND21-6241	Study of Rochelle salts oscillation.	3436
ND21-6242	Experiments on electrical theory of oscillation of X-450 cat Rochelle salt crystal.	3437
ND21-6243	Binaural listening.	3438
ND21-6245	Measuring performances of various hydrophones.	3440
ND21-6248	Hydrophone arrangement for sound reception.	3442
ND21-6265	Circular hydrophone arrangement for sound reception.	3446
ND21-6285	Explanation of underwater sound listening devices.	3448
	PART IV	
ND21-6238	Plans for sonar equipment.	3433

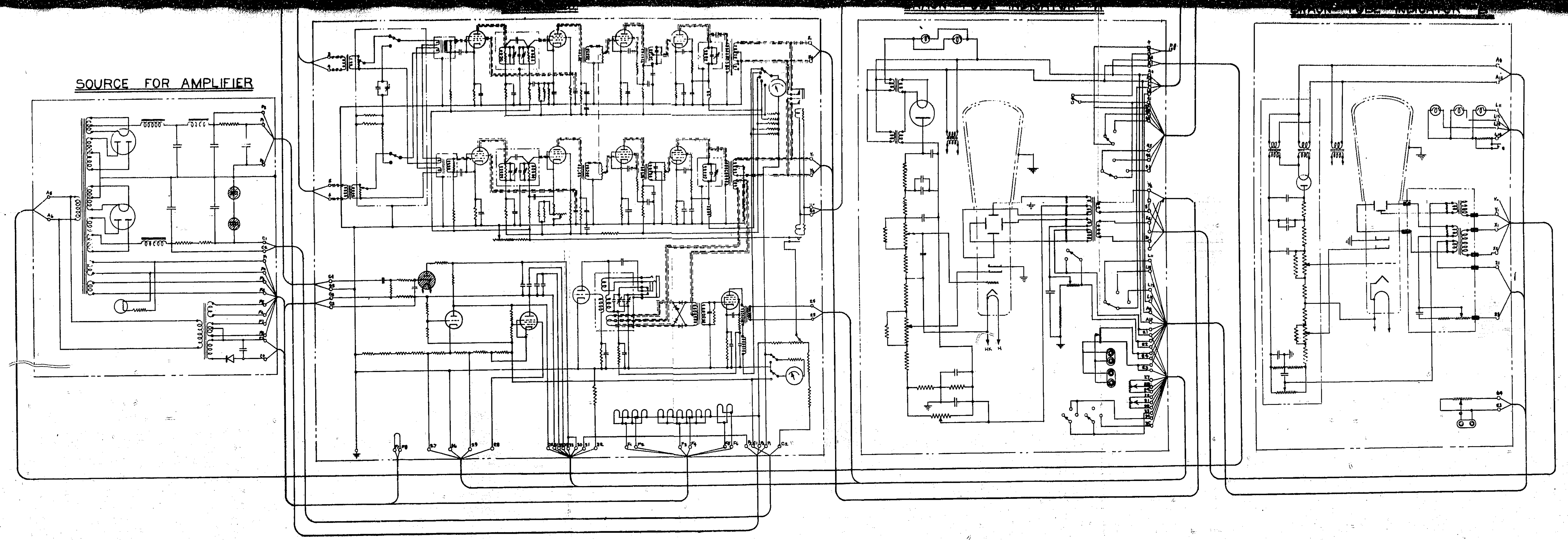
ENCLOSURE (A), continued

NavTechJap No.	Subject	ATIS No.
	PART V	
ND22-3015	Standard installation for ships of radio, radar, and underwater acoustic equipment.	4347
	PART VI	
ND21-6150	Measurement of attenuation ratio of vertically polarized supersonic waves on the surface of the sea and reflection ratios from the bottom of the sea.	3424
	PART VII	
	None	
	PART VIII	
ND21-6244	Experimental report on distribution in various directions of noise generated by submarines underway.	3439
ND21-6252	Research on sound and vibration absorbing materials (Third report): study on preventing noise generated in the ship's own sound room.	3418
ND21-6253	Research in sound and vibration absorbing materials (Fourth report): absorbtion effects of saddle-type shock absorbers.	3419
	PART IX	
	None	
	PART X	
	None	
	PART XI	
ND21-6151	Study of propagation of supersonic waves (1942).	3425
ND21-6153	Study on working of bubbles in underwater listening.	3427
ND21-6056	Investigation of the formation and electrical conductivity of sea-water.	3414
ND21-6240	Absolute measurement of underwater sound.	3435
ND21-6266	Propagation of supersonic waves (1942).	3447
	PART XII	
ND21-6144	Underwater wireless reception.	3416
ND21-6145/1	Underwater wireless reception material.	3417
ND21-6007	Results of experiments designed to determine depth of underwater radio receiver using watertight antenna.	3413

ENCLOSURE (B)

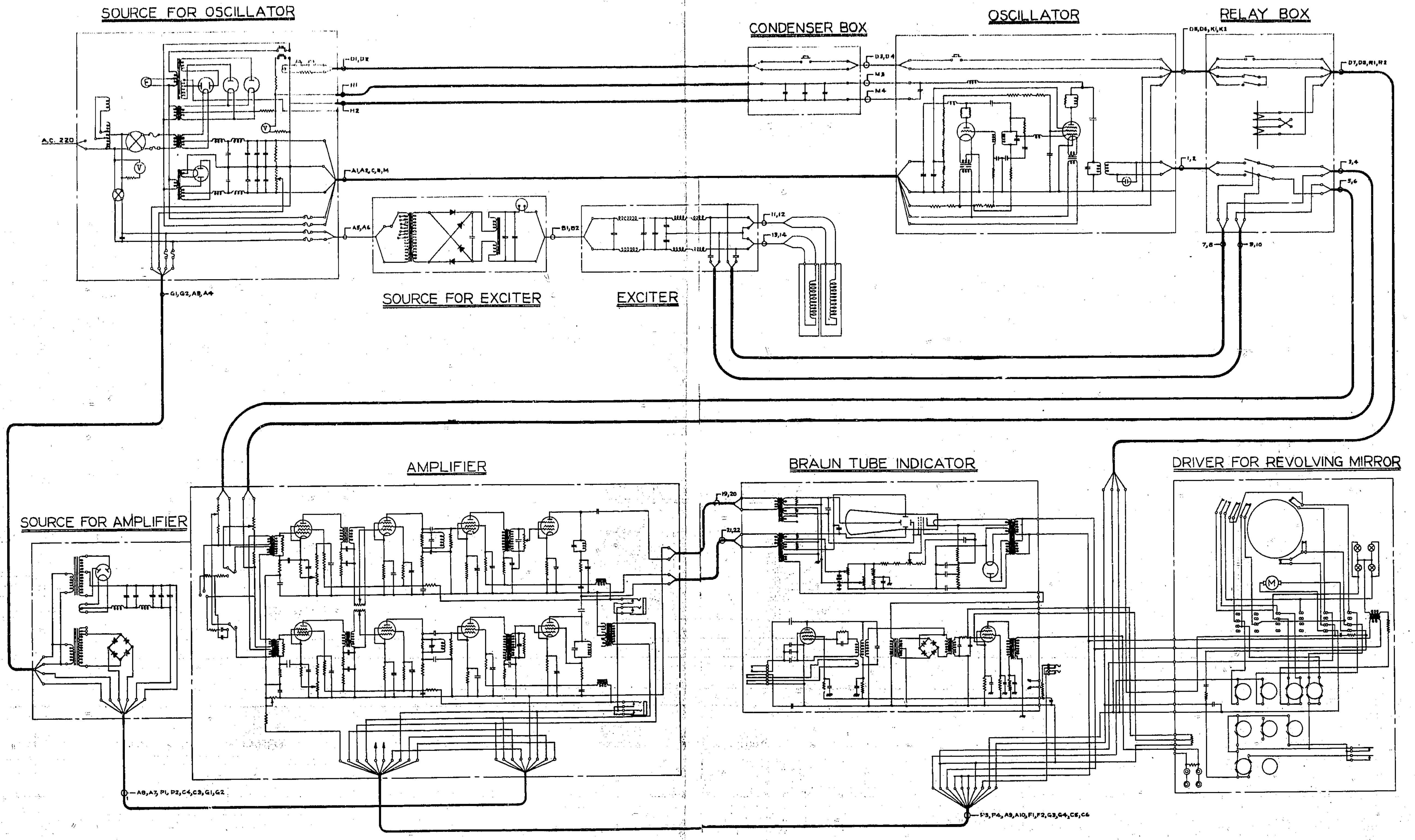
SCHEMATIC DIAGRAM - UNDERWATER ECHO RANGING DEVICE - TYPE 3 MODEL 2





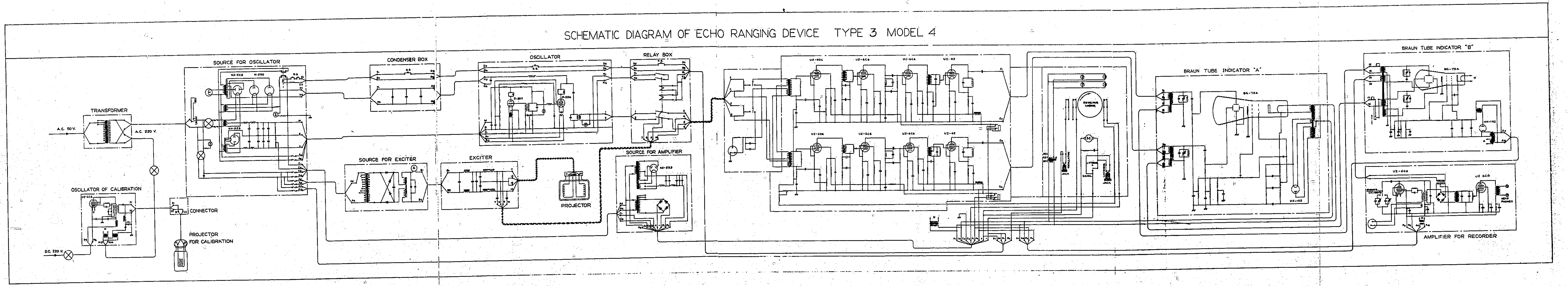
TYPE 3 MODEL 2 ECHO-RANGING SET

ENCLOSURE (C)



TYPE 3 MODEL 3 ECHO-RANGING SET

ENCLOSURE (D)


SCHEMATIC DIAGRAM OF ECHO RANGING DEVICE TYPE 3 MODEL 4
TRANSFORMER
A.C. 50 V.
A.C. 220 V.
SOURCE FOR OSCILLATOR
CONDENSER BOX
OSCILLATOR
RELAY BOX
OSCILLATOR OF CALIBRATION
D.C. 220 V.
CONNECTOR
PROJECTOR FOR CALIBRATION
SOURCE FOR EXCITER
EXCITER
PROJECTOR
SOURCE FOR AMPLIFIER
BRAUN TUBE INDICATOR "A"
BRAUN TUBE INDICATOR "B"
AMPLIFIER FOR RECORDER