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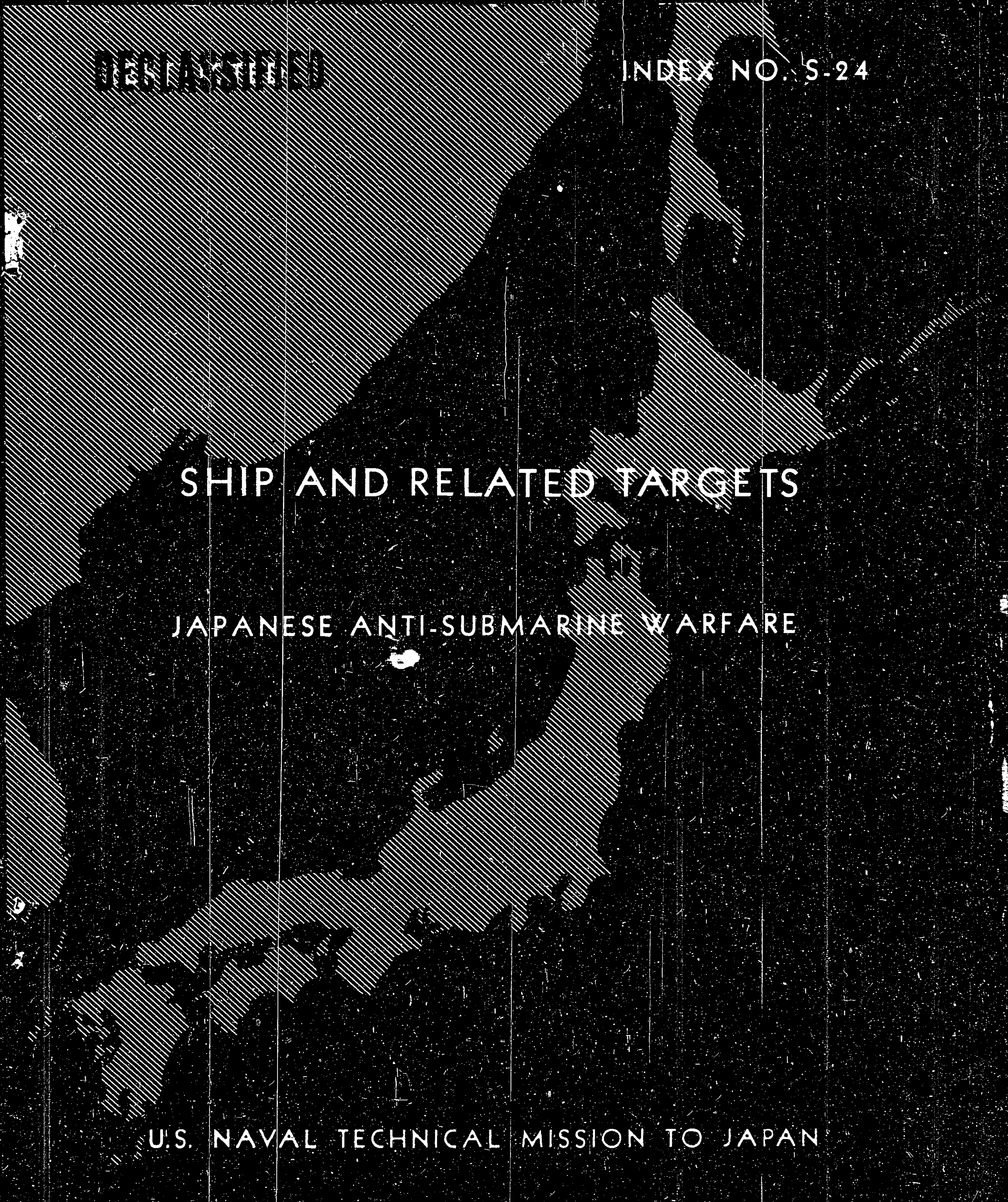
INDEX NO. S-24



SHIP AND RELATED TARGETS

JAPANESE ANTI-SUBMARINE WARFARE

U.S. NAVAL TECHNICAL MISSION TO JAPAN

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U. S. NAVAL TECHNICAL MISSION TO JAPAN
CARE OF FLEET POST OFFICE
SAN FRANCISCO, CALIFORNIA

8 February 1946

RESTRICTED

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

Subject: Target Report - Japanese Anti-Submarine Warfare.

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

1. Subject report, covering Targets S-24, S-26, S-71, S-72, S-75, and S-76, of Fascicle S-1 of reference (a), is submitted herewith.

2. The investigation of the targets and the target report were accomplished by Captain A. Jackson, Jr. USNR, assisted by Lt. Comdr J. E. Miller, USN.

C. G. GRIMES
Captain, USN

32416

RESTRICTED S-24

JAPANESE ANTI-SUBMARINE WARFARE

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

FASCICLE S-1, TARGETS S-24, S-26, S-71, S-72, S-75 AND S-76

FEBRUARY 1946

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

SHIP AND RELATED TARGETS

JAPANESE ANTI-SUBMARINE WARFARE

In summarizing the Japanese anti-submarine war effort, the most striking feature is the enormous gulf between their conceptions and their accomplishments.

The high command had given consideration to almost every phase of advanced anti-submarine warefare. Improved echo-ranging equipment, influence and acoustic depth charges, deep-setting depth charge pistols, chemical recorders, ultra high frequency voice radio, surface search for escorts and aircraft, magnetic detection equipment for planes, standardized and improved doctrine and tactics, ahead thrown rockets, and joint air-surface offensive tactics - all were considered, studied, and, in many cases, successful solutions obtained and production started.

Nevertheless, the end of the war found many escorts without radar. Those equipped with radar and the improved echo-ranging equipment were unable to obtain satisfactory results. Training was practically non-existent after the first shakedown cruise. One small land-based "hunter-killer" organization existed. Depth charges with deep-setting pistols and actuated by influence or acoustic devices had been developed but were not in production. Planes and surface escorts were equipped with voice radio but were still unable to communicate due to technical difficulties.

Lack of production, the devastating inroads on their supply lines by our submarines, and the necessary allocation of production to aircraft for the final defense of the Empire, of course, affected the anti-submarine forces, but there also existed a failure on the part of the operating personnel to use what they did have to best advantage. They showed a definite lack of adaptability in utilizing improved methods.

Summing up, it may be said that the failure of the Japanese to develop an ahead thrown weapon similar to our Mark 11 Projector marked the greatest single disparity between their ASW effort and ours, and in other respects as well there remained nothing to be learned from them in any phase of anti-submarine warfare.

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LIST OF ENCLOSURES

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REFERENCES

Japanese Personnel Interviewed:

Rear Adm. Toshio, AKIYOSHI, Chief, First Section, Hydrographic Office.
Comdr. Yasuo, FUJIMORI, CO of submarine, War College graduate, General Staff officer.
Comdr. Tsunaji, YONEHARA, ASW air groups.
Lt. General Chobe, MOMONOBE, Chief of Shipping Bureau.
Rear Adm. S. NABESHIMA, Chief of ASW School.
Lt. Comdr. Shisei, YASUMOTO, CO of Japanese DD in ASW and Staff, Escort Group #7.
Capt. S. YAJIMA, Technical Department, ASW Devices.
Capt. UOZUMI, IJN, Chief of Staff, First Escort Fleet, TAKAO.
Comdr. Toshigo, SUGITO, Staff Officer, Headquarters, Grand Escort Fleet.
Comdr. Kiezoshi, SOGAWA, Staff officer, Naval General Staff.
Rear Adm. S. HORIUCHI, CofS, First Escort Fleet and CO, 901st Air Group.

Pertinent Reports:

APO 925 Air Technical Intelligence Group, Report #92
USSBS Interrogation #371 Nav. #74
USSBS Interrogation #246
USSBS Interrogation #236
USSBS Interrogation #229 Nav. #57
USSBS Interrogation #228 Nav. #56
USSBS Interrogation #225 Nav. #53
USSBS Interrogation #208
USSBS Interrogation #200 Nav. #48
USSBS Interrogation #199 Nav. #47
USSBS Interrogation #194 Nav. #45
USSBS Interrogation #159 Nav. #37

NavTechJap Report "Japanese Submarine Operations", Index No. S-17

INTRODUCTION

The method of obtaining material was, first, to collate information previously obtained by other investigations and, second, to interview key Japanese officers responsible for the prosecution of anti-submarine warfare.

On 25 August 1945 the Grand Escort Fleet and subsidiary commands were dissolved and all records and publications, insofar as can be determined, were burned on that date. All staff officers of the higher commands have insisted upon this. This report, therefore, is based entirely upon verbal testimony. Statements which disagreed, however, were traced to responsible officers for solution, and it is believed that the final report reflects an accurate picture of Japanese anti-submarine warfare, its organization, methods, equipment, and procedure as it existed at the war's end.

The anti-submarine action reports submitted as enclosure (A) are not originals but were obtained from a personal notebook kept by Commander SOGAWA, a staff officer attached to the Navy General Staff.

NavTechJap Report, "Japanese Submarine Operations", Index No. S-17, contains a list of Japanese claimed sinkings of U.S. submarines. This list was compiled by Commander SUGITO with the assistance of other officers on the Staff of the Grand Escort Fleet.

THE REPORT

Part I
JAPANESE ASW ORGANIZATION

A. GENERAL

The original concept of the Japanese Navy was that the anti-submarine phase of naval warfare would, in general, be that of screening fleet units. The heavy shipping losses inflicted by U.S. submarines, however, soon made the defense of shipping a matter of vital importance to the Empire.

The eventual organization arrived at was the formation in November 1943 of an overall command, responsible entirely for the escort and protection of shipping. The organization was called the Grand Escort Fleet; it was commanded by an admiral and had its headquarters in TOKYO.

This command was divided into naval bases (insofar as matters concerning convoys and escorts were concerned) and the First Escort Fleet. The First Escort Fleet consisted of four surface escort groups, and a specially trained air group. Each surface escort group was a tactical unit and each was commanded by a flag officer. These forces completed the surface organization for major long range convoys. Area Fleet Commanders operated local convoys. A coast defense organization was maintained to augment surface escorts in convoys when they passed through waters known to be exceptionally dangerous; and to reinforce, and in some cases to relieve, convoy escorts when developing contacts. A number of captains were available to command small escort units with small convoys.

The air groups assigned to conduct ASW operations, and to provide air cover to convoys were specially trained groups, including four escort carriers. The carriers and Air Group 901 operated directly under the command of the First Escort Fleet. The other groups operated under the Grand Escort Fleet through naval base commanders.

The Anti-submarine Warfare School was organized and operated under the Grand Escort Fleet and was responsible for training and for the improvement of ASW technique.

An outline of the organization is shown in Figure 1.

B. COMMAND RELATIONS

1. Overall Command

The commander of the Grand Escort Fleet at TOKYO exercised overall command of escorts and convoys throughout all areas. The commander of the First Escort Fleet was responsible to him directly, as were the Commandants of all Naval Bases in regard to matters relating to the escort of convoys.

2. Convoy Tactical Groups

The commander of the First Escort Fleet Commanded the surface components of the forces involved in the escort of convoys. The surface forces were organized into four tactical groups for major convoys, each under the command of a rear admiral or vice admiral. These officers commanded both the convoy and the escorts when at sea. Smaller convoys were commanded by captains.

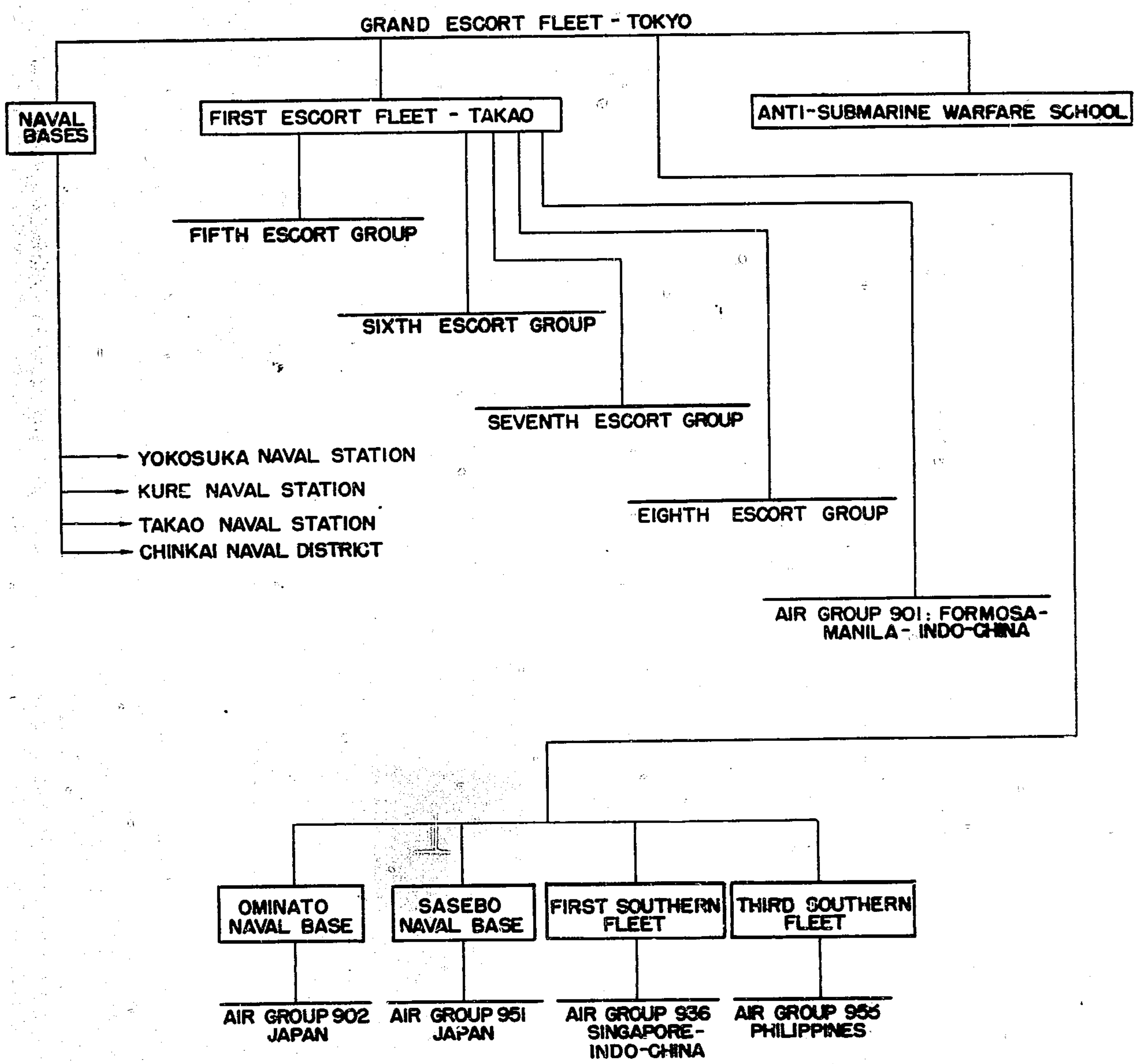


Figure 1
ASW ORGANIZATION

There was no permanent assignment of escorts to a particular group. The designation of escorts was effected by the First Escort Fleet Headquarters, the number and type of escorts depending upon the size of the convoy and the escorts available.

3. Area Fleet Commanders

Group Commanders after receiving their tasks were at first allowed to choose their own routing, subject to limitations and to change by the First Escort Fleet commander, or by local area fleet commanders if intelligence made the change advisable. Group commanders were also under the command of the local fleet area commanders for routing, change of routing and intelligence. Later, the Grand Escort Fleet Headquarters laid out the entire route with sailing instructions, from the start to the finish of the voyage.

4. Air Group Commanders

The ASW air groups were responsible for patrolling the convoy lanes and furnishing air cover to the convoys as they passed through their localities. As the lack of fuel became serious, routine searches were replaced by specific searches when submarines were suspected or sighted.

5. Air-Surface Commanders

Air-surface command, when contacts were made, theoretically became the function of the escort or group commander, but actually, plane to ship communications were so poor that no command was exercised.

Escort carriers, when operating in a convoy, were under the general command of the convoy group commander, but only four escort carriers were available, and they were therefore used only in particularly important convoys of twenty-five ships or more.

When used with convoys, these carriers remained in the convoys. They were not used offensively, and there had been no conception of their use with escorts for combined air-surface operations as hunter-killer groups.

Part II
AIR AND SURFACE SEARCH AND ATTACK PROCEDURE

A. SURFACE SEARCH AND ATTACK PROCEDURE

1. Harbor Protection

Typical Japanese anti-submarine harbor protection provided a magnetic loop at the harbor entrance as a warning device to alert local ASW craft and the operators of the controlled minefield.

Hydrophones attached to buoys were placed inside the harbor to pick up propeller noises of the submarine and to allow its position to be tracked as it approached the controlled minefield.

The controlled mines were wired to control boxes, each controlling twenty-four mines, so that any desired cluster of six could be exploded simultaneously. These mines contained microphones also, and when volume of propeller noise reached a peak in one section, a visual check was made on the bearing and if clear, the mines were fired. Mines were usually planted at twenty meter depths.

For technical details of the operation and wiring of these fields see "Survey of Japanese Seacoast Artillery" by GHQ, AFPAC, Seacoast Research Board, and NavTechJap Reports, "Japanese Mines," Index No. 0-04; "Japanese

Naval Mining Organizations and Operational Techniques," Index No. 0-05; and "Japanese Electronic Harbor Protection Equipment," Index No. E-26.

A typical installation is shown in Figure 2.

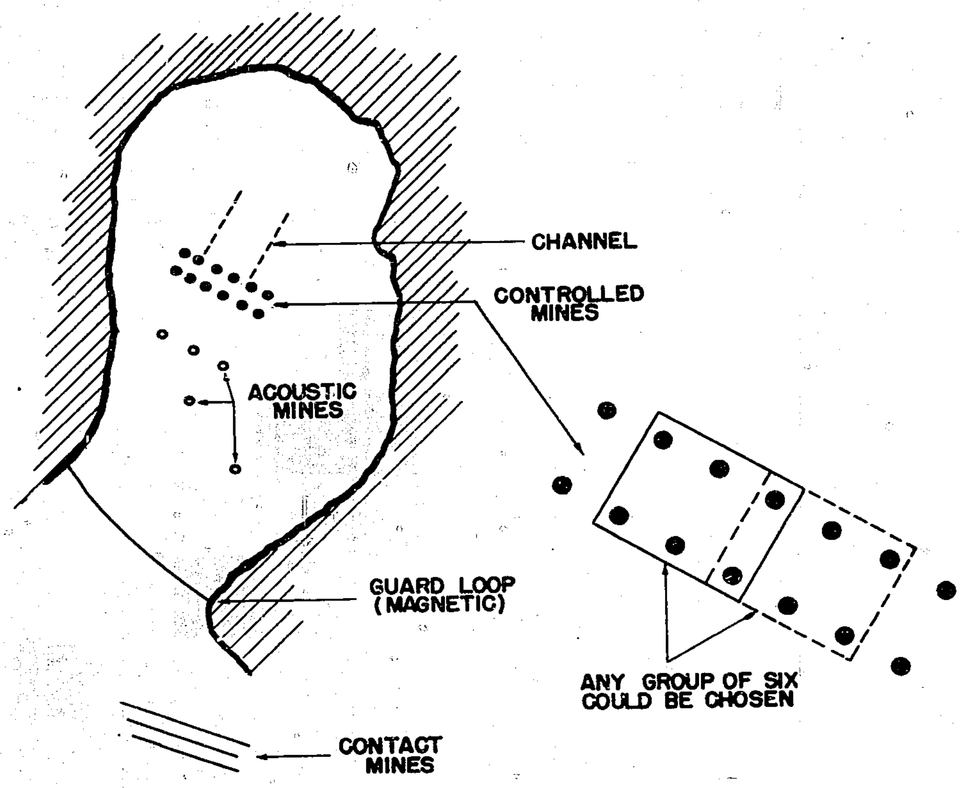


Figure 2

TYPICAL CONTROLLED MINEFIELD

2. Method of Search

Escorts partolled their stations and searched their sectors by echo-ranging throughout an arc of 60°. Japanese search doctrine designated six types of search to be used in the escort of convoys:

a. Visual
b. Echo-ranging
c. Sound gear
d. Radar
e. Counter radar (Radar transmission detection)
f. Aircraft

After considerable questioning, it was determined that (b) and (c) above were both conducted by echo-ranging but with different types of sonar gear.

3. Contact Procedure

Immediately upon picking up an echo, contact was reported; in daylight, by flag hoist; at night, by Very pistol. The escort then turned to head for the contact, went to twelve knots and commenced a deliberate attack.

4. Classification of Contact

Contacts were evaluated by the sound of the echo (clear or mushy), by noises in the receiver (they recognized fish noises, -(see NavTechJap Report, "Oceanography in Japan," Index X-40 (N)), bearing movement, bearing width, and "braun tube" indications. All officers questioned listed these as being complete and it was apparent that no use was made of doppler, range rate or recorder traces. The "braun tube" referred to above was the Japanese terminology for the range indicating device in the Japanese designed sound gear.

5. Conning Procedure in Conducting Attack

Conning procedure is listed below, in sequence of steps taken in the conduct of the depth charge attack:

a. Head for contact and slow to twelve knots.
b. Determine bearing change and commence hand plot (bearings from sound gear, ranges from chemical recorder or "braun tube").
c. If no bearing change, continue heading for target.
d. If bearing drift noted, turn to new bearing. Continue hand plot.
e. At 800 meters increase speed to 16 knots and lead target by amount that hand plot indicated for depth charges to reach submarine.
f. Drop charges, based on firing time from chemical recorder.

(Note: This seems to have been the only use made of the range-rate slope).

Sketches given in Figure 3 were those made by a Japanese destroyer captain in illustrating his conning procedure. Actually, the hand plot for determining the submarine's course and speed, and the lead angle was impractical and was determined by estimate. Note: Wake echos on beam targets were used to determine the submarine's stern from bow, the submarine's consequent course was determined entirely by sound of echo, recorder traces not being recognized.

An alternate method of attack was in use, in which echo-ranging was used until the ship was within 800 meters of the target at which time speed was reduced to six or eight knots, echo-ranging switched to listening, and the attack made by attempting to run down the bearing of propeller noises, and dropping charges when intensity of sound indicated the escort to be over the submarine target.

6. Depth Charge Patterns and Settings

The Japanese had no means of determining the depth of enemy submarines, and their depth charge patterns were designed to cover all depths within the limitations of the depth settings on their charges. Side throwers were used. Small patterns were used on doubtful contacts. Doctrine called for maximum patterns to be dropped on contacts classified definitely as submarines. Destroyers engaged in convoy work were capable of carrying ninety depth charges and on sure contacts dropped a pattern of thirty-six. A sketch showing the design of the pattern in depth is shown in Figure 4.

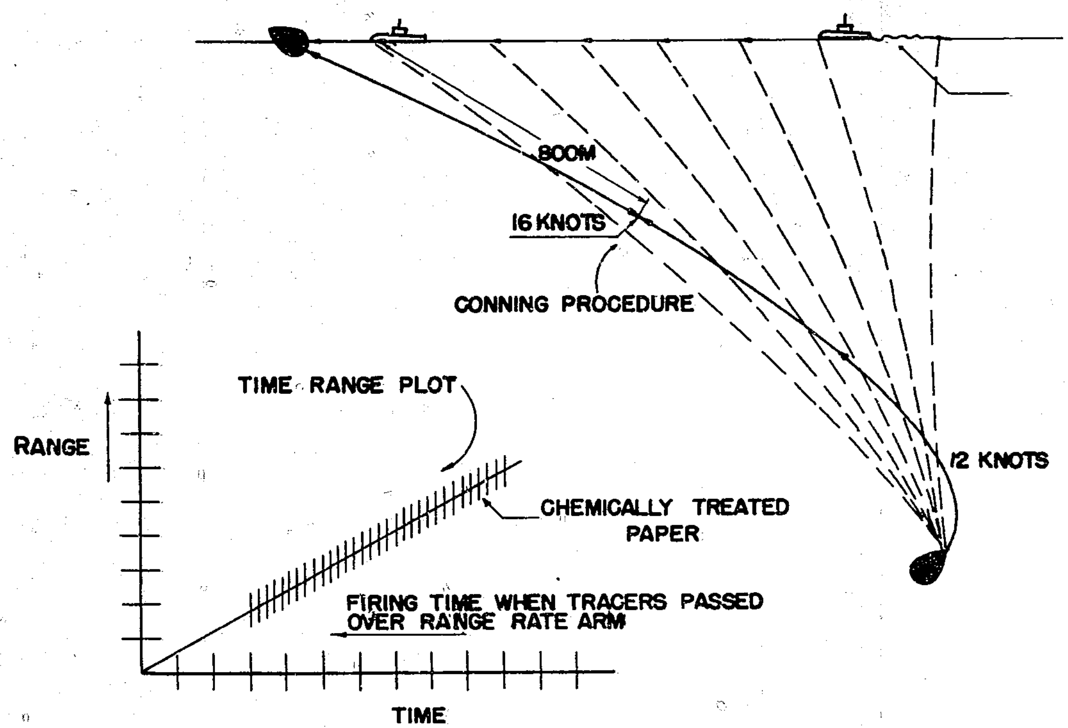


Figure 3

CONNING PROCEDURE AND TIME-RANGE PLOT

Charges were set just prior to the attack, patterns in width were dropped for the center of the pattern to cover the expected position of the submarine, and the size of this pattern varied with the number of side-throwers carried. The barrage was completed by dropping the remainder of the charges from the stern racks.

Figure 5 shows a typical pattern used by the "coast defense" ships (KAI-BOKAN), the counterpart of U.S. destroyer escorts.

7. Deep Submergence Attacks

As the Japanese were unable to estimate the depth of the submarine target, no specific technique had been developed for attacking submarines that took refuge in deep submergence. Maximum depth setting of charges usually carried was 120 meters and a proportionate number of charges with this setting was included in each pattern.

"Q" deep-setting pistol for depth charges had been developed, but, apparently, issue to ships had not become general and no specific doctrine for its use had been developed.

Inasmuch as deep-setting pistols had been designed it is possible that the Japanese were working on the idea of special procedure for this type of attack.

Influence and acoustic depth charges were in the process of development but operating personnel were not familiar with them.

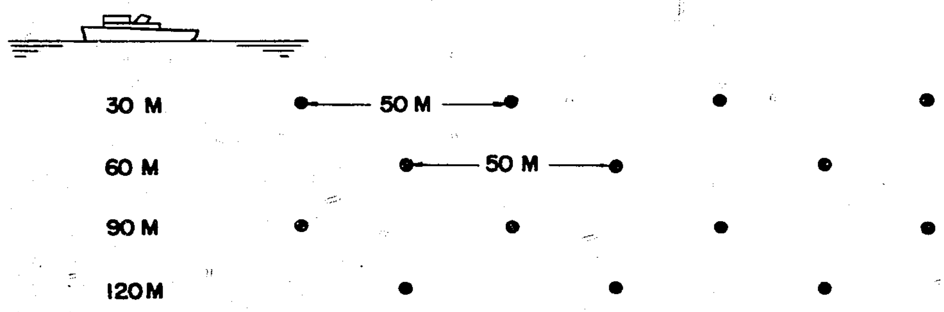


Figure 4

TYPICAL DEPTH CHARGE PATTERN - DESTROYERS

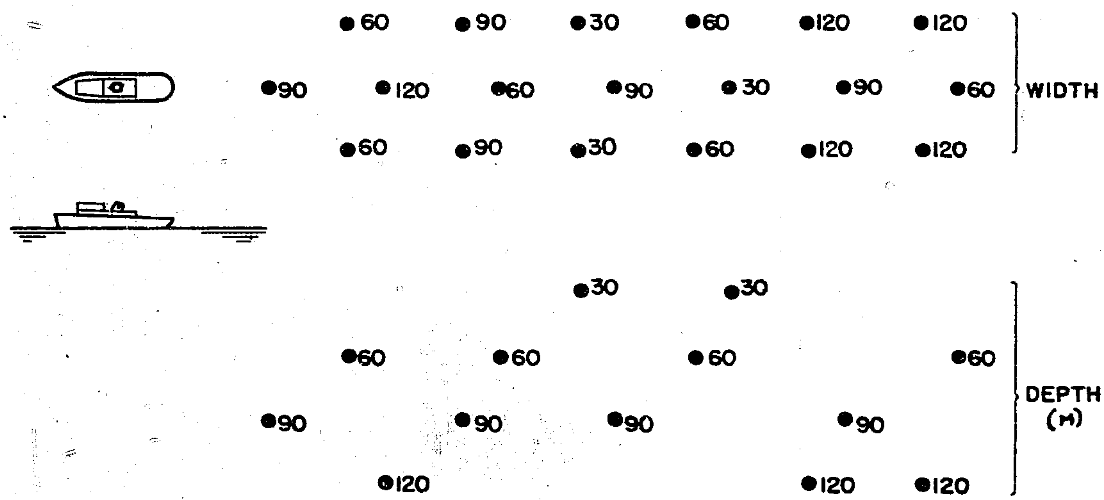


Figure 5

TYPICAL DEPTH CHARGE PATTERN - COAST DEFENSE SHIPS

8. <u>Lost Contact Procedure</u>

The doctrine for regaining contact, after delivering an attack, required the escort to continue on the attack course for approximately 1000 meters, go to 12 knots and reverse course to the right, returning to the area of attack and skirting the turbulent area at a distance of about 500 meters, searching by echo-ranging, and, if contact were not regained after circumnavigating the turbulent area, to steam back through the original point of contact, stop and listen.

If, after running through the original point of contact, contact were not regained, a single ship then steamed chords of an expanding spiral. The escort captain worked out his own courses at a speed selected by him, in conducting the search. His search was predicated on a submarine target speed of 3 knots. Convoy group commanders usually limited this type of search to twenty-four hours. An alternate type of single ship search was included in their doctrine and is illustrated in Figure 8.

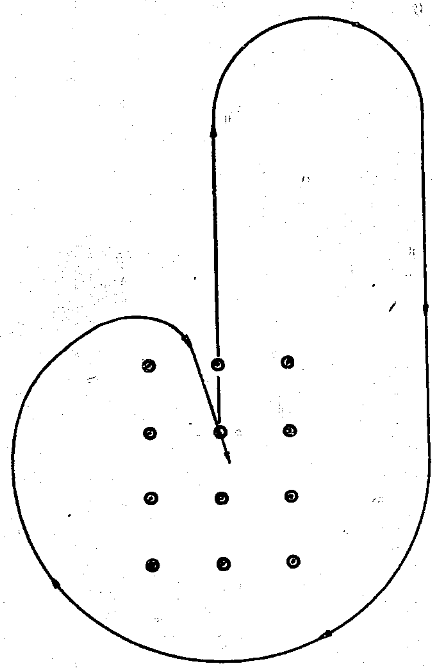


Figure 6
ESCORT GROUP LOST CONTACT PROCEDURE

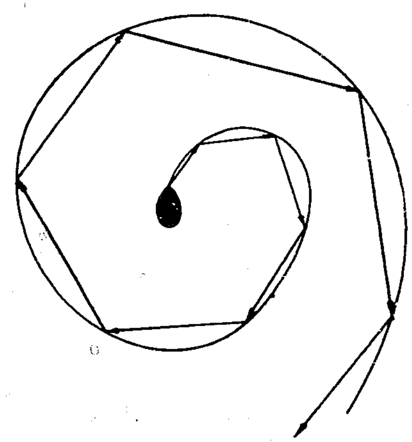


Figure 7
SINGLE SHIP LOST CONTACT PROCEDURE

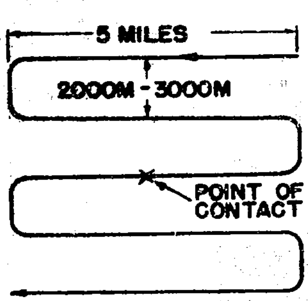


Figure 8
ALTERNATE SINGLE SHIP LOST CONTACT PROCEDURE

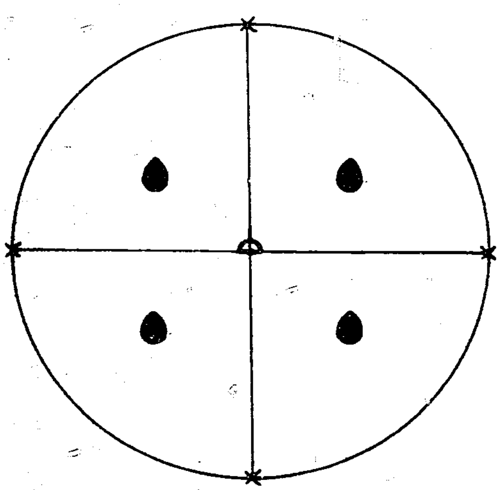


Figure 9
COORDINATING ESCORT GROUP LOST CONTACT PROCEDURE BY SINGLE SHIP SECTORS

If, however, a group of escorts were coordinating a search, the probable submarine area was divided into sectors by the senior escort captain and each escort searched its own area.

9. Coordinated Attacks

When the number of escorts permitted, doctrine required two or more escorts to coordinate attacks. The First Escort Fleet Operating Plans required convoy group commanders to designate the escorts detailed to the development of contacts prior to sailing. This number depended upon the number of escorts in the convoy.

The senior escort captain took command and detailed the order of attack. If he had contact, he attacked first. Due to interference, the other escorts listened while he conducted his attack. After completing his attack, he continued on for 600 or 700 meters, turned out to the right, stopped, discontinued echo-ranging, and listened.

In the meantime, the second escort commenced his run by echo ranging, delivered his attack and turned out to port. He then stopped, discontinued echo-ranging and listened.

His run was followed by the third escort's run, conducted in the same manner, except that he lay to between the first two escorts after the delivery of his attack.

The first escort had then returned and come in on his second run. (group's fourth run).

Coordination was accomplished by ultra-high frequency voice radio, as well as visual communications.

10. Air-Surface Coordinated Attacks

Aircraft were equipped with green dye markers, which were used to mark sightings, radar, or MAD contacts for surface vessels. Communication difficulties caused lack of coordination and this fact had been recognized. Planes and ships were being equipped with voice radio and some progress was being made in the direction of air surface coordination when the war ended.

11. Escort Vessel's Bridge Layout

A typical escort destroyer's bridge layout was sketched by Lieutenant Commander YASUMOTO.

12. Ahead Thrown Projectiles

During interrogations, mention was made of a special anti-submarine shell. This was investigated with the object of determining whether or not the Japanese had developed an ahead thrown weapon similar to our Mark 11 Projector (hedge-hog). Captain S. YAJIMA, the head of the section designing the shell, was called in for interview and it was determined that this special shell was one to be fired from the main battery, its special feature being a non-ricochet design.

His section was, however, working on ahead thrown rockets fired from "rocket guns" in salvos of five. The rockets were designed for a range of 2000 meters, but were not successful. According to Captain YAJIMA, this was the only type of ahead thrown anti-submarine weapons under consideration.

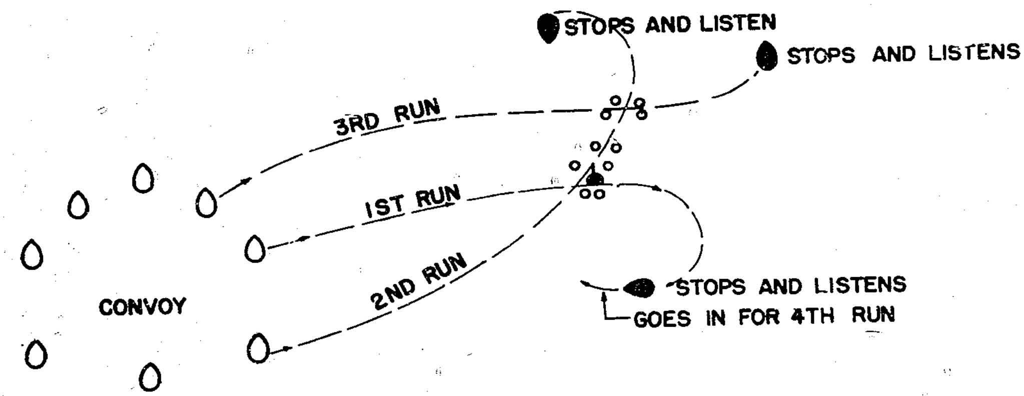


Figure 10
COORDINATED ATTACKS - SUCCESSIVE RUNS

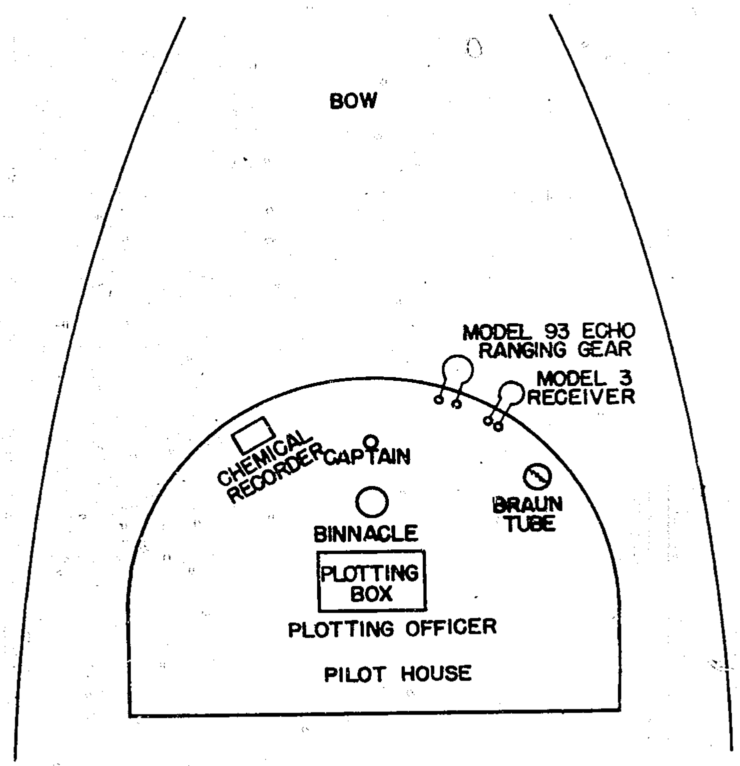


Figure 11
ESCORT VESSEL BRIDGE LAYOUT

B. AIR SEARCH AND ATTACK PROCEDURE

1. Organization and Discussion

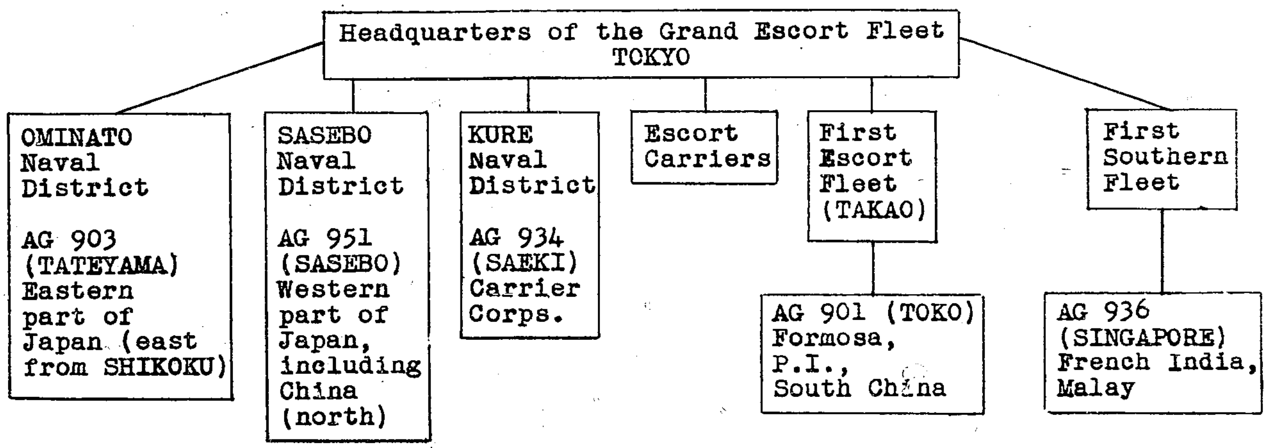


Figure 12

AIR SEARCH AND ATTACK ORGANIZATION

Air group 934 supplied the pilots for escort carriers.

The various squadrons were divided among bases in their respective area, each base being responsible for a given area. It was believed to be desirable to patrol the area each day but the shortage of planes necessitated a modification of the desirable plan wherein each base would patrol its area if a convoy were reported to be nearing the area, otherwise they would utilize their time for training. In fact, the shortage of planes and pilots was a primary drawback to the whole anti-submarine war.

Toward the end of the war the Army trained in anti-submarine patrol, and actually used the First Air Brigade (average strength about 110 planes) for partol in northernmost Japan. The VF carried one 15 kilo bomb, the light bombers from 50 to 100 kilo bombs, and the attack planes carried from 30 to 50 kilo bombs. Each type plane had its own area of operation and did not operate together. At various times in other areas, the Army aircraft would give some assistance to the Navy in A/S convoy escort or patrol, but they carried no radar or other special equipment and were quite unsuccessful.

2. Search Plans, Land Based

a. Discussion

The search plans outlined below are given in two categories, patrol and search, the differentiation being that patrol was the pattern flown when the presence of submarines had not been reported, whereas search was flown in trying to locate a submarine which had been reported to be in a particular area.

The following table is an example of the factors which were used in determining the interval between search or patrol lines.

Table I
FACTORS USED IN DETERMINING INTERVAL BETWEEN SEARCH OR PATROL LINES

Condition			Target	Sighting or Detecting Distance
From 15 minutes after sunrise to 15 minutes before sunset	Near the base	Presence of sub certain	Submerged sub seen thru water	Zone of 400 meters abeam
		Presence not confirmed	Periscope	3000 meters
	Far from base		Surfaced	10 miles
Other than above, twilite or moonlite night.			Surfaced	Moon or sun side, 3 miles. Opposite side, 1 mile
Dark night			Surfaced or neutralized by engine noise (sub intimidated into submerging by aircraft engine noise).	2000 meters
MAD	Day		Submerged	120 meters from plane to sub. (Improved later with improvement of MAD)
	Night		Surface or submerged.	
Radar			Surfaced	

When there were large and small planes at the same base, it was usual to have the large planes carry out long range patrol, while the small planes carried out direct escort or patrol of strategic points.

b. Patrol

The patrol plans in Figures 13 and 14 were used for visual search only since it was the general opinion that Japanese radar was so poor it was foolish to use it when the visibility was good enough for visual search. The dimensions of the pattern varied widely with conditions, air group, and plane used.

Line of bearing patrol was rarely used.

The pattern for night radar planes is shown in Figure 15. They wanted the spacing to be smaller but they had insufficient planes. They also recognized the advisability of having the planes take off from different fields in order to avoid the duplication of area flown over, but it was not practiced because of poor communications between fields.

Lookout sectors for the aerial observers in various Types of airplanes are shown in Figures 16 through 19.

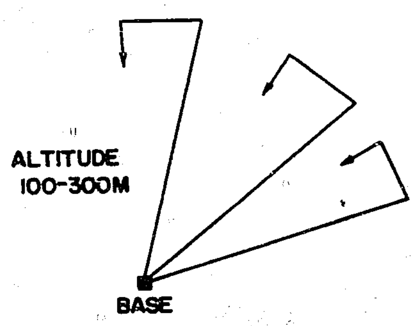


Figure 13
DAY PATROL PLAN (VISUAL)

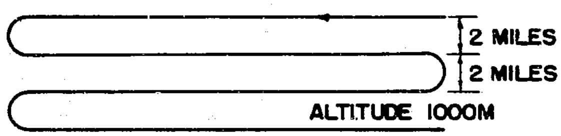


Figure 14
NIGHT PATROL PLAN (VISUAL)

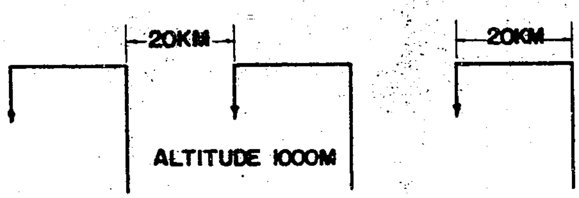


Figure 15
RADAR PATROL PLAN

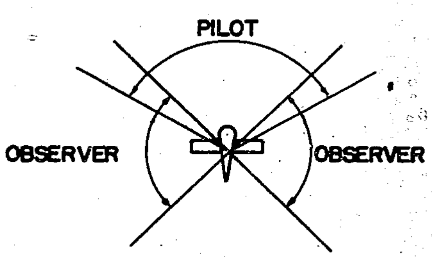


Figure 16
LOOKOUT SECTORS USING JAKE

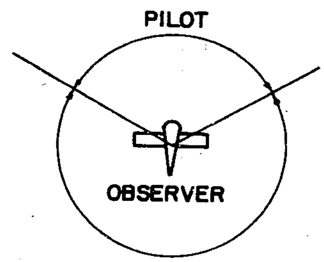


Figure 17
LOOKOUT SECTORS USING PETE

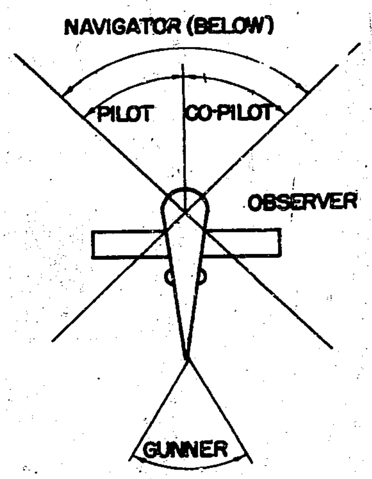


Figure 18
LOOKOUT SECTORS USING FLYING BOATS

For particularly careful search, a lookout was stationed in each blister.

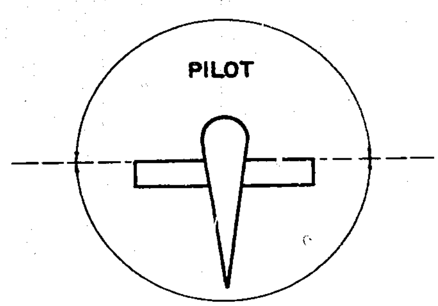


Figure 19
LOOKOUT SECTORS USING KATE

The man in the observer's seat was assigned the duties of communications and navigation.

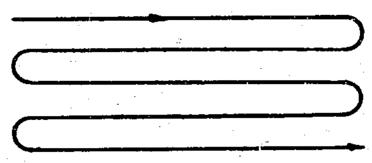


Figure 20
DAY AND NIGHT SEARCH PLAN
(VISUAL)

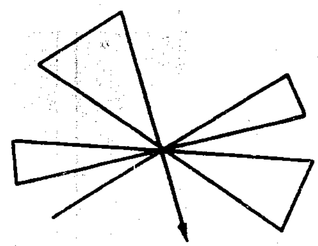


Figure 21
DAY SEARCH PLAN
(VISUAL)

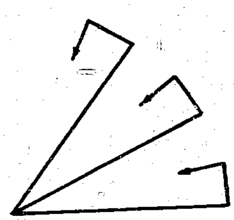


Figure 22
TWILIGHT SEARCH PLAN
(VISUAL)

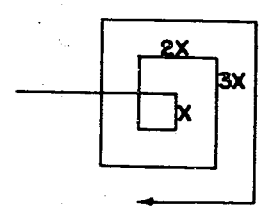


Figure 23
RECTANGULAR SEARCH PLAN
(VISUAL)

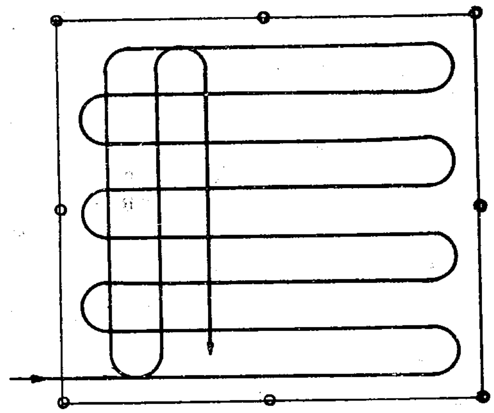


Figure 24
RECTANGULAR CRISS-CROSS SEARCH PLAN

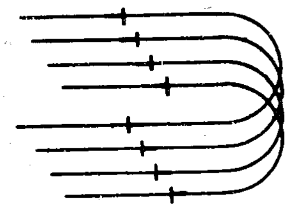


Figure 25
GROUP SEARCH PLAN

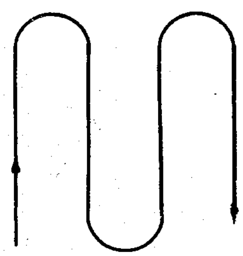


Figure 26
AREA COVERAGE
GROUP SEARCH PLAN

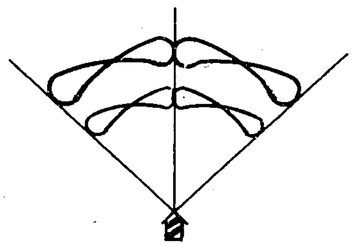


Figure 27
CARRIER BASED SECTOR SEARCH PLAN

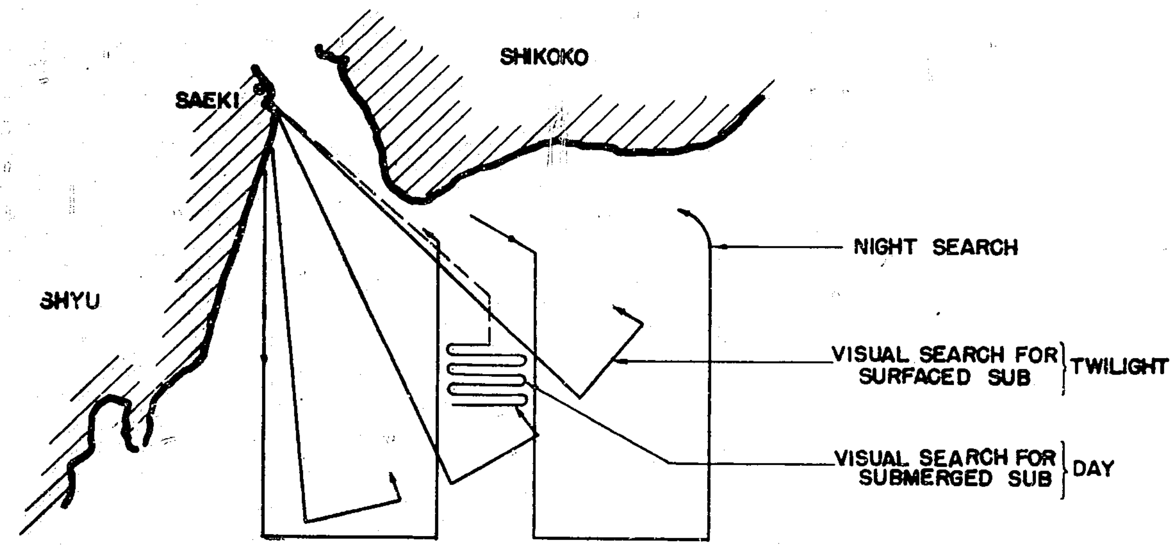


Figure 28
SEARCH PLAN AS USED BY THE SAEKI BASE

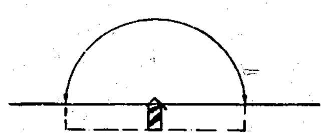


Figure 29
DIRECT ESCORT - SLOW CONVOY
(ONE PLANE)

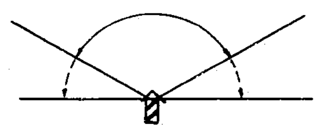


Figure 30
DIRECT ESCORT - FAST CONVOY
(ONE PLANE)

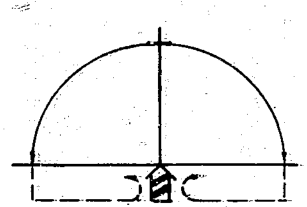


Figure 31
DIRECT ESCORT - SLOW CONVOY
(TWO PLANES)

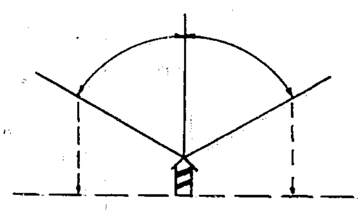


Figure 32
DIRECT ESCORT - FAST CONVOY
(TWO PLANES)

c. Search

(1) Visual

Often a flare was used to mark the center of this pattern. (shown Figure 22). One of the high echelon exhortations was to fly all the legs of this search pattern on the side of the expected submarine advance, but apparently this was never done in practice.

The length of leg X in Figure 23 varied with the object of the search (periscope, submerged sub, etc.) and with the length of time after the sighting that the search plane arrived on the scene-- the longer the lag, the longer leg X. Specific figures were not available.

The area coverage shown in Figure 24 was ten miles on a side when searching for a submerged sub, and 25 miles on a side for a periscope. The markers were used when maintenance of position was difficult. The first leg is chosen for:

(a) Smallest wind drift
(b) Course parallel to assumed sub's course.
(c) By considering the height and bearing of the sun.

(2) Radar

Radar was seldom used for search because of the lack of confidence of the Japanese in their equipment.

(3) MAD

Although the "higher echelons" thought it advisable to use the MAD equipment at night and suggested an altitude of from 80-100 meters, it was used but rarely because of the low ebb of pilot ability toward the end of the war. (See NavTechJap Report, "Japanese Magnetic Airborne Detector", Index No. E-14).

(4) Group

Group search was seldom used except in connection with MAD.

3. Search Plans, Using Carrier Based Planes

With the exception of the escort carriers which will be covered later, anti-submarine patrol by carrier aircraft was very meager. According to some reports the outer limit of ASP was 60 or 70 miles while according to others it was 150 miles, usually a sector search. But the ZEKES in the Coral Sea Battle patrolled to only 15 miles. A token A/S cover for task forces usually was maintained by torpedo bombers carrying only their machine guns and ordinary (not depth) bombs. Carrier pilots had no special training in ASP.

Table II
USUAL RANGES OF ALTITUDES USED IN PATROL AND SEARCH (METERS)

	Visual Only	With Radar	With MAD
Day patrol	100-800	1000	30-50 (carrier only)

	Visual Only	With Radar	With MAD
Night patrol	200-500	1000	not used
Day search	300-700	1000	30-50
Night search	5000	1000	80-100

4. Escort

It was the duty of the small aircraft carrier to provide direct escort for convoys while the larger aircraft carried out long range patrol of the convoy lanes. They realized more and more the value of aircraft in convoy escort, but the aircraft became less and less available with the result that, toward the end of war when their ideas were the most ambitious, they were the least able to carry them out and had to be content with modified plans.

One command authority promulgated the following conditions under which the line of advance would be patrolled rather than direct escort being provided:

a. When the probability of the appearance of enemy subs is slight and there is no need for the disposition of direct escort planes.

b. When due to weather, etc., it is difficult to station direct escort at night.

c. When at a great distance from the base.

When direct escort was provided, primary stress was given to areas from which enemy submarines could be expected to fire torpedoes, and secondary stress was given to patrolling behind to prevent trailing.

The angle on the bow covered varied with the speed of the convoy and with the air group supplying the escort. (See Figures 29, 30, 31, and 32). For slow convoys, (under 8-10 knots) some groups flew completely around the convoy at a distance of 2-4 kilometers except astern where they flew close aboard, whereas other groups never widened the angle to greater than 90° on the bow. Likewise, for fast convoys some groups flew out to 90° on the bow whereas other groups closed the angle to 60°.

The variation with convoy speed and air group which existed using one plane escorts applied also when two planes were used--some for high speed convoys, flying out to 90° and for slow convoys flying clear around astern before reversing course.

At the beginning of the war the outer escort started close to the convoy and spiralled upward and outward, but as the war progressed this station became more stabilized. If only one plane were available, the out circle was sometimes flown at 40 miles which was believed to be the limit at which the smoke of the convoy could be seen by a submarine. If there were a shortage of escort planes, the circumferential sweep was the first to be abandoned. As the shortage of planes became progressively more acute, the other stations were abandoned in the following order: (1) the circumferential sweep, (2) the patrol to limit the distance from which a trailing sub (assuming sub speed of 20 knots) could overtake the convoy or advance in its path, (3) patrol to the effective range of the submarine's radar which was assumed to be 40 miles, (4) patrol to the limit of visibility.

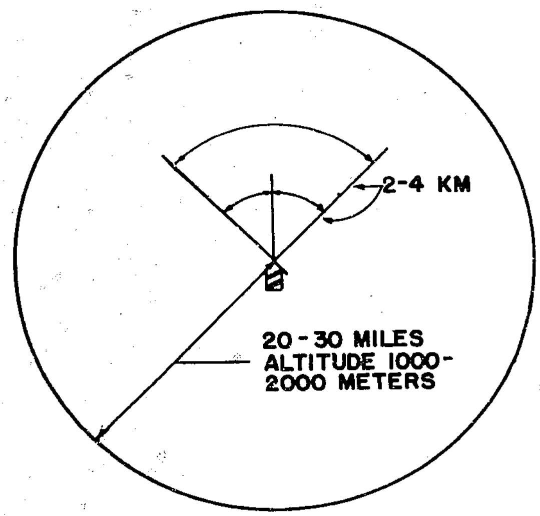


Figure 33
TWO PLANE CIRCUMFERENTIAL SEARCH PLAN

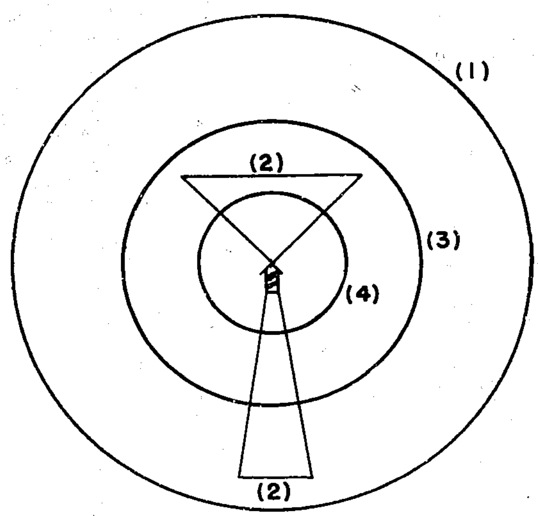


Figure 34
ORDER OF ABANDONMENT OF SEARCH PLANES

Land escorts using radar usually flew a box around the convoy at night.

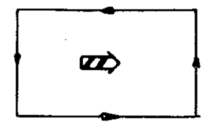


Figure 35
LAND ESCORT SEARCH PLANE USING RADAR

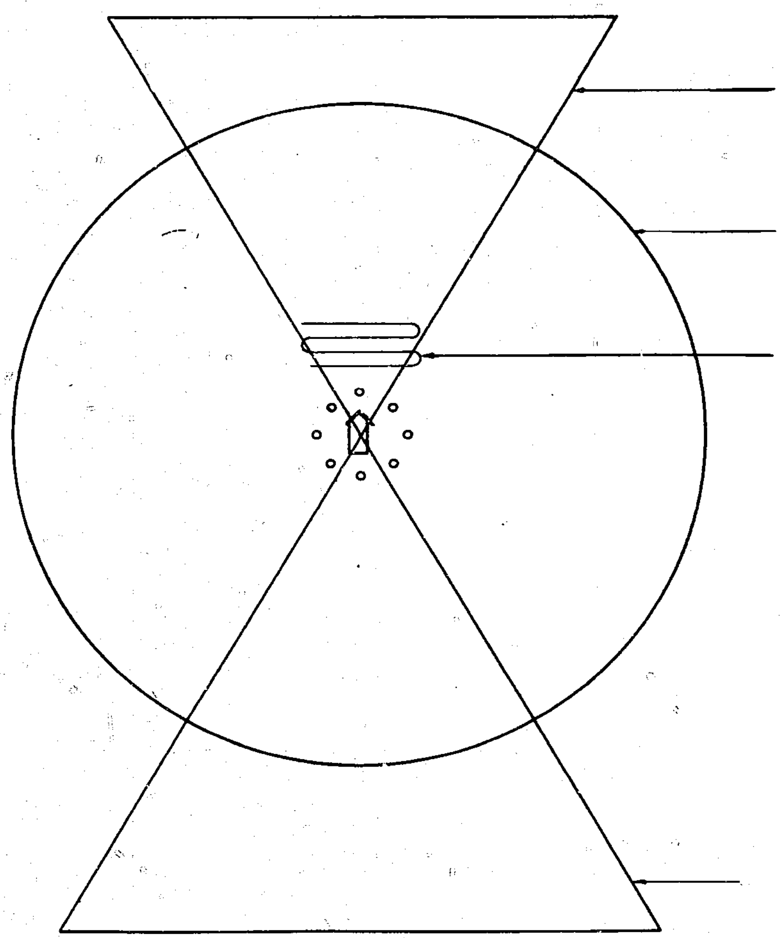


Figure 36
CARRIER PLANE ESCORT - DAY

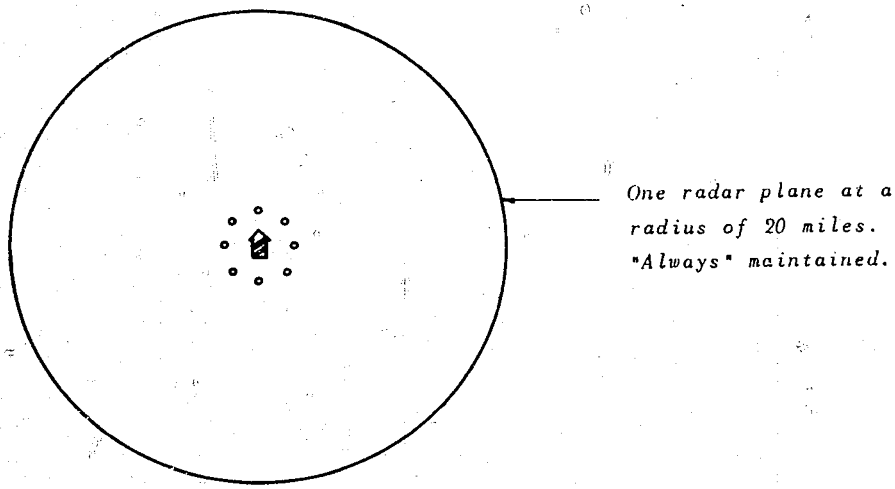


Figure 37
CARRIER PLANE ESCORT - NIGHT

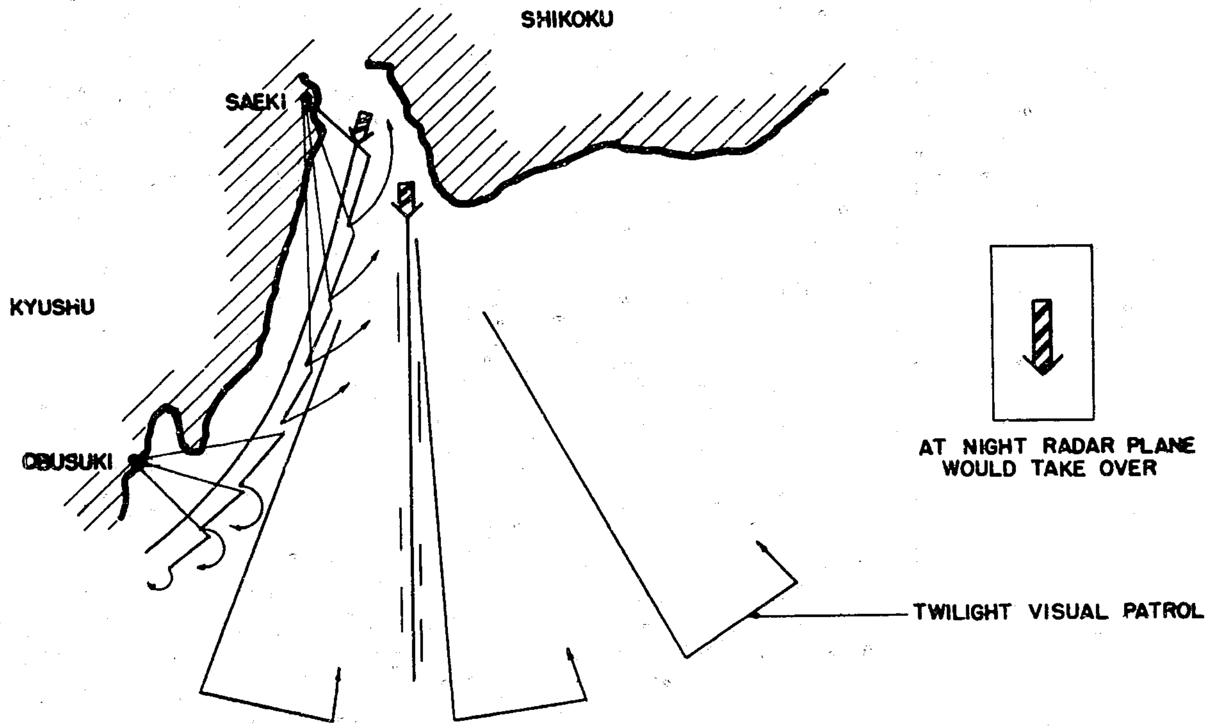


Figure 38
SEARCH PLAN AS USED BY SAEKI BASE
IN CONJUNCTION WITH OTHER BASES

Carrier escorts (carrying only KATE) steamed in the convoy except when launching or recovering planes.

If the dawn or dusk patrol sighted a submarine, he reported and attacked, then marked the place for aircraft or surface vessels sent out from shore bases (the escort carriers were always used near the shoreline), but no planes were sent out from the escort carriers since they felt they could not spare them. If the plane making the circumferential sweep sighted a sub, three or four planes were usually sent out to follow up the attack. If one of the MAD planes made contact, he would be joined by one or two of the closer escort ships for the attack, while the other two MAD planes stayed with the convoy (which would change course).

While the convoy was close to the base the plane stayed with it for the longest period of time (about 2½ hours), but as the convoy moved further away the period became progressively shorter, the last and shortest being about ½ hour. The next base down the line would then take over the escort.

5. <u>Attack Procedures</u>

The doctrine upon sighting a submarine was generally:

a. Target sighted at a distance

(1) Report
(2) Attack
(3) Circle
(4) Mark

b. Target sighted nearby

(1) Attack
(2) Circle
(3) Mark
(4) Report

Some groups recognized the importance of attacking at once upon sighting, placing the emphasis upon speed rather than attaining good position for a run, but other groups considered it more important to get into optimum position first, sometimes even dropping a buoy, then circling around to the optimum position.

The optimum position was considered to be downwind, downsun, and dead ahead. Further figures are given in Table III for several frequently used types.

Table III
OPTIMUM POSITIONS FOR ATTACK APPROACH

Plane	Altitude of Approach	Speed of Approach	Direction of Approach	Type run	Strafe
PETE	700 meters	80 kts	dead ahead	50° glide	no
JAKE	700 meters	80 kts	dead ahead	40° glide	no
KATE	800 meters	90-100 kts	ahead	low level, 250-300 kts over target	sometimes (observer)

The reason for the approach from ahead evidently was because the pilots received no training in deflection bombing and figured the range as the only variable. Each type plane was equipped with a card, similar to the one shown below, for figuring the range. For some planes, the lead was shown in sight angles, while for others it was shown in meters. The large type planes usually used a shallow glide and dropped a pattern at an angle of about 30° to the submarine's course if possible.

Table IV
LEAD ANGLE CARD FOR FIGURING RANGE
(Partial Data)

Depth (meters)	Speed (knots)	Headwind (knots)				Tailwind (knots)				
	2	8	6	4	2	0	2	4	6	8
5	4				-2.5	-1.5	-0.8	0	1.0	2.2
	6			-2.7	-1.7	-0.9	- 0	0.8	1.9	2.6
	2									
10	4									
	6									
	2									
15	4									
	6									

Table V is an example of how the factors governing the sighting point were taken into account. Pilots were also advised to drop as many bombs as possible since they frequently had a bad underwater trajectory, and exploded at the wrong depth.

Table V
USE OF FACTORS GOVERNING SIGHTING POINTS

Target	Sighting Point	Remarks
On surface	Center	If possible
Periscope	Center	Parallel enemy's course
Seen thru water	Ten meters ahead	
Moving oil slick	First attack 80-170 meters ahead of the most recent oil slick. Second and later attacks same as above 120-240 meters. (A table showing lead for certain sub depth and speed was also used, computed on the basis of the time it took oil to reach the surface.	Approach as near parallel to the line of oil slicks as possible. Try to guide patrol craft. Bombing is to be carried out along with guiding.

The depth bombs carried time rather than hydrostatic fuzes, and were set before take-off on settings decided by the air group commander. The settings varied with conditions, being shallower when the expectations of sighting a surfaced submarine or periscope were greater than contacting a submerged sub. Where more than one bomb was carried, it was usual to set the first one shallow, the next deeper, and so on. The tendency throughout the war was toward shallower settings for aircraft depth bombs.

Examples of Japanese bomb loads are given below.

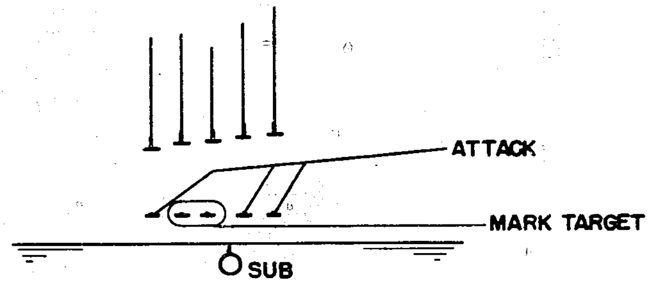


Figure 39
COORDINATED ATTACK PROCEDURE USING "MAD"

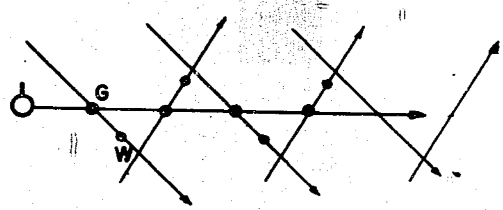


Figure 40
PATTERN OF MARKERS

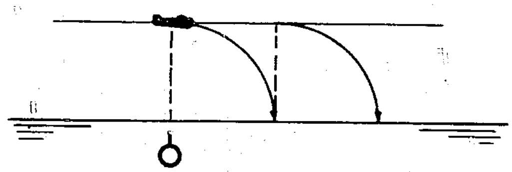


Figure 41
OLD METHOD - MARKERS DROPPED

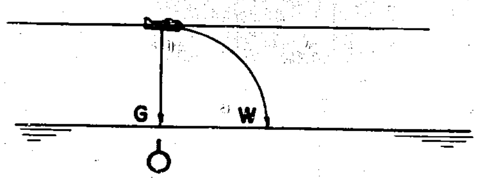


Figure 42
NEW METHOD - MARKERS DROPPED OVER CONTACT

New method--over contact, green marker is fired astern at 120 knots hence drops immediately over contact. At the same time the white marker is dropped, hence falls away from contact.

MAVIS	PETE	LILY	JAKE
60 kg(6) 250 kg(4) old type(6) newest type(12)	60 kg(6)	60 kg(12) 250 kg(4)	60 kg(4) 250 kg(1)

Coordinated attacks were practically non-existent, except by planes using MAD. If there were other aircraft in the vicinity when a plane had a contact, they would fly to the scene, but would drop only if they could see the submarine. If the sub were out of sight when they arrived, they would return to their patrol without making an attack.

The procedure in using MAD is outlined in Figures 39-43. In the new method - over contact (Figure 42), the green marker is fired astern at 120 knots, hence drops immediately over contact. At the same time the white marker is dropped, hence falls away from contact.

A MAD search usually consisted of 5 planes flying in formation. When one made contact, one of the adjacent planes stayed with him to mark the target while the others climbed and circled until there was enough information from the markers to make a good attack. The marker planes marked only - they made no attacks. When MAD was first used a green marker (fluorescent dye) was dropped when contact was made, and then a white marker (aluminum) was dropped away from the target, but later they developed the technique of dropping the white marker upon contact while at the same time firing the green marker astern at the speed of the plane (120 knots), with the result the green marker fell on the target and the white one away from the target instead of both away as in the old method. They were continually improving their equipment; for instance, the range was improved from 120 meters (plane to sub) to 280 meters and they had considerable faith in it.

The Japanese recognized the value of radar in anti-submarine work, both for search and blind attack, but their equipment was so poor they had no success in using it for bombing. The image faded from the screen at 5 kilometers, so they tried choosing a distance from the target at which they still had good information, then noting the time, by stop-watch, it took to fly half the distance. By flying a duplicate period of time they would then be in the vicinity of the target, where a pattern of bombs was dropped. If there was a moon, they made their approach with the moon behind the target in the hope of being able to bomb visually when the target was reached. They would fly great distances around a target in order to get it into position relative to the moon. (See Figure 44.)

6. Surface-Air Coordination

Coordination of any kind by the Japanese seemed to be hampered by poor communications, and the coordination between aircraft and surface vessels in anti-submarine work was no exception. Had there been better communications, a full-fledged hunter-killer technique probably would have been developed at a relatively early date, since there were many attempts to extend the cooperation between surface vessels and aircraft. The only organization organized for a "hunt-kill", however, was that of the 102nd Surface Squadron and the 934th Air Squadron, which covered the area between Formosa and Shanghai.

When on routine patrol, the airplanes (ZEKES) flew over the area 20 miles apart using both radar and eyesight. They also carried MAD to use in following up a contact. For patrol, they usually carried two sixty kilogram depth bombs, and for attack, one 250 kilogram bomb, altho the 250 kilogram bomb was carried sometimes on patrol. The depth setting was fairly deep at first, but at the end of the war the setting was shallow (about 10 meters). Their sweeps were day only, with the exception of pre-dawn take-offs. The ships (patrol craft) operated half their number at a time, patrolling the area behind the planes while the other half remained in port.

When a submarine was contacted, the aircraft made attacks and reported by voice radio to the base. The ships were monitoring the aircraft re porting frequency in order to get the first information available from the aircraft, but could not transmit on the frequency in order to acknowledge the receipt to the aircraft. The base then would re-transmit to the ships and dispatch planes equipped for attack (carrying 250 kilogram bombs).

Part III
ESCORT OF THE CONVOY

A. COMMAND

Major, long distance convoys were commanded by convoy group commanders who were flag officers embarked in light cruisers as flagships. These officers commanded both the convoy and the escort. The convoy proper was commanded by a captain, whose sole duty was to command the convoy.

Smaller convoys were commanded by captains who commanded both convoy and escort.

Army transports were made up into convoys by the Grand Escort Fleet, and while in convoy were subject to the orders of the convoy group commander.

Escort carriers, when included in convoys, were also under the command of the convoy group commander.

B. CONVOY FORMATIONS AND SCREEN DISPOSITIONS

Many differences of opinion existed in regard to convoy formations and the disposition of the screening units. Convoy group commanders formulated and issued their own plans and doctrine until the latter part of the war. On the whole, it was recognized that a broad front was desirable and that maneuverability was a necessary factor. Representative formations that were used are shown below.

C. SCREENING DOCTRINE AND STATIONS OF ESCORTS

In March 1944, plans were issued by the First Escort Fleet in a publication entitled "Number One Escort Fleet Operating Plans". This publication was chiefly the work of Captain UOZUMI and contained formations, screening, and attack doctrine.

Inner screens and outer screens were specified. Inner screens were formed in what was termed ring formations. They were not properly circular formations, as escorts were stationed on relative bearings from ships in the convoy, and at distances limited to between one and two thousand meters. This distance was dictated by Japanese experience that U.S. submarines delivered their attacks between these limits.

1. Outer Screens

When escorts were available, outer screens were specified and the escorts so detailed took stations approximately 10,000 meters ahead of the convoy.

2. Horizon Sweeps

When outer screens were stationed, dawn and dusk horizon sweeps were made

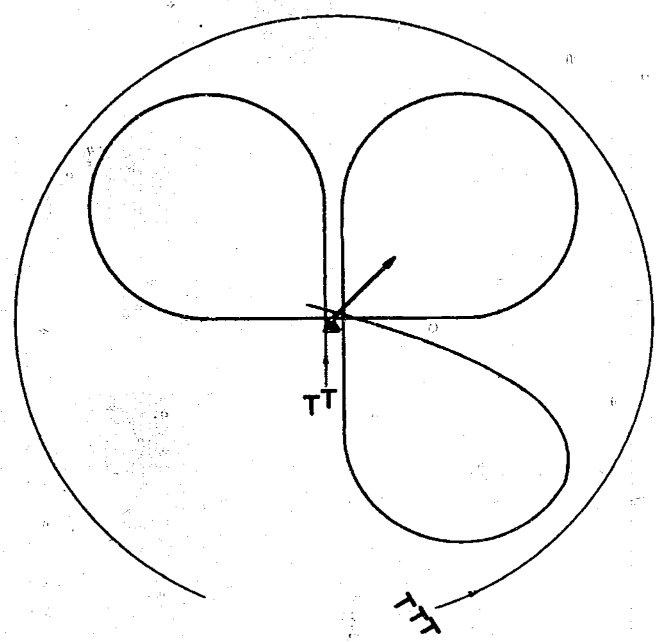


Figure 43
COORDINATED ATTACK PROCEDURE USING "MAD"

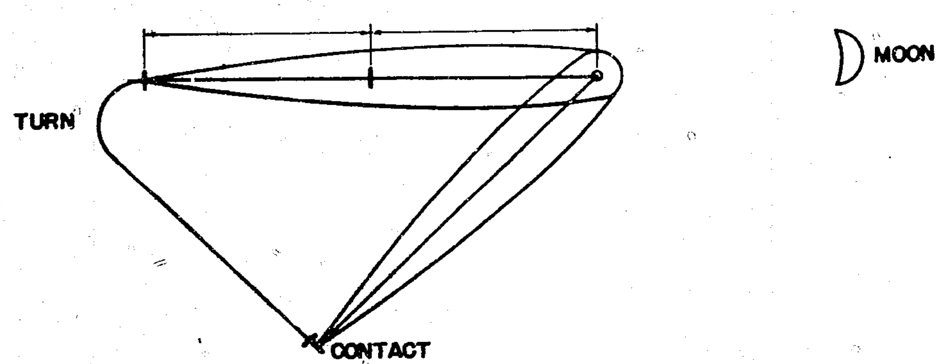


Figure 44
RADAR BOMBING PLAN

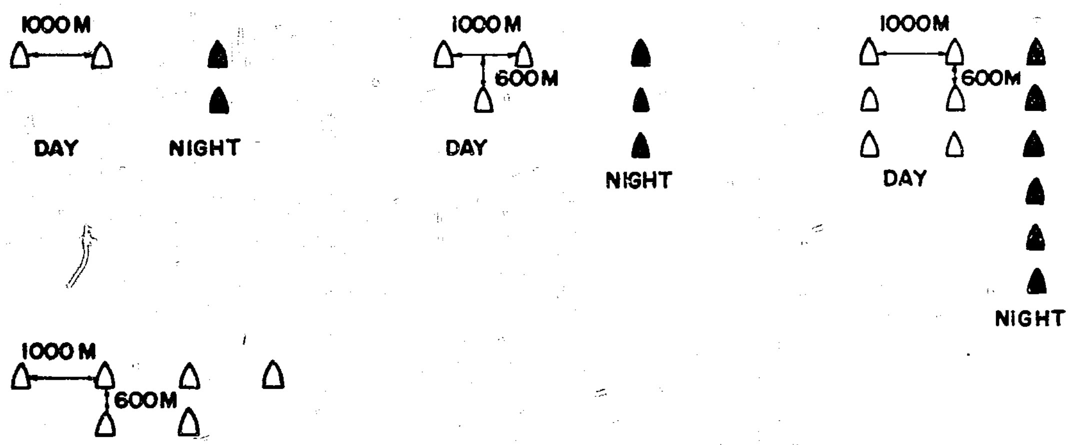


Figure 45

REPRESENTATIVE FORMATION FOR SMALL CONVOYS

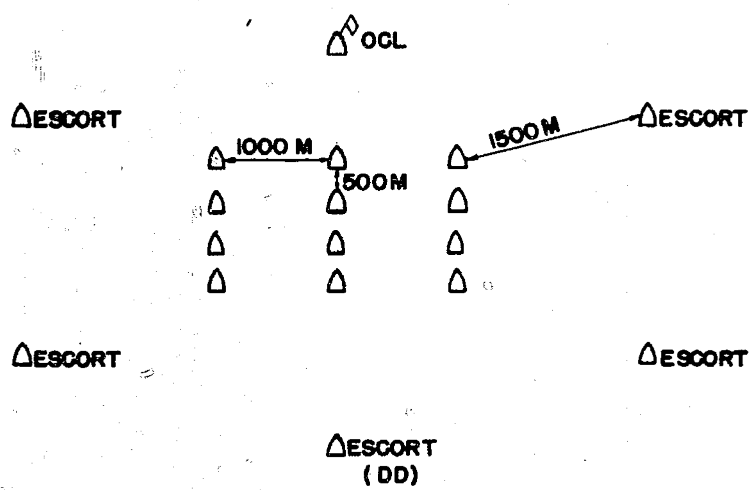


Figure 46

REPRESENTATIVE FORMATION FOR LARGE CONVOY (1)

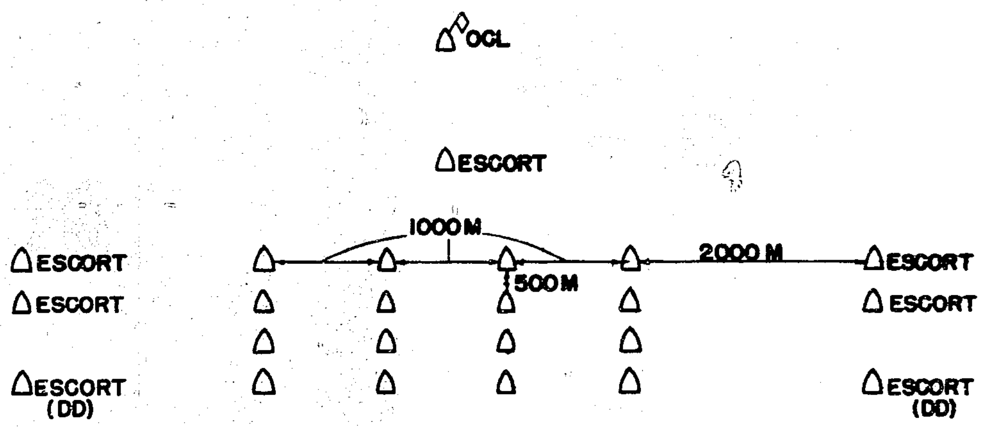


Figure 47
REPRESENTATIVE FORMATION FOR LARGE CONVOY (2)

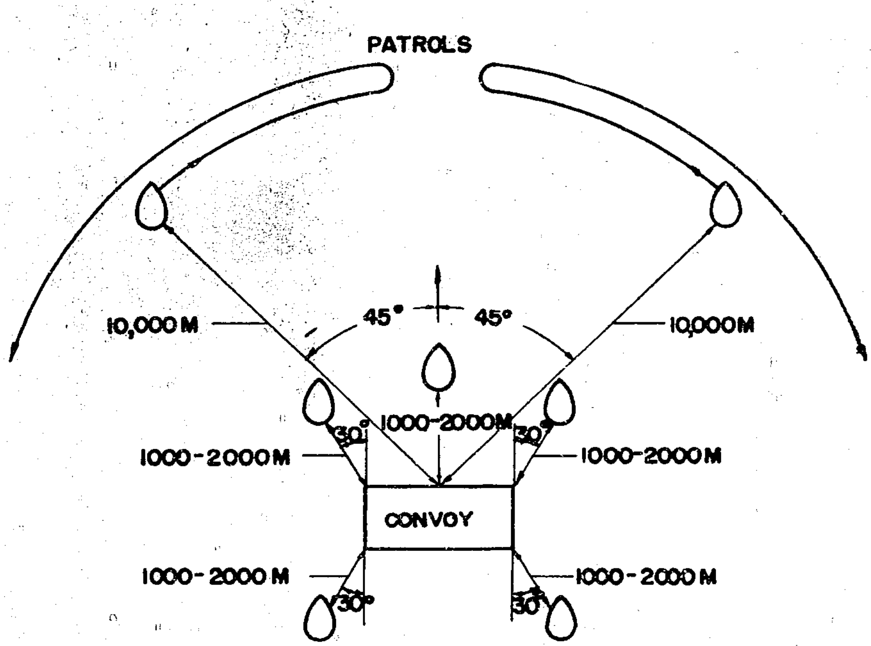


Figure 48
SCREENING DISPOSITION FOR 7 ESCORT CONVOY

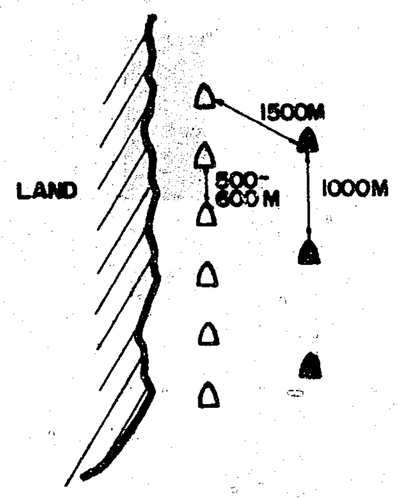


Figure 49
CONVOY FORMATION AND SCREENING DISPOSITION

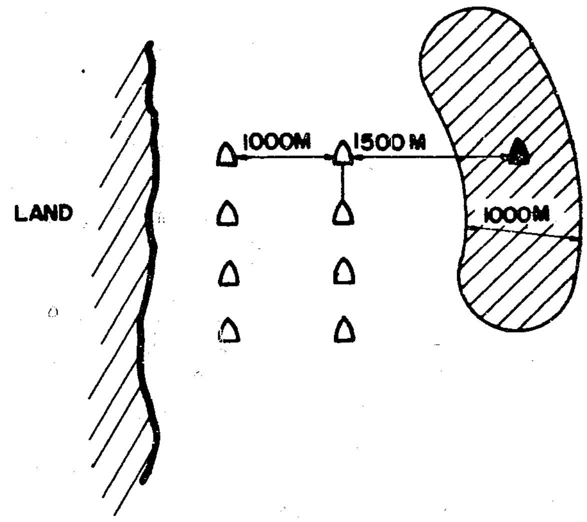


Figure 50
CONVOY FORMATION AND SCREENING DISPOSITION

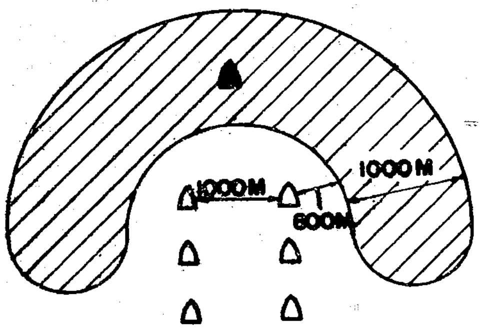


Figure 51
CONVOY FORMATION AND SCREENING DISPOSITION

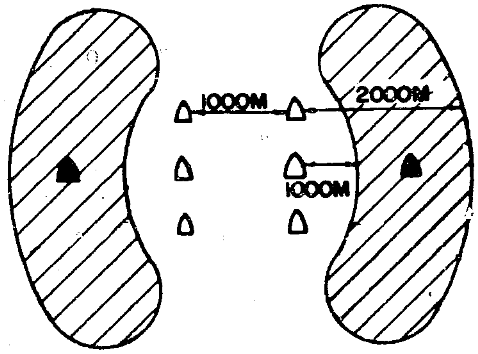


Figure 52
CONVOY FORMATION AND SCREENING DISPOSITION

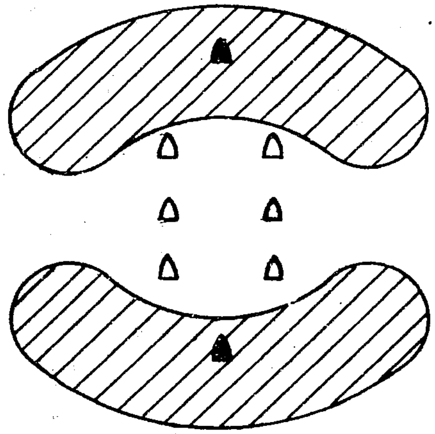


Figure 53
CONVOY FORMATION AND SCREENING DISPOSITION

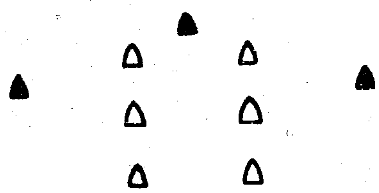


Figure 54
CONVOY FORMATION AND SCREENING DISPOSITION

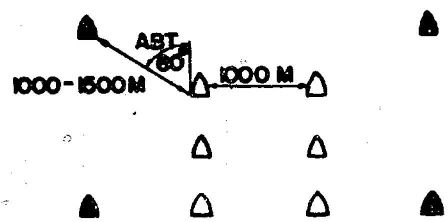


Figure 55
CONVOY FORMATION AND SCREENING DISPOSITION

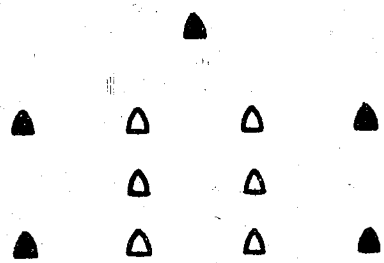


Figure 56
CONVOY FORMATION AND SCREENING DISPOSITION

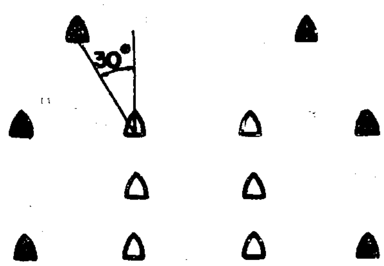


Figure 57
CONVOY FORMATION AND SCREENING DISPOSITION

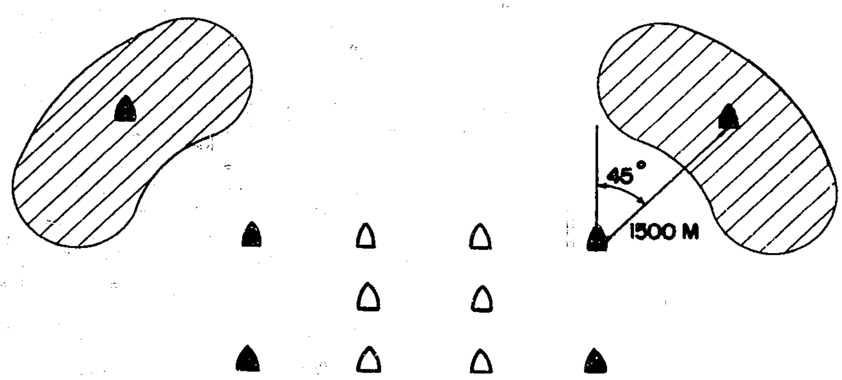


Figure 58
CONVOY FORMATION AND SCREENING DISPOSITION

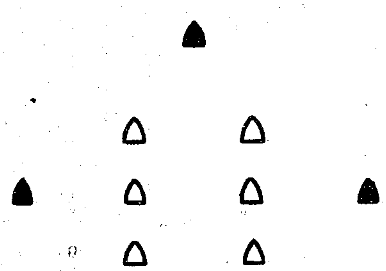


Figure 59
CONVOY FORMATION AND SCREENING DISPOSITION

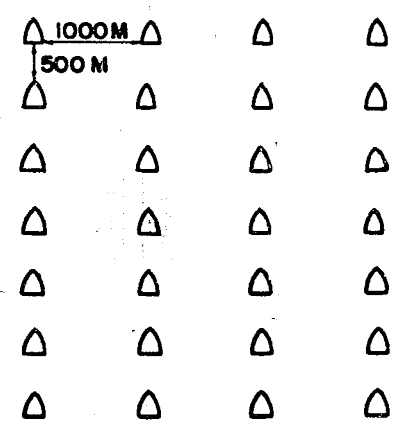


Figure 60
FORMATION FOR 28 SHIP CONVOY (MAX.)

astern by one escort. In the absence of an outer screen, these sweeps were made to cover the horizon limits of the convoy throughout 360°. When a shortage of escorts prohibited, the sweeps were confined to the sector from which attacks were expected.

3. Patrolling of Stations

Patrolling of stations was mandatory and was generally done at a speed of four knots over convoy speed. In faster convoys, the differential was not so great. This lesser differential was imposed by the limitations of the sound gear at higher speeds.

4. Typical Screening Disposition

The sketch in Figure 48 describes one of the screening dispositions contained in "Number One Escort Fleet Operating Plans" for seven escorts, and indicates in detail the method of stationing screening units. This disposition represented the desired disposal of escorts for maximum protection. Shortage of escorts, however, seldom allowed this disposition to be used. There follows other formations and screening dispositions contained in the operating plans. They were obtained from Captain UOZUMI, former Chief of Staff to the Commander in Chief, First Escort Fleet, and author of the afore-mentioned publication.

5. Sonar Screens

Sonar screens were based on search arcs of 60°, and individual sectors to be covered were specified in the operating plans. The screens were not interlocking.

A sonar screen for six escorts is sketched below.

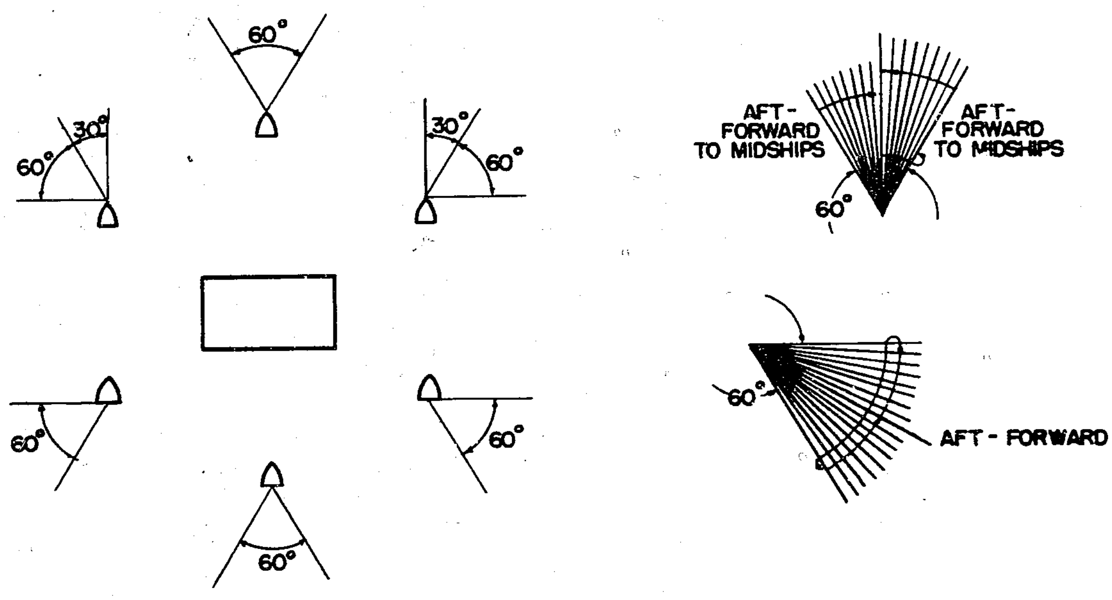


Figure 61
SONAR SCREEN FOR 6 ESCORT CONVOY

The patrolling of stations was considered to cover the gaps in the screen.

At first listening was used exclusively, but echo-ranging replaced its use in the latter part of the war. Ships equipped with Type 3 and Type 93, alternated equipment every four hours.

6. Effective Sonar Ranges

The stationing of escorts at a distance of one to two thousand meters from the convoy was dictated by Japanese experience that U.S. submarines generally delivered their torpedo attacks from points within these limits, and was not influenced by the effective sonar range.

Rear Admiral Toshio AKIYOSHI, former Chief of the First Section of the Hydrographic Office, was fully cognizant of density layers and gradients in sea water and their effect in deflecting sonic transmissions in echo-ranging, thereby influencing sonar conditions. The Hydrographic Office had been asked for assistance in solving echo-ranging problems, and had responded by issuing two charts made up from statistical data which indicated general seasonal conditions that could be expected.

These charts were named "Charts for Sonic Ranging" (numbers 2775 and 2776) and were issued to all escorts. (See Enclosure (B) and NavTechJap Report, "Japanese Hydrography, Article 2" - Index No. X-18-2.)

Escorts were not equipped with bathythermographs and made no tactical use of such information as could be ascertained from charts; that is, the effective sonar range for the locality did not influence the disposition of the screen. This information was derived from answers given to the question of what use was made of the sonic ranging charts. In all instances the reply was that the charts were used for information as to what sound range could be expected. It was apparent that the operating personnel had not conceived the idea that effective ranges were a tactical factor, but it is believed that they may have influenced convoy routes.

D. RADAR

Escorts were equipped with radar for air detection, and later, some were equipped with surface radar. The importance of the use of radar by surface ships to detect submarines was recognized, and a determined effort was made to develop it, but because of inferior equipment and inefficiency of operators, it was generally ineffective. Surface ships were provided with equipment to detect radar being used by U.S. submarines. Bearings obtained were considered to be accurate within ten degrees.

E. CONDUCT OF THE CONVOY

Large convoys were formed in two, three, or four columns, with 1000 meter distances between columns when sea room permitted. Maneuverability was stressed and the convoys were exercised frequently in executing simultaneous turns.

Convoys zigzagged at all times when sea room permitted.

When coasting, special orders were sometimes issued to seek shelter in coastal ports at night and to cruise only by day.

When U.S. task forces were known to be in the vicinity, convoys were directed to scatter.

F. DOCTRINE WHEN ATTACKED

1. General

When attacked by submarines, convoy group commanders usually executed simultaneous turns either towards or away from the direction of attack.

They turned away from sonar contacts or MAD contacts made by planes. Individual ships sighting submarines, periscopes or wakes close aboard, were instructed to attempt to ram. Notification of sightings was made immediately to the convoy group commander. Information on MAD contacts was apparently obtained by visual observation of the fact that the plane had dropped a buoy, or, by intercepting its report to its base.

When convoys were attacked, some group commanders required all escorts to drop depth charges to keep submarines down and to prevent further attacks. Screening doctrine, however, required the escorts in the sector attacked to drop charges and to conduct offensive sweeps in the direction from which the attack came. Other escorts remained with the convoy, which had turned away. The number of escorts designated to conduct offensive operations against the attacking submarine depended on the total number of escorts present. Doctrine required them to remain with the contact as long as it could be maintained, and if contact was not made, to continue the search persistently. Convoy commanders usually limited the search to twenty-four hours.

2. Urgent Attacks

Urgent attacks were made only when contacts were picked up at a range too close to make a deliberate attack. A small pattern was dropped and the escort maneuvered to make a deliberate attack. Other than this, urgent attacks were prohibited by doctrine. Many escort commanding officers in the screen, however, in their excitement upon making contact, did head for the submarine and start delivering full destructive attacks, thus, in effect, unconsciously making urgent attacks.

3. Deliberate Attacks

Deliberate attacks were made on all sonar contacts classified as submarine. Conning procedure is described in Part II, Section A, Article 5 of this report.

G. AIR COVER

Air cover was occasionally provided by escort carriers for large important convoys containing twenty-five ships or more. Four 10,000 ton CVE's, were a part of the First Escort Air Fleet, and each carried twelve Type 97 planes. In general, air cover was provided by land based planes under the direction of the anti-submarine air groups. From one to five planes, some equipped with radar and some with magnetic detection devices, comprised the air cover for convoys. Small convoys were provided with one or two planes; large convoys with four or five.

Communications were maintained between the bases and the planes. Communication between planes and ships was attempted but results were generally unsatisfactory. In January 1945 voice radio was installed and an effort to improve communications met with some success. Coordination between planes and escorts was, on the whole, poor, and the plane did little more than mark the spot for an escort if, by chance, the escort found the plane which had the contact. When planes reported contacts, convoy group commanders would sometimes send surface vessels to assist and at other times would not. Rear Admiral Mitsuhara MATSUYAMA stated that his escorts were never able to produce results when he sent them to develop contacts reported by MAD equipped planes.

Part IV
THE ANTI-SUBMARINE WARFARE SCHOOL

A. ORGANIZATION

The Anti-Submarine Warfare School was established and operated under a somewhat involved dual command. It was primarily under the command of the Commander-in-Chief of the Grand Escort Fleet. It was also under the command of the Commandant of the Kure Naval Station, the reason being that an Anti-Submarine Training Center was established at SAEKI under the auspices of the school; the tactical command of this group was under the Kure Coast Defense Squadron which in turn was under the command of the Naval Station at KURE

B. MISSION

The mission of the school was to train sonar operators and sonar officers, to develop and disseminate anti-submarine attack doctrine, to indoctrinate newly commissioned ships in ASW, and to conduct ASW refresher training. Its mission was also to analyse the reports of all attacks made by escorts and to criticize them.

C. TRAINING PROGRAM

When the school was first established, the demand for sonar operators and technicians was so great that the only program possible was to turn out personnel at maximum rate. As soon as possible the school settled down to a program of furnishing replacements for the fleet, and teams for newly commissioned ships.

D. TRAINING DEVICES

Sonar receivers and transmitters were set up in the school at YOKOSUKA. Recordings of fish noises, water noises, sound transmissions, and echoes were available. There were no attack teachers or conning trainers, the closest approach being a transmitter and receiver installed in a room over water, and a small boat towing an underwater spar as a target.

E. TRAINING OF OPERATORS

Enlisted men were trained in the operation and maintainence of sonar equipment. After completion of the course, operators were sent to SAEKI and given practical experience on board ship (usually newly commissioned ships to which they were assigned as crew members) operating against tame submarines. The length of the course at the school was seven months.

F. TRAINING OF SONAR OFFICERS

Sonar officers were trained in the theory and operation of the different types of sonar gear, in plotting and in attack technique. The length of the course for officers was six months. After completion, they were sent to ships at SAEKI for shipboard training against tame submarines. One ASW school graduate was sent to each escort. An attempt was made to send commanding officers through the school for a command course, but due to the shortage of commanding officers, only a small percentage attended.

G. ATTACK TEACHERS AND TRAINING FACILITIES

There were no attack teachers. A training center was established at SAEKI for the training of newly commissioned ships, and to give refresher training to escorts when they were available between convoy runs, but the pressing need for escorts generally precluded them from this. Training at SAEKI was on board ship against tame submarines.

The only training available to escorts was that of opportunity - echo ranging against ships in the convoy, and occasional runs on tame submarines while engaged in escorting them to departure points.

H. DISSEMINATION OF DOCTRINE

Formulation of attack doctrine and development of attack procedure was a function of the school. At first, as progress was made, bulletins were issued; later, two manuals, "Text Book for Anti-Submarine Attack" and "Rules for Conducting Anti-Submarine Warfare", were issued to all anti-submarine commands.

Copies of all anti-submarine action reports were sent to the school for analysis and criticism of procedure. Mistakes, or better procedures were pointed out to the commanding officer by letter or by personal discussion when possible.

Part V
THE GRAND ESCORT FLEET

A. MISSION

This command was charged with the responsibility of moving and safeguarding shipping to and from the Empire. Its functions were the making up of convoys, including transports for troop movements, designation of escort vessels to the various subordinate commands, assignment of tasks, intelligence, training, protection of shipping and patrol of the convoy lanes, and the issuance of general instructions and directives to subordinate commanders.

B. INTELLIGENCE

The headquarters of this command maintained liaison with the Intelligence Division of the Navy Ministry, and also maintained its own intelligence for the location of U.S. submarines. This was done chiefly, by statistical data. The Japanese felt that their intelligence was good. Statistical information was supplemented by radio interception from the Intelligence Division of the Ministry to a certain extent and by RDF, aircraft sightings and ship's reports. U.S. submarine transmissions could be picked up, but the Japanese were unable to interpret them. Submarines did not transmit often enough for interceptions to be of value other than the fact that calls could be recognized.

C. PLOT OF SUBMARINE MOVEMENTS

Bearings obtained by RDF stations were sent to the Grand Escort Fleet in TOKYO for plotting and analysis. Plots of the entire Pacific area were maintained and sent via radio to appropriate Fleet Area Commanders. Radio communication difficulties at times, hampered prompt tactical use of RDF bearings.

Sightings resulted in prompt coverage by planes, which were sent from the nearest base operated by the ASW air groups. Each naval base maintained a sighting and intelligence center. Communications from all stations other than YOKOSUKA, was by radio due to the poor service of the Japanese long distance telephone system.

The Japanese believed that the Grand Escort Fleet could determine arrivals and departures of certain groups of U.S. submarines, and predict their reappearance upon the scene. Printed intelligence bulletins covering expected arrivals and activities of U.S. submarines, were issued to all escorts prior to departure from port. Escort commanders relied heavily upon these bulletins and placed much confidence in them.

Special intelligence was transmitted to various fleet commanders for tactical use. For example, Rear Admiral Mitsuhara MATSUYAMA, related that in September 1944, he was in command of an eleven ship convoy enroute from Formosa to Manila, when he received a radio despatch from the First Escort Fleet Headquarters advising him that two submarines were across his track. At about 0330, after moonrise, his convoy was attacked by submarine and two of his ships were sunk.

The First Escort Fleet consistently altered routing based on submarine position information.

Part VI
RECORDS OF ANTI-SUBMARINE OPERATIONS

A. EVALUATION OF ACTION REPORTS

Commanding Officers of escorts made up their action reports which were submitted by their group commanders to the First Escort Fleet Headquarters from which the reports were forwarded to the Grand Escort Fleet in TOKYO for final evaluation. Copies were submitted to the Anti-Submarine Warfare School at YOKOSUKA for analysis and criticism. Similarly, reports of anti-submarine action by aircraft were forwarded by air group commanders with photographic evidence, via the chain of command to the Grand Escort Fleet for assessment.

Bulletins containing attack evaluations, were issued by the Grand Escort Fleet Headquarters monthly.

Until the establishment of the Grand Escort Fleet, action reports were not analyzed with a view of assessing damage, and claims were wildly exaggerated. After its establishment, a board consisting of seven to nine officers was convened at the Grand Escort Fleet headquarters. This board studied action reports, correlated intelligence, and made decisions as to damage inflicted. The Naval General Staff was represented on this board.

In assessing kills, the board used the following factors:

1. Oil and the length of time it continued to come up.
2. Debris
3. Insulating material
4. Buoys from submarines
5. Crew members captured

Factors 1, 2, 3 and 4 were modified by intelligence factors. For example, a wolf-pack would arrive and the Grand Escort Fleet would become familiar with the vessels' calls. If a promising attack report came in and one of the calls was no longer heard after the date of the attack, this factor would be used as a weight factor to establish a successful attack. A careful account was kept of losses announced by the United States of submarines presumed lost. This involved another factor which entered into the final estimates. Members of the board felt that their own operating personnel exaggerated claims and arrived at a 33% reduction factor to offset this. They also believed that the U.S. Navy reported only about one-third or one-fourth of its losses. They therefore, divided their analyzed credited sinkings by three and multiplied U.S. reported sinkings by three or four as a balancing factor to verify their results.

The overall results were that the evaluation of their results was exaggerated. This exaggeration came chiefly from the inability of the escort commanding officers and pilots to restrain themselves from injecting exaggerated claims into their action reports, and in the inability of the high command to believe that the U.S. would make truthful announcements of losses.

Their total of losses, based on announcements made by our Navy, was checked against our actual losses and was in substantial agreement.

Commander SUGITO, with other officers who had been attached to the Grand Escort Fleet Headquarters, reconstructed the estimate of sinkings credited as follows:

From To	November 15, 1943 December 7, 1944	161
From To	December 8, 1944 August 15, 1945	53
Total for period		214

Commander SOGAWA stated that the Naval General Staff believed that they actually had sunk about 120 submarines.

B. FUNCTIONS OF AIRCRAFT IN ASW

Japanese conception of the function of aircraft in anti-submarine warfare was:

1. Patrol of the convoy lanes
2. Close air cover for the escort of convoys
3. Offensive sweeps or patrols in coordination with surface forces

C. FUNCTIONS OF SURFACE ESCORTS

The primary mission of surface escorts according to Japanese doctrine was the direct escort of convoys. A secondary mission was that of offensive sweeps in coordination with aircraft. This concept was forced by the lack of escorts, the vital necessity for getting shipping through, and the offensive and successful operations of U.S. submarines and later, aircraft, from the U.S. fast carrier task groups. Attacks were so constant and so serious that until 1945 no consideration was given to any other use than escorting convoys.

In 1945, however, an air surface "hunter-killer" group was organized. The surface forces consisted of five "coast defense" ships (KAIBOKAN) organized as the 102nd Squadron and aircraft of the Shanghai Air Force, a squadron of twenty Navy fighters based at Shanghai. These planes were equipped with radar and MAD and modified to carry depth charges.

Searches were coordinated by the commander of the 102nd Squadron, and the method of operation was to dispatch two or three vessels on offensive sweeps between Shanghai and Formosa. From dawn to dusk flights of from 4 to 6 planes, flew radar searches in line of bearing twenty miles apart, over the same area. Aircraft contacts were reported by radio to the base, then attacks were made by depth charge runs using MAD gear. Surface escorts intercepted contact and proceeded to the scene to continue the attack until the submarine was destroyed.

This was the only attempt made in the nature of special ASW combined air-surface offensive tactics.

D. FUNCTIONS OF SUBMARINES IN ASW

Submarines were not contemplated for use in anti-submarine warfare in any capacity other than to attack if a contact was made. During the latter part of the war, when it was learned that U.S. submarines were being used in air-sea rescue missions, an attempt was made to combat these submarines with submarines. The Japanese did not, in general, consider anti-submarine warfare as a function of their submarines.

E. FUNCTIONS OF CONVOY ROUTING

During the latter part of the war the Headquarters of the Grand Escort Fleet handled all routing to insure that convoys would receive air cover by passing through certain areas at certain times; and to insure that the safest routes were used based upon intelligence at hand. Change of routing was also used to avoid submarines.

F. FUNCTIONS OF MINES

Controlled minefields were relied upon as the chief harbor defense weapon against submarines. Mine lines were planted across the Yellow Sea as a defense measure against submarines. Minefields were planted to protect the convoy lane off the NANSEI SHOTO between KYUSHU and Formosa, according to Commander SOGAWA, which, combined with aircraft, lookout stations and local ascorts, offered considerable protection to this leg of the convoy lane.

The sketch below was submitted by him to explain the system.

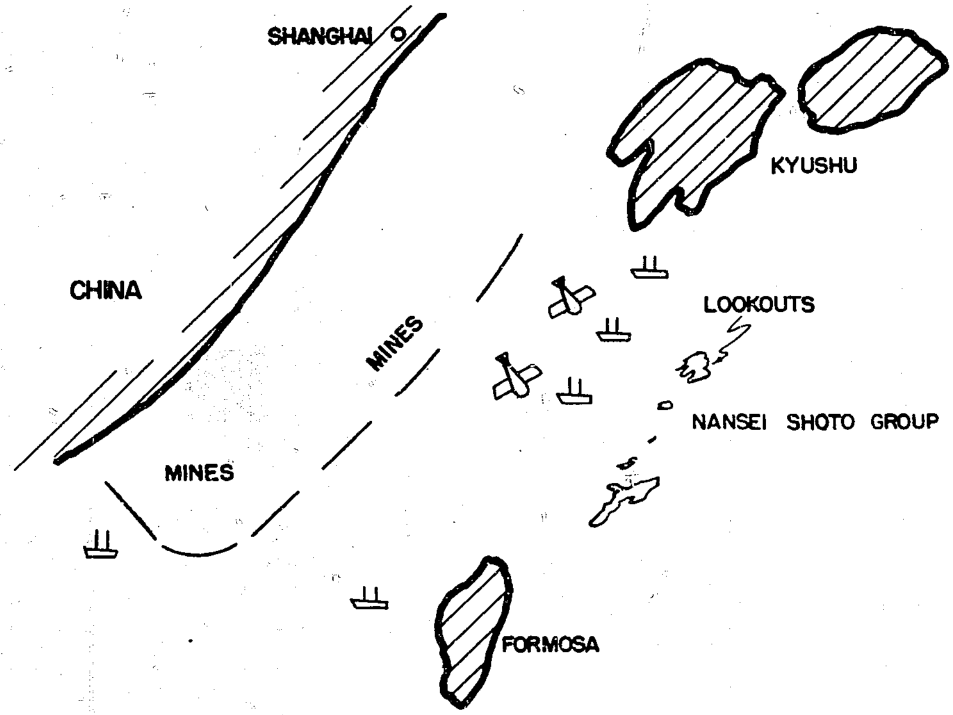


Figure 62

KYUSHU, FORMOSA, AND NANSEI SHOTO MINEFIELDS

G. <u>EVALUATION OF THE EFFECTIVENESS OF DIFFERENT METHODS OF ASW</u>

Surface escorts were considered highly effective in making kills.

Great weight was placed on the effectiveness of the searches made by anti-submarine aircraft. Confidence was growing in the effectiveness of MAD attacks.

Much confidence was placed in Japanese anti-submarine intelligence; routing was considered to have been very effective in avoiding submarine attacks.

Complete reliance was placed on the effectiveness of controlled mine fields for harbor protection against submarines. The use of off-shore mine fields to protect coastal shipping was considered effective.

Submarines were not considered effective in the anti-submarine war effort.

Part VII
RECORDS

Persistent interrogations consistently resulted in statements from all officers attached to the staffs of the higher commands that on 25 August 1945 the Grand Escort Fleet and its subordinate commands were dissolved and that all action reports were destroyed by burning.

Efforts to locate such records have been unsuccessful.

Enclosure (A) contains extracts of action reports which Commander SOGAWA made in his notebook, while he was a member of the evaluating board.

A reconstructed estimate of the sinkings published by the Grand Escort Fleet was prepared by Commander SUGITO and other officers who had been attached to the Grand Escort Fleet Headquarters. The total is given in Part VI.

Enclosure (H), "List of Japanese Attacks on U.S. Submarines (claimed sinkings)" of NavTechJap Report "Japanese Submarine Operations", Index No. S-17, does not contain a true reflection of Japanese opinion of their own efforts. Staff officers freely admit that until the Grand Escort Fleet commenced evaluation in November 1943 credit was given to practically all claims and the list of sinkings was therefore grossly in error.

ENCLOSURE (A)

ASW ACTION REPORTS FROM NOTEBOOK OF COMMANDER SOGAWA, IJN

(1) At 21°-51'N, 120°-43'E at 2215 on 7 August 1944, Subchaser #61 with its radar intercept receiver picked up a high sensitivity electric wave of 165 megacycles. With its own radar it picked up an enemy submarine 600 meters off its bow during the early warning search. During the search it picked it up with its echo ranging equipment and at 2255 undertook a depth charge attack. There were reports that the results were very good.

(2) At 33°-20'N, 124°-40'E at 2300 on 17 November 1944, the Coast Defense Ship, DAITO, intercepted a 5675 kilocycle telephone wave. During its early warning search on the following day, 18 November, it picked up with its radar an enemy submarine at 0105 at 1000 meters bearing 20 degrees to port. Immediately it sighted a floating submarine and carried out a depth charge attack effective up to 200 meters with its echo ranging equipment. There were reports indicating that the enemy submarine was sunk.

(3) At 35°-27'N, 124°-10'E at 1135 on 21 March 1945, the Coast Defense Ship, UKITA, intercepted a telephone wave suggesting an enemy submarine. At 0526 on the following day it picked it up at bearing 130 degrees, 8000 meters (the weather was misty). At 0615 it sighted a submarine at 1500 meters, and, at the same time, one torpedo trace passed it by. At 0618 gunfire was started. The enemy submarine, still afloat, sped off at a speed of 20 knots and, though followed for 2 hours, could not be caught. At 0708 a gunfire attack (5 rounds) utilizing radar was carried out at 5000 meters. Radar sensitivity disappeared at 0713 and the enemy let fly one rubber balloon for purposes of deception and submerged.

(4) At 24°-42'N, 120°-40'E at 1410 on 21 February 1944, the torpedo boat, HATO, picked up an enemy submarine. Utilizing its echo ranging recording gear it proceeded up to about 150 meters and when it was almost at a point thought to be directly above the submarine, it carried out a precise depth charge attack (30 rounds). There were reports that it was definitely sunk.

(5) While sailing alone and heading for the BUNGO Strait from PALAU at 32°-10'N, 131°-51'E on 29 May 1943, the SHINTO MARU (1215 gross tons, speed 9 knots) received a total of 5 torpedo attacks. Nevertheless, it successfully avoided them and finally fired, getting one hit on the enemy's conning tower and one on the part below it. Next, when it had sailed over the then submerged enemy, large quantities of oil and bubbles were gushing forth. There were reports that it was definitely sunk.

(6) At 26°-13'N, 122°-39'E at 1540 on 16 July 1944, magnetic detector equipped aircraft of the escort carrier, SHINYO, detected a submerged enemy submarine. According to reports the Coast Defense Ships, SADO and #7, which were in the vicinity immediately carried out an effective attack and there were reports that it was definitely sunk.

(7) On 18 August 1944, in the north strait at BALABAK, the UGA MARU (4433 gross tons; speed 9 knots) detected with its hydrophones the echo-ranging sound which an enemy submarine was transmitting. It knew the submarine was following it. By firing it pointed out the submarine's approximate position to friendly planes and craft which were in the area and started operations for attacking and sinking it.

(8) On 17 November 1943, while returning from RABAUL to TRUK, the submarine I-176 encountered an enemy submarine about 90 nautical miles south of TRUK. It launched torpedoes, two of which hit the target. There were reports that it was definitely sunk.

ENCLOSURE (A), continued

(9) At 1230 on 7 November 1944, a converted picket boat (a small merchant ship of about 80 to 150 tons, armed so as to be capable of carrying out observation duties) discovered the tracks of an enemy submarine about 6000 meters east of EZAN MISAKI on HOKKAIDO. While being pursued, the enemy submarine ran into one of our minefields. A great underwater explosion occurred, and clothing and books (novels) which seemed to belong to the crew floated up to the surface.

(10) At about 0900 on 6 November 1944, a SURABAYA-based reconnaissance seaplane discovered and attacked a moving oil slick about 60 nautical miles NNW of SURABAYA. On the following day the Minesweeper #12 detected an enemy submarine at approximately the same location and carried out depth charge attacks against it. There were reports that it was definitely sunk.

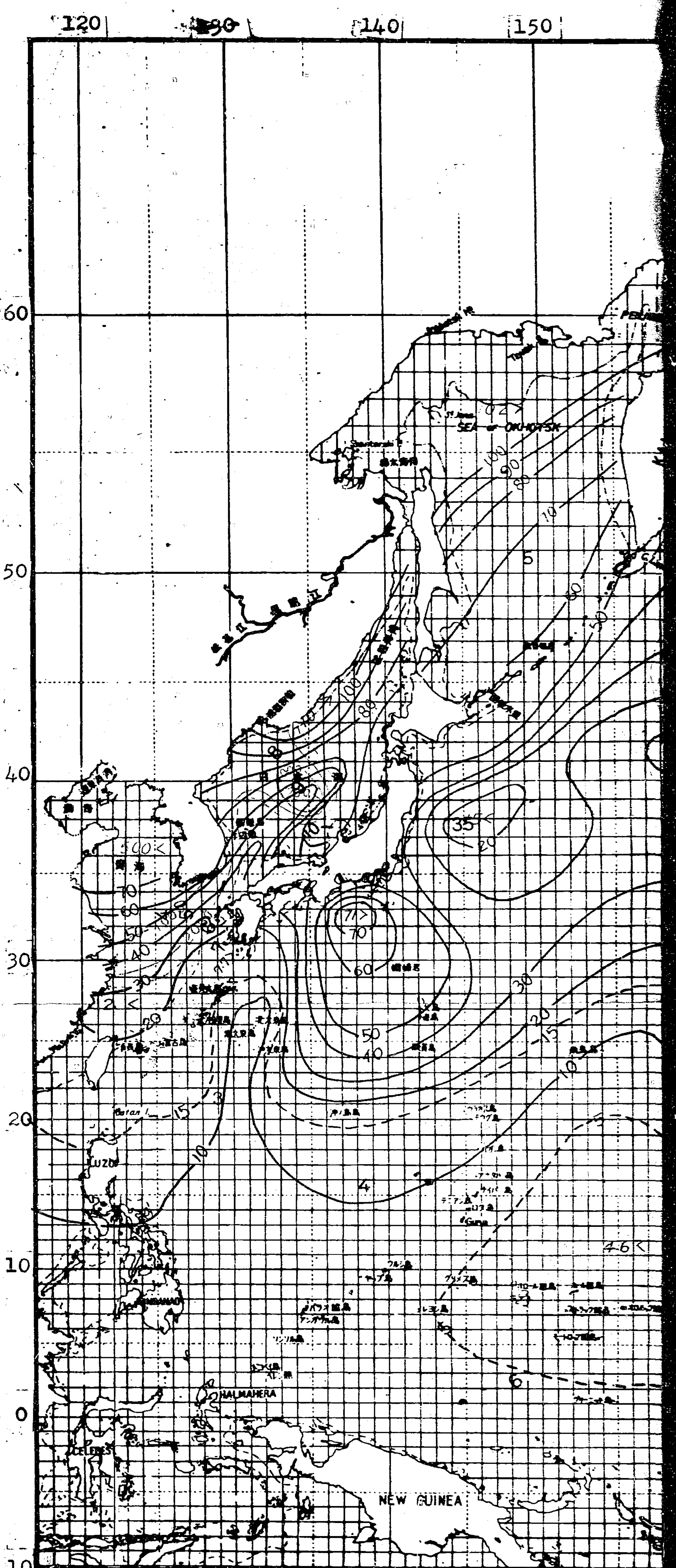
Note: The results of an attack can be determined by considering such points as: floating oil; the duration and quantity of air bubbles; floating debris; the reasonableness of the method of attack; search with echo-ranging gear after the attack; the condition of the enemy's radio transmission after the attack; and whether or not any ships are damaged thereafter in the area.

ENCLOSURE (B)

CHARTS FOR ECHO RANGING - ATTENUATION AND MAXIMUM AUDIBLE RANGE

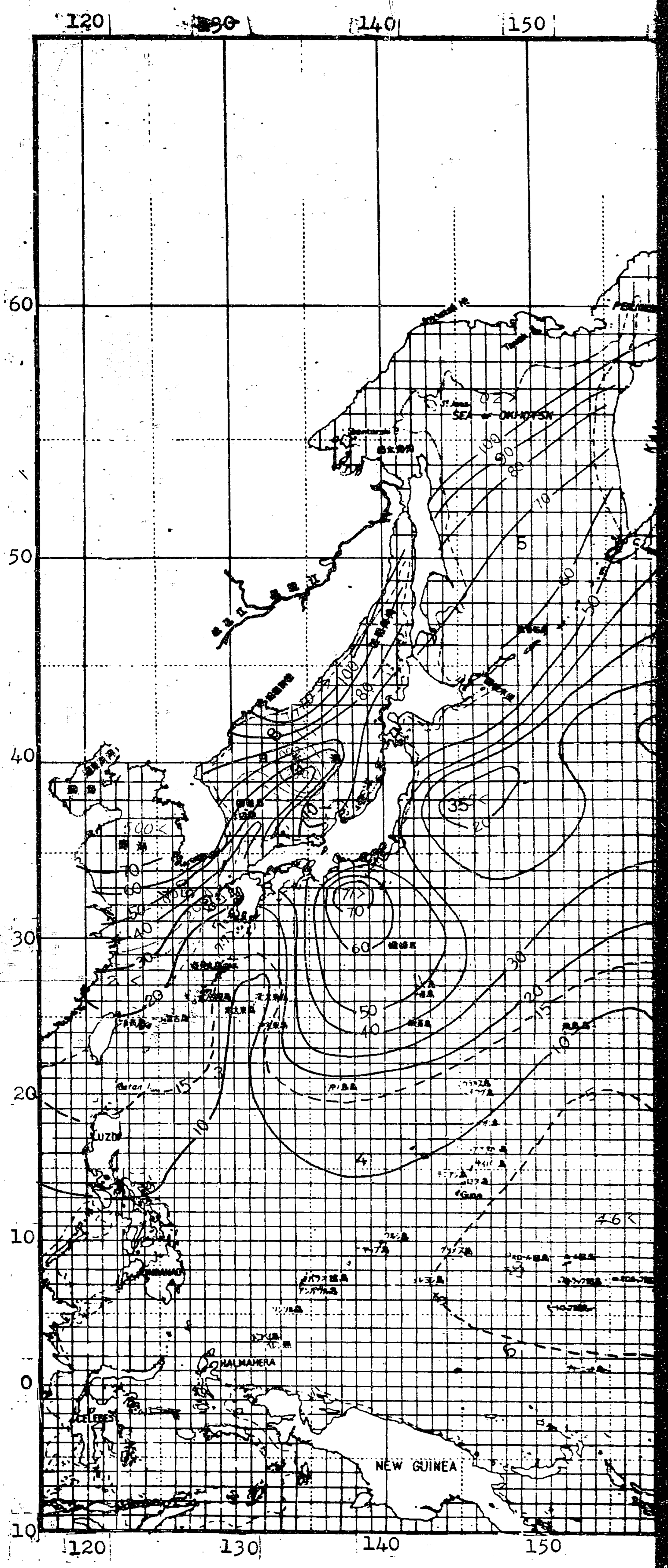
The following charts show the values of two constants "a" and "b" over large areas of the Pacific Ocean, in summer and winter, Chart No. 2776 being on the larger scale. These two constants, which depend upon the physical characteristics of the water, determine the speed of sound in water. Attenuation and maximum audible range equations are derived on Chart No. 2775. Chart 2776 gives examples of the use of the charts.

Note: Chart 2776 has been reduced photographically, about 50%, for convenience in publishing.



a 10⁻⁴ m⁻¹ / x m	0	1	2	3	4	5	6	7	8	9	10
100	40	40	40	40	40	40	40	40	40	40	40
200	46	46	46	46	46	46	46	46	46	46	46
300	50	50	50	50	50	50	50	50	50	50	50
400	52	52	52	52	52	52	52	52	52	52	52
500	54	54	54	54	54	54	54	54	54	54	54
600	56	56	56	56	56	56	56	56	56	56	56
700	57	57	57	57	57	57	57	57	57	57	57
800	58	58	58	58	58	58	58	58	58	58	58
900	59	59	59	59	59	59	59	59	60	60	60
1,000	60	60	60	60	60	60	60	60	61	61	61
1,500	64	64	64	64	64	64	64	64	65	65	65
2,000	66	66	66	66	66	67	67	68	68	68	69
3,000	70	70	70	70	71	71	72	72	73	74	75
4,000	72	72	72	73	74	75	76	77	78	79	80
5,000	74	74	75	75	77	78	79	81	82	84	86
6,000	76	76	77	77	79	81	83	85	87	89	91
7,000	77	77	78	80	82	84	86	88	91	93	96
8,000	78	78	80	82	84	86	89	92	95	98	101
9,000	79	80	81	83	86	89	92	95	99	102	106
10,000	80	81	83	85	88	92	95	99	103	107	111
20,000	86	89	94	101	109	116	124	132	140	149	157
30,000	90	95	105	116	128	140	152	165	177	190	202
x m / a 10⁻⁴ m⁻¹	0	1	2	3	4	5	6	7	8	9	10

a 10⁻⁴ m⁻¹ / x m	0	1	2	3	4	5	6	7	8	9	10
100	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	[illegible]
200	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	[illegible]
300	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	[illegible]
400	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.61}$	$\overset{5}{0.61}$	[illegible]
500	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.39}$	$\overset{5}{0.39}$	$\overset{5}{0.39}$	$\overset{5}{0.39}$	[illegible]
600	$\overset{5}{0.28}$	$\overset{5}{0.28}$	$\overset{5}{0.28}$	$\overset{5}{0.28}$	$\overset{5}{0.28}$	$\overset{5}{0.27}$	$\overset{5}{0.27}$	$\overset{5}{0.27}$	$\overset{5}{0.27}$	$\overset{5}{0.26}$	[illegible]
700	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.19}$	$\overset{5}{0.19}$	[illegible]
800	$\overset{5}{0.16}$	$\overset{5}{0.16}$	$\overset{5}{0.16}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.14}$	[illegible]
900	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.11}$	$\overset{5}{0.11}$	[illegible]
1,000	$\overset{5}{0.10}$	$\overset{5}{0.10}$	$\overset{6}{0.99}$	$\overset{6}{0.99}$	$\overset{6}{0.97}$	$\overset{6}{0.96}$	$\overset{6}{0.94}$	$\overset{6}{0.92}$	$\overset{6}{0.90}$	$\overset{6}{0.88}$	[illegible]
1,500	$\overset{6}{0.44}$	$\overset{6}{0.44}$	$\overset{6}{0.44}$	$\overset{6}{0.43}$	$\overset{6}{0.42}$	$\overset{6}{0.41}$	$\overset{6}{0.39}$	$\overset{6}{0.37}$	$\overset{6}{0.35}$	$\overset{6}{0.33}$	[illegible]
2,000	$\overset{6}{0.25}$	$\overset{6}{0.25}$	$\overset{6}{0.24}$	$\overset{6}{0.24}$	$\overset{6}{0.23}$	$\overset{6}{0.21}$	$\overset{6}{0.20}$	$\overset{6}{0.18}$	$\overset{6}{0.17}$	$\overset{6}{0.15}$	[illegible]
3,000	$\overset{6}{0.11}$	$\overset{6}{0.11}$	$\overset{6}{0.10}$	$\overset{7}{0.97}$	$\overset{7}{0.88}$	$\overset{7}{0.78}$	$\overset{7}{0.68}$	$\overset{7}{0.58}$	$\overset{7}{0.49}$	$\overset{7}{0.41}$	[illegible]
4,000	$\overset{7}{0.62}$	$\overset{7}{0.61}$	$\overset{7}{0.56}$	$\overset{7}{0.50}$	$\overset{7}{0.42}$	$\overset{7}{0.34}$	$\overset{7}{0.27}$	$\overset{7}{0.21}$	$\overset{7}{0.16}$	$\overset{7}{0.12}$	[illegible]
5,000	$\overset{7}{0.40}$	$\overset{7}{0.38}$	$\overset{7}{0.34}$	$\overset{7}{0.28}$	$\overset{7}{0.22}$	$\overset{7}{0.17}$	$\overset{7}{0.12}$	$\overset{8}{0.85}$	$\overset{8}{0.59}$	$\overset{8}{0.40}$	[illegible]
6,000	$\overset{7}{0.28}$	$\overset{7}{0.26}$	$\overset{7}{0.22}$	$\overset{7}{0.17}$	$\overset{7}{0.12}$	$\overset{8}{0.83}$	$\overset{8}{0.55}$	$\overset{8}{0.35}$	$\overset{8}{0.22}$	$\overset{8}{0.14}$	[illegible]
7,000	$\overset{7}{0.20}$	$\overset{7}{0.19}$	$\overset{7}{0.15}$	$\overset{7}{0.11}$	$\overset{8}{0.70}$	$\overset{8}{0.43}$	$\overset{8}{0.26}$	$\overset{8}{0.15}$	$\overset{9}{0.85}$	$\overset{9}{0.47}$	[illegible]
8,000	$\overset{7}{0.16}$	$\overset{7}{0.14}$	$\overset{7}{0.11}$	$\overset{8}{0.69}$	$\overset{8}{0.41}$	$\overset{8}{0.23}$	$\overset{8}{0.12}$	$\overset{9}{0.65}$	$\overset{9}{0.33}$	$\overset{9}{0.17}$	[illegible]
9,000	$\overset{7}{0.12}$	$\overset{7}{0.11}$	$\overset{8}{0.76}$	$\overset{8}{0.45}$	$\overset{8}{0.24}$	$\overset{8}{0.12}$	$\overset{9}{0.60}$	$\overset{9}{0.29}$	$\overset{9}{0.13}$	$\overset{10}{0.61}$	[illegible]
10,000	$\overset{7}{0.10}$	$\overset{8}{0.85}$	$\overset{8}{0.55}$	$\overset{8}{0.30}$	$\overset{8}{0.15}$	$\overset{9}{0.67}$	$\overset{9}{0.30}$	$\overset{9}{0.13}$	$\overset{10}{0.54}$	$\overset{10}{0.22}$	[illegible]
20,000	$\overset{8}{0.25}$	$\overset{8}{0.14}$	$\overset{9}{0.37}$	$\overset{10}{0.74}$	$\overset{10}{0.13}$	$\overset{11}{0.23}$	$\overset{12}{0.37}$	$\overset{13}{0.58}$	$\overset{14}{0.90}$	$\overset{14}{0.14}$	[illegible]
30,000	$\overset{8}{0.11}$	$\overset{9}{0.33}$	$\overset{10}{0.33}$	$\overset{11}{0.25}$	$\overset{12}{0.16}$	$\overset{13}{0.10}$	$\overset{15}{0.61}$	$\overset{16}{0.35}$	$\overset{17}{0.20}$	$\overset{18}{0.11}$	[illegible]
x m / a 10⁻⁴ m⁻¹	0	1	2	3	4	5	6	7	8	9	10



a $10^{-4}m^{-1}$ / x m	0	1	2	3	4	5	6	7	8	9	10
100	40	40	40	40	40	40	40	40	40	40	40
200	46	46	46	46	46	46	46	46	46	46	46
300	50	50	50	50	50	50	50	50	50	50	50
400	52	52	52	52	52	52	52	52	52	52	52
500	54	54	54	54	54	54	54	54	54	54	54
600	56	56	56	56	56	56	56	56	56	56	56
700	57	57	57	57	57	57	57	57	57	57	57
800	58	58	58	58	58	58	58	58	58	58	58
900	59	59	59	59	59	59	59	59	60	60	60
1,000	60	60	60	60	60	60	60	60	61	61	61
1,500	64	64	64	64	64	64	64	64	65	65	65
2,000	66	66	66	66	66	67	67	68	68	68	69
3,000	70	70	70	70	71	71	72	72	73	74	75
4,000	72	72	72	73	74	75	76	77	78	79	80
5,000	74	74	75	75	77	78	79	81	82	84	86
6,000	76	76	77	77	79	81	83	85	87	89	91
7,000	77	77	78	80	82	84	86	88	91	93	96
8,000	78	78	80	82	84	86	89	92	95	98	101
9,000	79	80	81	83	86	89	92	95	99	102	106
10,000	80	81	83	85	88	92	95	99	103	107	111
20,000	86	89	94	101	109	116	124	132	140	149	157
30,000	90	95	105	116	128	140	192	165	177	190	202
x m / a $10^{-4}m^{-1}$	0	1	2	3	4	5	6	7	8	9	10

a $10^{-4}m^{-1}$ / x m	0	1	2	3	4	5	6	7	8	9	10
100	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$
200	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	[illegible]
300	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	[illegible]
400	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.62}$	$\overset{5}{0.61}$	$\overset{5}{0.61}$	[illegible]
500	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.40}$	$\overset{5}{0.39}$	$\overset{5}{0.39}$	$\overset{5}{0.39}$	$\overset{5}{0.39}$	[illegible]
600	$\overset{5}{0.28}$	$\overset{5}{0.28}$	$\overset{5}{0.28}$	$\overset{5}{0.28}$	$\overset{5}{0.28}$	$\overset{5}{0.27}$	$\overset{5}{0.27}$	$\overset{5}{0.27}$	$\overset{5}{0.27}$	$\overset{5}{0.26}$	[illegible]
700	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.20}$	$\overset{5}{0.19}$	$\overset{5}{0.19}$	[illegible]
800	$\overset{5}{0.16}$	$\overset{5}{0.16}$	$\overset{5}{0.16}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.15}$	$\overset{5}{0.14}$	[illegible]
900	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.12}$	$\overset{5}{0.11}$	$\overset{5}{0.11}$	[illegible]
1,000	$\overset{5}{0.10}$	$\overset{5}{0.10}$	$\overset{6}{0.99}$	$\overset{6}{0.99}$	$\overset{6}{0.97}$	$\overset{6}{0.96}$	$\overset{6}{0.94}$	$\overset{6}{0.92}$	$\overset{6}{0.90}$	$\overset{6}{0.88}$	[illegible]
1,500	$\overset{6}{0.44}$	$\overset{6}{0.44}$	$\overset{6}{0.44}$	$\overset{6}{0.43}$	$\overset{6}{0.42}$	$\overset{6}{0.41}$	$\overset{6}{0.39}$	$\overset{6}{0.37}$	$\overset{6}{0.35}$	$\overset{6}{0.33}$	[illegible]
2,000	$\overset{6}{0.25}$	$\overset{6}{0.25}$	$\overset{6}{0.24}$	$\overset{6}{0.24}$	$\overset{6}{0.23}$	$\overset{6}{0.21}$	$\overset{6}{0.20}$	$\overset{6}{0.18}$	$\overset{6}{0.17}$	$\overset{6}{0.15}$	[illegible]
3,000	$\overset{6}{0.11}$	$\overset{6}{0.11}$	$\overset{6}{0.10}$	$\overset{7}{0.97}$	$\overset{7}{0.88}$	$\overset{7}{0.78}$	$\overset{7}{0.68}$	$\overset{7}{0.58}$	$\overset{7}{0.49}$	$\overset{7}{0.41}$	[illegible]
4,000	$\overset{7}{0.62}$	$\overset{7}{0.61}$	$\overset{7}{0.56}$	$\overset{7}{0.50}$	$\overset{7}{0.42}$	$\overset{7}{0.34}$	$\overset{7}{0.27}$	$\overset{7}{0.21}$	$\overset{7}{0.16}$	$\overset{7}{0.12}$	[illegible]
5,000	$\overset{7}{0.40}$	$\overset{7}{0.38}$	$\overset{7}{0.34}$	$\overset{7}{0.28}$	$\overset{7}{0.22}$	$\overset{7}{0.17}$	$\overset{7}{0.12}$	$\overset{8}{0.85}$	$\overset{8}{0.59}$	$\overset{8}{0.40}$	[illegible]
6,000	$\overset{7}{0.28}$	$\overset{7}{0.26}$	$\overset{7}{0.22}$	$\overset{7}{0.17}$	$\overset{7}{0.12}$	$\overset{8}{0.83}$	$\overset{8}{0.55}$	$\overset{8}{0.35}$	$\overset{8}{0.22}$	$\overset{8}{0.14}$	[illegible]
7,000	$\overset{7}{0.20}$	$\overset{7}{0.19}$	$\overset{7}{0.15}$	$\overset{7}{0.11}$	$\overset{8}{0.70}$	$\overset{8}{0.43}$	$\overset{8}{0.26}$	$\overset{8}{0.15}$	$\overset{9}{0.85}$	$\overset{9}{0.47}$	[illegible]
8,000	$\overset{7}{0.16}$	$\overset{7}{0.14}$	$\overset{7}{0.11}$	$\overset{8}{0.69}$	$\overset{8}{0.41}$	$\overset{8}{0.23}$	$\overset{8}{0.12}$	$\overset{9}{0.65}$	$\overset{9}{0.33}$	$\overset{9}{0.17}$	[illegible]
9,000	$\overset{7}{0.12}$	$\overset{7}{0.11}$	$\overset{8}{0.76}$	$\overset{8}{0.45}$	$\overset{8}{0.24}$	$\overset{8}{0.12}$	$\overset{9}{0.60}$	$\overset{9}{0.29}$	$\overset{9}{0.13}$	$\overset{10}{0.61}$	[illegible]
10,000	$\overset{7}{0.10}$	$\overset{8}{0.85}$	$\overset{8}{0.55}$	$\overset{8}{0.30}$	$\overset{8}{0.15}$	$\overset{9}{0.67}$	$\overset{9}{0.30}$	$\overset{9}{0.13}$	$\overset{10}{0.54}$	$\overset{10}{0.22}$	[illegible]
20,000	$\overset{8}{0.25}$	$\overset{8}{0.14}$	$\overset{9}{0.37}$	$\overset{10}{0.74}$	$\overset{10}{0.13}$	$\overset{11}{0.23}$	$\overset{12}{0.37}$	$\overset{13}{0.58}$	$\overset{14}{0.90}$	$\overset{14}{0.14}$	[illegible]
30,000	$\overset{8}{0.11}$	$\overset{9}{0.33}$	$\overset{10}{0.33}$	$\overset{11}{0.25}$	$\overset{12}{0.16}$	$\overset{13}{0.10}$	$\overset{15}{0.61}$	$\overset{16}{0.35}$	$\overset{17}{0.20}$	$\overset{18}{0.11}$	[illegible]
x m / a $10^{-4}m^{-1}$	0	1	2	3	4	5	6	7	8	9	10

ENCLOSURE (B), continued

CHART FOR SONIC RANGING - ATTENUATION & MAXIMUM AUDIBLE
(JAPANESE HYDROGRAPHIC CHART NO. 2775 - 20 FEB, 1945)
MAP #1 - DISTRIBUTION OF a AND OF MAXIMUM AUDIBLE DISTANCE

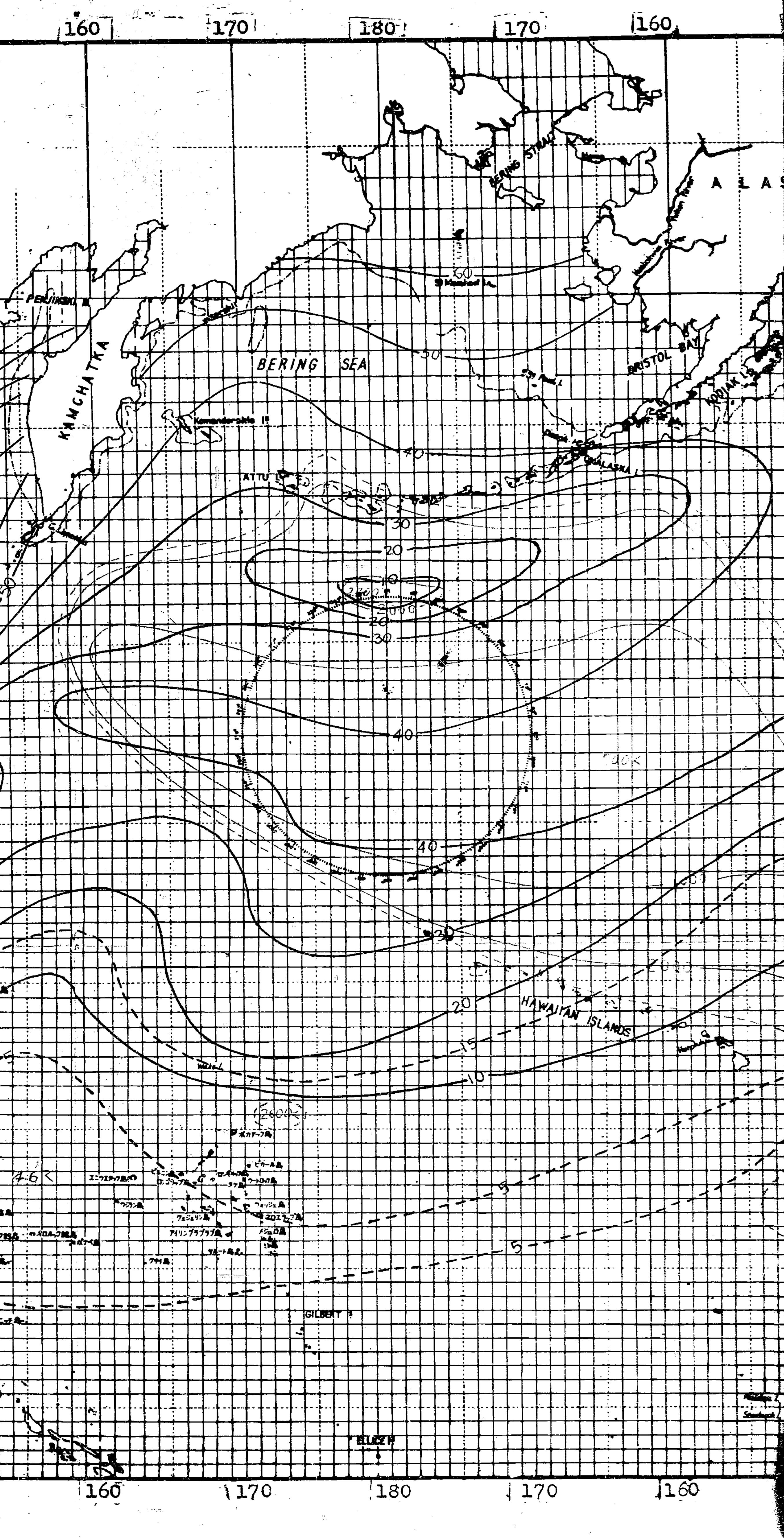


TABLE I

DECREASE OF POWER OF SOUND
(Unit-Decible)

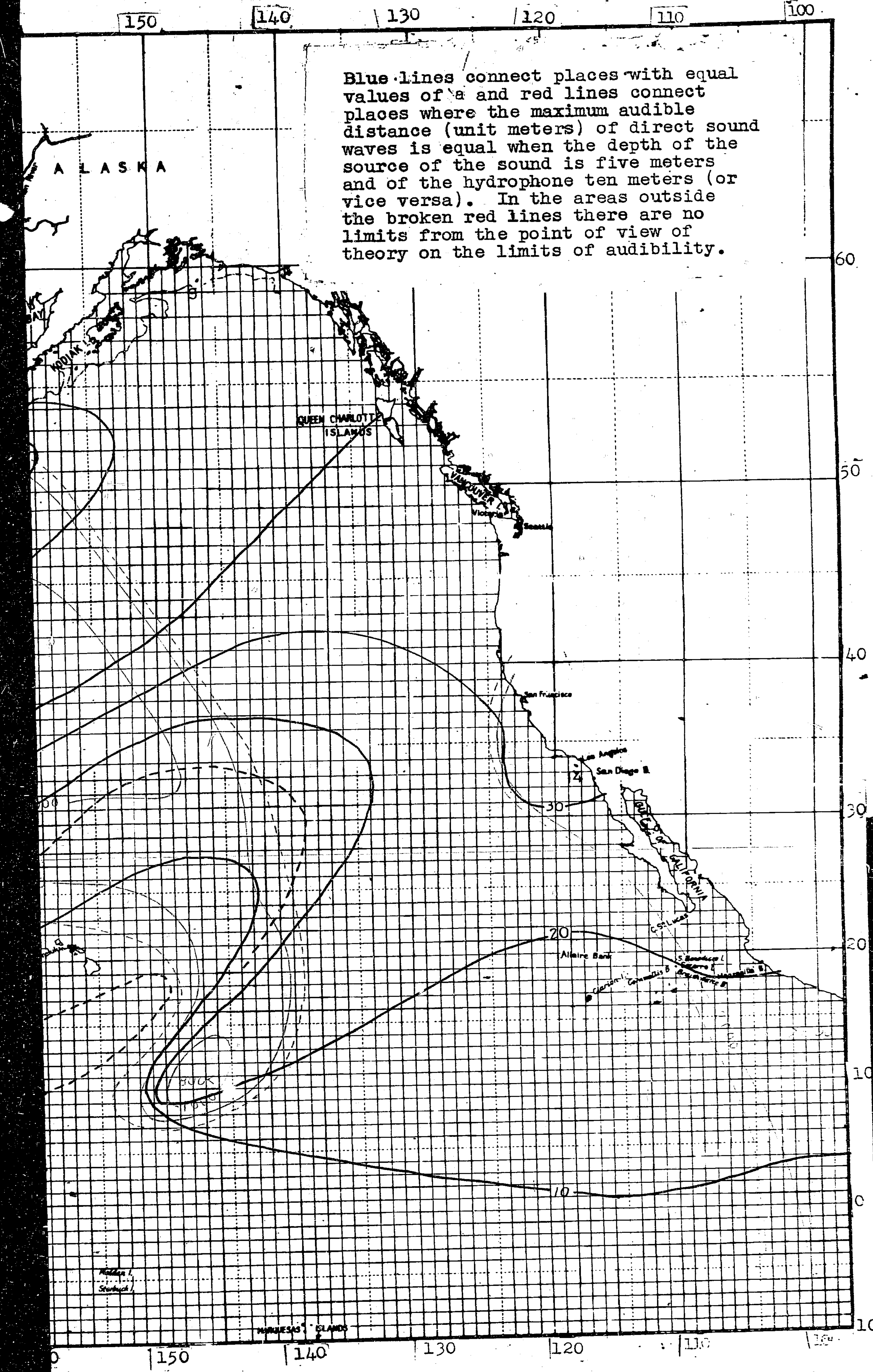
9	10	12	15	20	25	30	35	40	45	50	55	60	65	70	75	80
40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
46	46	46	46	46	46	46	46	46	47	47	47	47	47	47	48	48
50	50	50	50	50	50	50	50	51	51	51	51	52	52	52	53	53
52	52	52	52	53	53	53	53	54	54	55	55	56	56	57	57	58
54	54	54	54	55	55	56	56	57	57	58	59	59	60	61	62	62
56	56	56	56	57	57	58	58	59	60	61	62	63	64	65	66	67
57	57	58	58	58	59	60	61	62	63	64	65	66	67	68	70	71
58	58	59	59	60	61	62	63	64	65	66	68	69	70	72	73	75
60	60	60	60	61	62	64	65	66	68	69	71	72	74	75	77	79
61	61	61	62	63	64	65	67	68	70	72	74	75	77	79	81	83
65	65	66	67	69	71	74	76	79	82	84	87	90	93	96	99	102
68	69	70	71	74	78	81	85	89	93	96	100	104	108	112	116	121
74	75	77	80	85	90	96	102	108	114	120	126	132	138	145	151	157
79	80	83	87	95	102	110	118	126	135	143	151	160	168	176	185	193
84	86	89	95	104	114	124	135	145	155	166	176	187	197	207	218	229
89	91	95	102	114	126	138	151	163	176	188	201	213	226	239	251	264
93	96	101	109	123	138	152	166	181	196	211	225	240	255	270	285	300
98	101	107	116	133	149	166	182	199	216	233	250	267	284	301	318	335
102	106	113	123	142	160	179	199	217	236	255	274	293	313	332	351	370
107	111	118	130	151	172	193	214	235	256	277	299	320	341	363	384	405
149	157	173	199	241	283	326	369	411	454	497	540	583	626	670	713	756
190	202	227	265	329	394	458	522	587	652	716	781	846	911	975	1040	1115
9	10	12	15	20	25	30	35	40	45	50	55	60	65	70	75	80

TABLE II

DECREASE OF POWER OF SOUND

9	10	12	15	20	25	30	35	40	45	50	55	60	65	70	75	80
$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{3}{0.10}$	$\overset{4}{0.99}$	$\overset{4}{0.99}$	$\overset{4}{0.99}$	$\overset{4}{0.98}$	$\overset{4}{0.97}$	$\overset{4}{0.97}$	$\overset{4}{0.96}$	$\overset{4}{0.95}$	$\overset{4}{0.94}$	$\overset{4}{0.93}$	$\overset{4}{0.92}$	$\overset{4}{0.91}$	$\overset{4}{0.90}$
$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.25}$	$\overset{4}{0.24}$	$\overset{4}{0.24}$	$\overset{4}{0.24}$	$\overset{4}{0.23}$	$\overset{4}{0.23}$	$\overset{4}{0.22}$	$\overset{4}{0.21}$	$\overset{4}{0.21}$	$\overset{4}{0.20}$	$\overset{4}{0.19}$	$\overset{4}{0.18}$	$\overset{4}{0.18}$	$\overset{4}{0.17}$
$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.11}$	$\overset{4}{0.10}$	$\overset{4}{0.10}$	$\overset{5}{0.97}$	$\overset{5}{0.93}$	$\overset{5}{0.88}$	$\overset{5}{0.83}$	$\overset{5}{0.78}$	$\overset{5}{0.73}$	$\overset{5}{0.68}$	$\overset{5}{0.63}$	$\overset{5}{0.58}$	$\overset{5}{0.53}$	$\overset{5}{0.49}$
$\overset{5}{0.61}$	$\overset{5}{0.61}$	$\overset{5}{0.60}$	$\overset{5}{0.59}$	$\overset{5}{0.56}$	$\overset{5}{0.53}$	$\overset{5}{0.50}$	$\overset{5}{0.46}$	$\overset{5}{0.42}$	$\overset{5}{0.38}$	$\overset{5}{0.34}$	$\overset{5}{0.31}$	$\overset{5}{0.27}$	$\overset{5}{0.24}$	$\overset{5}{0.21}$	$\overset{5}{0.19}$	$\overset{5}{0.16}$
$\overset{5}{0.39}$	$\overset{5}{0.38}$	$\overset{5}{0.38}$	$\overset{5}{0.36}$	$\overset{5}{0.34}$	$\overset{5}{0.31}$	$\overset{5}{0.28}$	$\overset{5}{0.25}$	$\overset{5}{0.22}$	$\overset{5}{0.19}$	$\overset{5}{0.17}$	$\overset{5}{0.14}$	$\overset{5}{0.12}$	$\overset{5}{0.10}$	$\overset{6}{0.85}$	$\overset{6}{0.71}$	$\overset{6}{0.59}$
$\overset{5}{0.26}$	$\overset{5}{0.26}$	$\overset{5}{0.26}$	$\overset{5}{0.24}$	$\overset{5}{0.22}$	$\overset{5}{0.20}$	$\overset{5}{0.17}$	$\overset{5}{0.15}$	$\overset{5}{0.12}$	$\overset{5}{0.10}$	$\overset{6}{0.83}$	$\overset{6}{0.68}$	$\overset{6}{0.55}$	$\overset{6}{0.44}$	$\overset{6}{0.35}$	$\overset{6}{0.28}$	$\overset{6}{0.22}$
$\overset{5}{0.19}$	$\overset{5}{0.19}$	$\overset{5}{0.18}$	$\overset{5}{0.17}$	$\overset{5}{0.15}$	$\overset{5}{0.13}$	$\overset{5}{0.11}$	$\overset{6}{0.87}$	$\overset{6}{0.70}$	$\overset{6}{0.55}$	$\overset{6}{0.43}$	$\overset{6}{0.33}$	$\overset{6}{0.26}$	$\overset{6}{0.20}$	$\overset{6}{0.15}$	$\overset{6}{0.11}$	$\overset{7}{0.85}$
$\overset{5}{0.14}$	$\overset{5}{0.14}$	$\overset{5}{0.13}$	$\overset{5}{0.12}$	$\overset{5}{0.11}$	$\overset{6}{0.86}$	$\overset{6}{0.69}$	$\overset{6}{0.53}$	$\overset{6}{0.41}$	$\overset{6}{0.31}$	$\overset{6}{0.23}$	$\overset{6}{0.17}$	$\overset{6}{0.12}$	$\overset{7}{0.90}$	$\overset{7}{0.65}$	$\overset{7}{0.46}$	$\overset{7}{0.33}$
$\overset{5}{0.11}$	$\overset{5}{0.11}$	$\overset{5}{0.10}$	$\overset{6}{0.93}$	$\overset{6}{0.76}$	$\overset{6}{0.59}$	$\overset{6}{0.45}$	$\overset{6}{0.33}$	$\overset{6}{0.24}$	$\overset{6}{0.17}$	$\overset{6}{0.12}$	$\overset{7}{0.87}$	$\overset{7}{0.60}$	$\overset{7}{0.42}$	$\overset{7}{0.29}$	$\overset{7}{0.20}$	$\overset{7}{0.13}$
$\overset{6}{0.88}$	$\overset{6}{0.85}$	$\overset{6}{0.80}$	$\overset{6}{0.70}$	$\overset{6}{0.55}$	$\overset{6}{0.41}$	$\overset{6}{0.30}$	$\overset{6}{0.21}$	$\overset{6}{0.15}$	$\overset{6}{0.10}$	$\overset{7}{0.67}$	$\overset{7}{0.45}$	$\overset{7}{0.30}$	$\overset{7}{0.20}$	$\overset{7}{0.13}$	$\overset{8}{0.83}$	$\overset{8}{0.54}$
$\overset{6}{0.33}$	$\overset{6}{0.31}$	$\overset{6}{0.27}$	$\overset{6}{0.21}$	$\overset{6}{0.13}$	$\overset{7}{0.78}$	$\overset{7}{0.44}$	$\overset{7}{0.24}$	$\overset{7}{0.13}$	$\overset{8}{0.70}$	$\overset{8}{0.37}$	$\overset{8}{0.19}$	$\overset{9}{0.99}$	$\overset{9}{0.51}$	$\overset{9}{0.26}$	$\overset{9}{0.13}$	$\overset{10}{0.66}$
$\overset{6}{0.15}$	$\overset{6}{0.14}$	$\overset{6}{0.11}$	$\overset{7}{0.75}$	$\overset{7}{0.37}$	$\overset{7}{0.17}$	$\overset{8}{0.74}$	$\overset{8}{0.32}$	$\overset{8}{0.13}$	$\overset{9}{0.56}$	$\overset{9}{0.23}$	$\overset{10}{0.92}$	$\overset{10}{0.37}$	$\overset{10}{0.15}$	$\overset{11}{0.58}$	$\overset{11}{0.23}$	$\overset{12}{0.90}$
$\overset{7}{0.41}$	$\overset{7}{0.33}$	$\overset{7}{0.22}$	$\overset{7}{0.11}$	$\overset{8}{0.33}$	$\overset{9}{0.92}$	$\overset{9}{0.25}$	$\overset{10}{0.64}$	$\overset{10}{0.16}$	$\overset{11}{0.41}$	$\overset{11}{0.10}$	$\overset{12}{0.25}$	$\overset{13}{0.61}$	$\overset{13}{0.15}$	$\overset{14}{0.35}$	$\overset{15}{0.85}$	$\overset{15}{0.20}$
$\overset{7}{0.12}$	$\overset{8}{0.92}$	$\overset{8}{0.49}$	$\overset{8}{0.19}$	$\overset{9}{0.34}$	$\overset{10}{0.57}$	$\overset{11}{0.92}$	$\overset{11}{0.15}$	$\overset{12}{0.23}$	$\overset{13}{0.34}$	$\overset{14}{0.52}$	$\overset{15}{0.77}$	$\overset{15}{0.11}$	$\overset{16}{0.17}$	$\overset{17}{0.24}$	$\overset{18}{0.35}$	$\overset{19}{0.51}$
$\overset{8}{0.40}$	$\overset{8}{0.27}$	$\overset{8}{0.12}$	$\overset{9}{0.33}$	$\overset{10}{0.35}$	$\overset{11}{0.37}$	$\overset{12}{0.37}$	$\overset{13}{0.35}$	$\overset{14}{0.33}$	$\overset{15}{0.30}$	$\overset{16}{0.28}$	$\overset{17}{0.25}$	$\overset{18}{0.22}$	$\overset{19}{0.20}$	$\overset{20}{0.18}$	$\overset{21}{0.16}$	$\overset{22}{0.14}$
$\overset{8}{0.14}$	$\overset{9}{0.83}$	$\overset{9}{0.30}$	$\overset{10}{0.62}$	$\overset{11}{0.41}$	$\overset{12}{0.25}$	$\overset{13}{0.15}$	$\overset{15}{0.88}$	$\overset{16}{0.50}$	$\overset{17}{0.28}$	$\overset{18}{0.16}$	$\overset{20}{0.85}$	$\overset{21}{0.46}$	$\overset{22}{0.25}$	$\overset{23}{0.13}$	$\overset{25}{0.72}$	$\overset{26}{0.38}$
$\overset{9}{0.47}$	$\overset{9}{0.26}$	$\overset{10}{0.77}$	$\overset{10}{0.12}$	$\overset{12}{0.48}$	$\overset{13}{0.18}$	$\overset{15}{0.65}$	$\overset{16}{0.23}$	$\overset{18}{0.79}$	$\overset{19}{0.27}$	$\overset{21}{0.90}$	$\overset{22}{0.30}$	$\overset{24}{0.96}$	$\overset{25}{0.32}$	$\overset{26}{0.10}$	$\overset{28}{0.34}$	$\overset{29}{0.11}$
$\overset{9}{0.17}$	$\overset{10}{0.84}$	$\overset{10}{0.20}$	$\overset{11}{0.23}$	$\overset{13}{0.56}$	$\overset{14}{0.13}$	$\overset{16}{0.28}$	$\overset{18}{0.61}$	$\overset{19}{0.13}$	$\overset{21}{0.26}$	$\overset{23}{0.53}$	$\overset{24}{0.11}$	$\overset{26}{0.21}$	$\overset{28}{0.42}$	$\overset{30}{0.84}$	$\overset{31}{0.16}$	$\overset{33}{0.32}$
$\overset{10}{0.61}$	$\overset{10}{0.27}$	$\overset{11}{0.54}$	$\overset{12}{0.46}$	$\overset{14}{0.68}$	$\overset{16}{0.94}$	$\overset{17}{0.13}$	$\overset{19}{0.14}$	$\overset{21}{0.21}$	$\overset{23}{0.26}$	$\overset{25}{0.32}$	$\overset{27}{0.39}$	$\overset{29}{0.47}$	$\overset{31}{0.57}$	$\overset{33}{0.68}$	$\overset{35}{0.81}$	$\overset{37}{0.96}$
$\overset{10}{0.22}$	$\overset{11}{0.91}$	$\overset{11}{0.15}$	$\overset{13}{0.92}$	$\overset{15}{0.82}$	$\overset{17}{0.69}$	$\overset{19}{0.56}$	$\overset{21}{0.44}$	$\overset{23}{0.34}$	$\overset{25}{0.26}$	$\overset{27}{0.19}$	$\overset{29}{0.14}$	$\overset{31}{0.11}$	$\overset{34}{0.77}$	$\overset{36}{0.56}$	$\overset{38}{0.40}$	$\overset{40}{0.29}$
$\overset{14}{0.14}$	$\overset{15}{0.21}$	$\overset{17}{0.45}$	$\overset{19}{0.14}$	$\overset{24}{0.85}$	$\overset{28}{0.48}$	$\overset{32}{0.26}$	$\overset{36}{0.14}$	$\overset{41}{0.72}$	$\overset{45}{0.37}$	$\overset{49}{0.19}$	$\overset{54}{0.93}$	$\overset{58}{0.46}$	$\overset{62}{0.23}$	$\overset{66}{0.11}$	$\overset{71}{0.54}$	$\overset{75}{0.26}$
$\overset{18}{0.11}$	$\overset{20}{0.62}$	$\overset{22}{0.19}$	$\overset{26}{0.29}$	$\overset{32}{0.12}$	$\overset{39}{0.45}$	$\overset{45}{0.16}$	$\overset{52}{0.58}$	$\overset{58}{0.20}$	$\overset{65}{0.70}$	$\overset{71}{0.24}$	$\overset{78}{0.80}$	$\overset{84}{0.27}$	$\overset{91}{0.89}$	$\overset{97}{0.29}$	$\overset{104}{0.97}$	$\overset{111}{0.31}$
9	10	12	15	20	25	30	35	40	45	50	55	60	65	70	75	80

AUDIBLE RANGE
EB, 1945)
DISTANCE IN SUMMER



Blue lines connect places with equal values of a and red lines connect places where the maximum audible distance (unit meters) of direct sound waves is equal when the depth of the source of the sound is five meters and of the hydrophone ten meters (or vice versa). In the areas outside the broken red lines there are no limits from the point of view of theory on the limits of audibility.

5	80	85	90	95	100	105	$a\ 10^{-4}m^{-1}$ / x m
0	40	41	41	41	41	41	100
8	48	48	48	48	49	49	200
3	53	54	54	54	55	55	300
7	58	59	59	60	60	61	400
2	62	63	64	65	66	67	500
66	67	68	69	70	71	72	600
70	71	72	73	75	76	77	700
73	75	76	78	79	81	82	800
77	79	81	82	84	86	87	900
81	83	85	87	89	91	92	1,000
99	102	105	108	111	114	117	1,500
16	121	125	129	133	137	141	2,000
51	157	163	170	176	182	188	3,000
85	193	201	210	218	227	235	4,000
18	229	239	250	261	271	282	5,000
51	264	277	290	303	316	328	6,000
85	300	315	330	344	360	374	7,000
18	335	352	369	386	404	421	8,000
51	370	390	409	428	447	467	9000
34	405	427	448	470	491	513	10,000
13	756	799	842	885	929	972	20,000
40	1,115	1,170	1,235	1,300	1365	1,430	30,000
5	80	85	90	95	100	105	x m / $a\ 10^{-4}m^{-1}$

NOTES

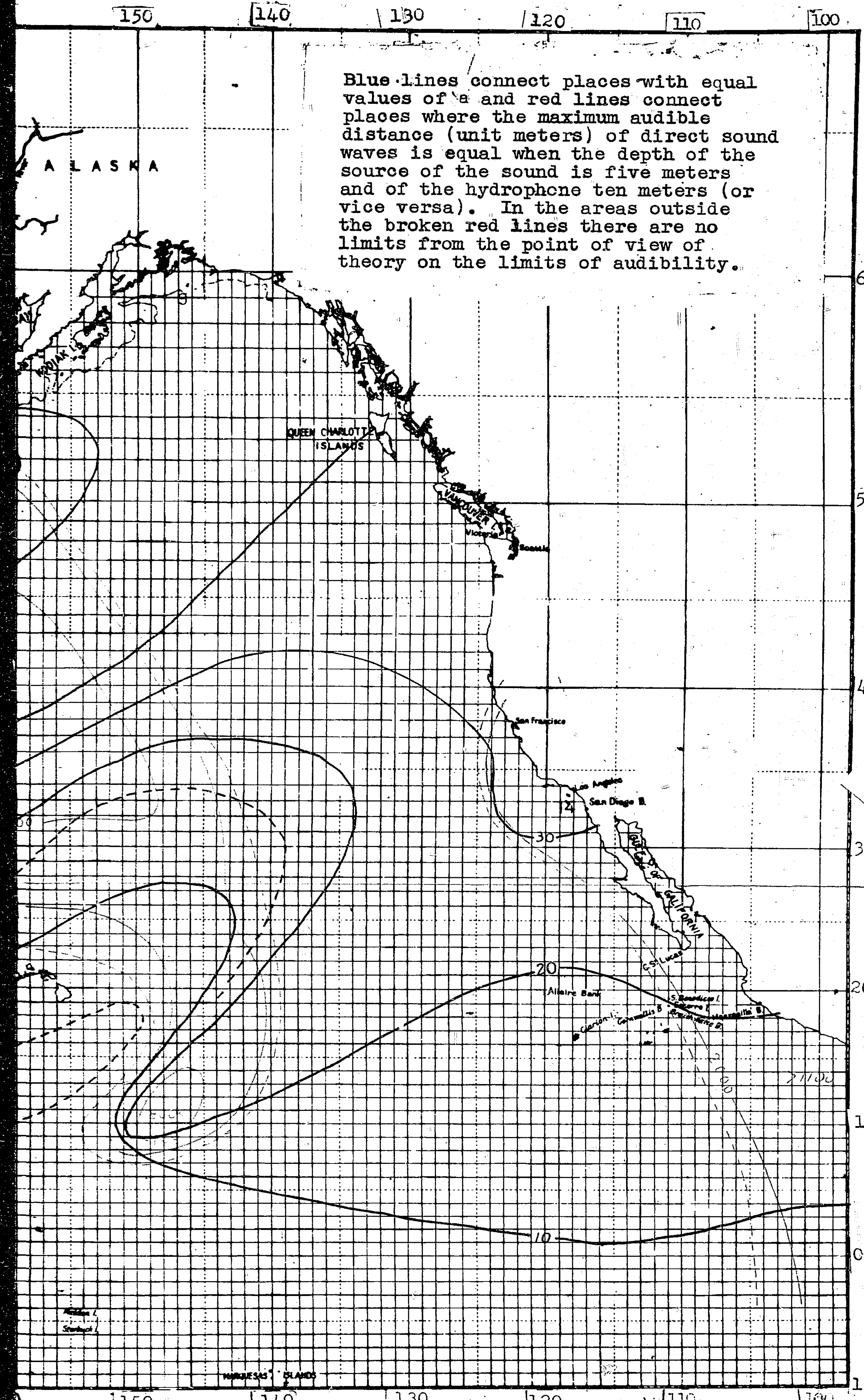
1. The values in Table I are all negative.
2. Assume that sound possibility is 9,000 meters on a sea surface of a=5, sound detection is possible up to an attenuation of 90 decibles on the hydrophone. Therefore, the limits above the division line shown in Table I are those of audibility when the force of sound of the sound source is equal. That is, when the sea surface is a=25, 3000 meters is the audibility.

5	80	85	90	95	100	105	$a\ 10^{-4}m^{-1}$ / x m
91	$\overset{4}{0.90}$	$\overset{4}{0.89}$	$\overset{4}{0.88}$	$\overset{4}{0.86}$	$\overset{4}{0.85}$	$\overset{4}{0.84}$	100
8	$\overset{4}{0.17}$	$\overset{4}{0.16}$	$\overset{4}{0.15}$	$\overset{4}{0.15}$	$\overset{4}{0.14}$	$\overset{4}{0.13}$	200
3	$\overset{5}{0.49}$	$\overset{5}{0.45}$	$\overset{5}{0.41}$	$\overset{5}{0.37}$	$\overset{5}{0.33}$	$\overset{5}{0.30}$	300
9	$\overset{5}{0.16}$	$\overset{5}{0.14}$	$\overset{5}{0.12}$	$\overset{5}{0.11}$	$\overset{6}{0.92}$	$\overset{6}{0.79}$	400
1	$\overset{6}{0.59}$	$\overset{6}{0.49}$	$\overset{6}{0.40}$	$\overset{6}{0.33}$	$\overset{6}{0.27}$	$\overset{6}{0.22}$	500
28	$\overset{6}{0.22}$	$\overset{6}{0.17}$	$\overset{6}{0.14}$	$\overset{6}{0.11}$	$\overset{7}{0.83}$	$\overset{7}{0.64}$	600
1	$\overset{7}{0.85}$	$\overset{7}{0.63}$	$\overset{7}{0.47}$	$\overset{7}{0.35}$	$\overset{7}{0.26}$	$\overset{7}{0.19}$	700
6	$\overset{7}{0.33}$	$\overset{7}{0.24}$	$\overset{7}{0.17}$	$\overset{7}{0.12}$	$\overset{8}{0.84}$	$\overset{8}{0.59}$	800
0	$\overset{7}{0.13}$	$\overset{8}{0.90}$	$\overset{8}{0.61}$	$\overset{8}{0.41}$	$\overset{8}{0.27}$	$\overset{8}{0.18}$	900
3	$\overset{8}{0.54}$	$\overset{8}{0.35}$	$\overset{8}{0.22}$	$\overset{8}{0.14}$	$\overset{9}{0.91}$	$\overset{9}{0.58}$	1,000
3	$\overset{10}{0.66}$	$\overset{10}{0.33}$	$\overset{10}{0.16}$	$\overset{11}{0.82}$	$\overset{11}{0.41}$	$\overset{11}{0.20}$	1,500
3	$\overset{12}{0.90}$	$\overset{12}{0.35}$	$\overset{12}{0.14}$	$\overset{13}{0.53}$	$\overset{13}{0.21}$	$\overset{14}{0.80}$	2,000
5	$\overset{15}{0.20}$	$\overset{16}{0.48}$	$\overset{16}{0.11}$	$\overset{17}{0.27}$	$\overset{18}{0.62}$	$\overset{18}{0.15}$	3,000
5	$\overset{19}{0.51}$	$\overset{20}{0.73}$	$\overset{20}{0.10}$	$\overset{21}{0.15}$	$\overset{22}{0.21}$	$\overset{23}{0.29}$	4,000
6	$\overset{22}{0.14}$	$\overset{23}{0.12}$	$\overset{24}{0.10}$	$\overset{26}{0.89}$	$\overset{27}{0.77}$	$\overset{28}{0.66}$	5,000
2	$\overset{26}{0.38}$	$\overset{27}{0.20}$	$\overset{28}{0.11}$	$\overset{30}{0.56}$	$\overset{31}{0.28}$	$\overset{32}{0.15}$	6,000
4	$\overset{29}{0.11}$	$\overset{31}{0.35}$	$\overset{32}{0.11}$	$\overset{34}{0.36}$	$\overset{35}{0.11}$	$\overset{37}{0.36}$	7,000
6	$\overset{33}{0.32}$	$\overset{34}{0.62}$	$\overset{36}{0.12}$	$\overset{38}{0.23}$	$\overset{40}{0.45}$	$\overset{42}{0.87}$	8,000
1	$\overset{37}{0.96}$	$\overset{38}{0.12}$	$\overset{40}{0.13}$	$\overset{42}{0.16}$	$\overset{44}{0.18}$	$\overset{46}{0.21}$	9,000
0	$\overset{40}{0.29}$	$\overset{42}{0.21}$	$\overset{44}{0.15}$	$\overset{46}{0.10}$	$\overset{49}{0.74}$	$\overset{51}{0.53}$	10,000
4	$\overset{75}{0.26}$	$\overset{79}{0.13}$	$\overset{84}{0.60}$	$\overset{88}{0.29}$	$\overset{92}{0.14}$	$\overset{97}{0.66}$	20,000
7	$\overset{111}{0.31}$	$\overset{116}{0.10}$	$\overset{123}{0.33}$	$\overset{129}{0.11}$	$\overset{136}{0.34}$	$\overset{142}{0.11}$	30,000
5	80	85	90	95	100	105	x m / $a\ 10^{-4}m^{-1}$

NOTE

1. $\overset{5}{0.63}$ = 0.0000063
   0.63×10^{-5}

AUDIBLE RANGE
B, 1945)
DISTANCE IN SUMMER



80	85	90	95	100	105	a $10^{-4}m^{-1}$ / x m
40	41	41	41	41	41	100
48	48	48	48	49	49	200
53	54	54	54	55	55	300
58	59	59	60	60	61	400
62	63	64	65	66	67	500
67	68	69	70	71	72	600
71	72	73	75	76	77	700
75	76	78	79	81	82	800
79	81	82	84	86	87	900
83	85	87	89	91	92	1,000
102	105	108	111	114	117	1,500
121	125	129	133	137	141	2,000
157	163	170	176	182	188	3,000
193	201	210	218	227	235	4,000
229	239	250	261	271	282	5,000
264	277	290	303	316	328	6,000
300	315	330	344	360	374	7,000
335	352	369	386	404	421	8,000
370	390	409	428	447	467	9000
405	427	448	470	491	513	10,000
756	799	842	885	929	972	20,000
1,115	1,170	1,235	1,300	1,365	1,430	30,000
80	85	90	95	100	105	x m / a $10^{-4}m^{-1}$

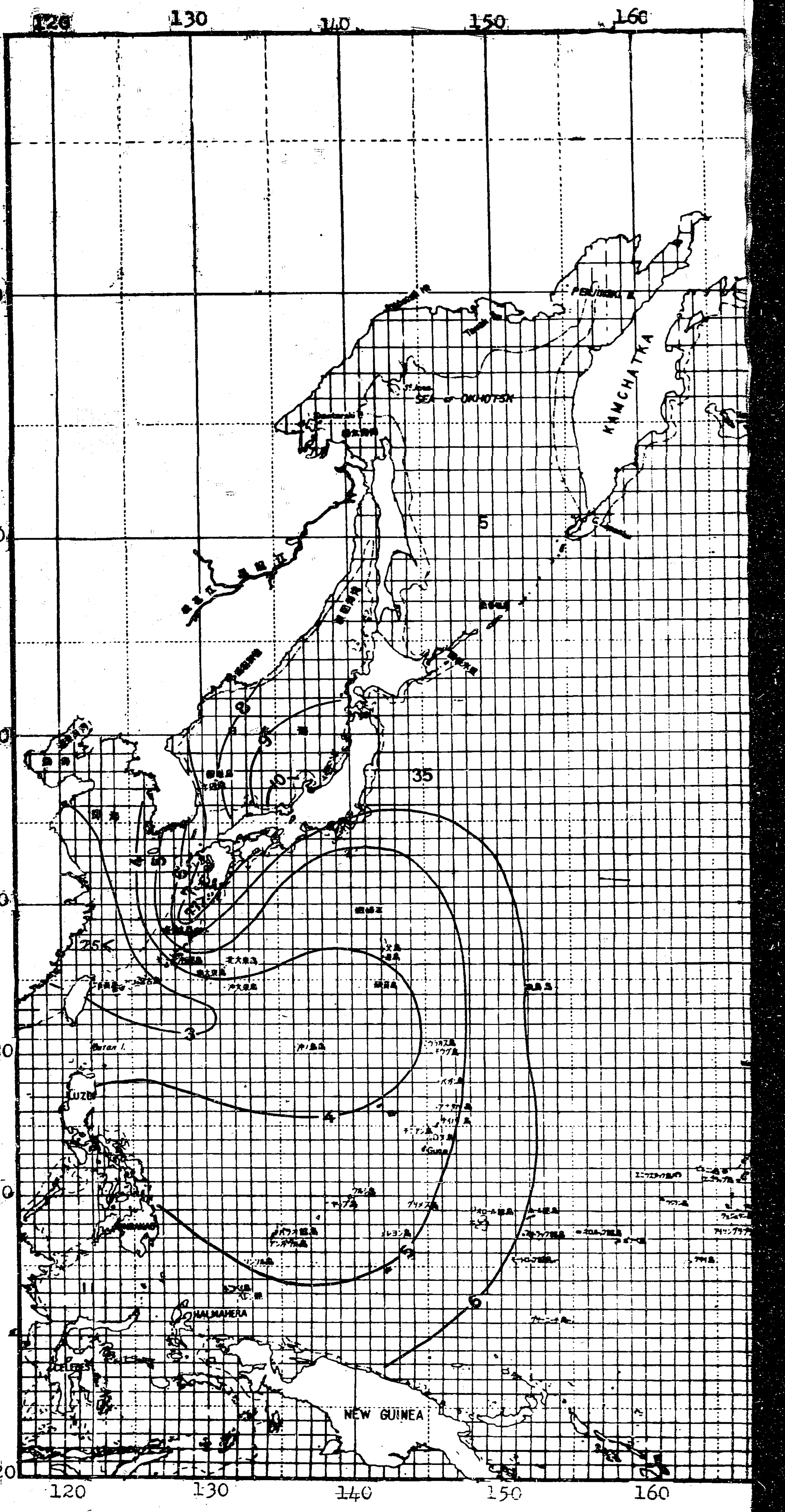
NOTES

1. The values in Table I are all negative.
2. Assume that sound possibility is 9,000 meters on a sea surface of a=5, sound detection is possible up to an attenuation of 90 decibles on the hydrophone. Therefore, the limits above the division line shown in Table I are those of audibility when the force of sound of the sound source is equal. That is, when the sea surface is a=25, 3000 meters is the audibility.

80	85	90	95	100	105	a $10^{-4}m^{-1}$ / x m
$\overset{4}{0.90}$	$\overset{4}{0.89}$	$\overset{4}{0.88}$	$\overset{4}{0.86}$	$\overset{4}{0.85}$	$\overset{4}{0.84}$	100
$\overset{4}{0.17}$	$\overset{4}{0.16}$	$\overset{4}{0.15}$	$\overset{4}{0.15}$	$\overset{4}{0.14}$	$\overset{4}{0.13}$	200
$\overset{5}{0.49}$	$\overset{5}{0.45}$	$\overset{5}{0.41}$	$\overset{5}{0.37}$	$\overset{5}{0.33}$	$\overset{5}{0.30}$	300
$\overset{5}{0.16}$	$\overset{5}{0.14}$	$\overset{5}{0.12}$	$\overset{5}{0.11}$	$\overset{6}{0.92}$	$\overset{6}{0.79}$	400
$\overset{6}{0.59}$	$\overset{6}{0.49}$	$\overset{6}{0.40}$	$\overset{6}{0.33}$	$\overset{6}{0.27}$	$\overset{6}{0.22}$	500
$\overset{6}{0.22}$	$\overset{6}{0.17}$	$\overset{6}{0.14}$	$\overset{6}{0.11}$	$\overset{7}{0.83}$	$\overset{7}{0.64}$	600
$\overset{7}{0.85}$	$\overset{7}{0.63}$	$\overset{7}{0.47}$	$\overset{7}{0.35}$	$\overset{7}{0.26}$	$\overset{7}{0.19}$	700
$\overset{7}{0.33}$	$\overset{7}{0.24}$	$\overset{7}{0.17}$	$\overset{7}{0.12}$	$\overset{8}{0.84}$	$\overset{8}{0.59}$	800
$\overset{7}{0.13}$	$\overset{8}{0.90}$	$\overset{8}{0.61}$	$\overset{8}{0.41}$	$\overset{8}{0.27}$	$\overset{8}{0.18}$	900
$\overset{8}{0.54}$	$\overset{8}{0.35}$	$\overset{8}{0.22}$	$\overset{8}{0.14}$	$\overset{9}{0.91}$	$\overset{9}{0.58}$	1,000
$\overset{10}{0.66}$	$\overset{10}{0.33}$	$\overset{10}{0.16}$	$\overset{11}{0.82}$	$\overset{11}{0.41}$	$\overset{11}{0.20}$	1,500
$\overset{12}{0.90}$	$\overset{12}{0.35}$	$\overset{12}{0.14}$	$\overset{13}{0.53}$	$\overset{13}{0.21}$	$\overset{14}{0.80}$	2,000
$\overset{15}{0.20}$	$\overset{16}{0.48}$	$\overset{16}{0.11}$	$\overset{17}{0.27}$	$\overset{18}{0.62}$	$\overset{18}{0.15}$	3,000
$\overset{19}{0.51}$	$\overset{20}{0.73}$	$\overset{20}{0.10}$	$\overset{21}{0.15}$	$\overset{22}{0.21}$	$\overset{23}{0.29}$	4,000
$\overset{22}{0.14}$	$\overset{23}{0.12}$	$\overset{24}{0.10}$	$\overset{26}{0.89}$	$\overset{27}{0.77}$	$\overset{28}{0.66}$	5,000
$\overset{26}{0.38}$	$\overset{27}{0.20}$	$\overset{28}{0.11}$	$\overset{30}{0.56}$	$\overset{31}{0.28}$	$\overset{32}{0.15}$	6,000
$\overset{29}{0.11}$	$\overset{31}{0.35}$	$\overset{32}{0.11}$	$\overset{34}{0.36}$	$\overset{35}{0.11}$	$\overset{37}{0.36}$	7,000
$\overset{33}{0.32}$	$\overset{34}{0.62}$	$\overset{36}{0.12}$	$\overset{38}{0.23}$	$\overset{40}{0.45}$	$\overset{42}{0.87}$	8,000
$\overset{37}{0.96}$	$\overset{38}{0.12}$	$\overset{40}{0.13}$	$\overset{42}{0.16}$	$\overset{44}{0.18}$	$\overset{46}{0.21}$	9,000
$\overset{40}{0.29}$	$\overset{42}{0.21}$	$\overset{44}{0.15}$	$\overset{46}{0.10}$	$\overset{49}{0.74}$	$\overset{51}{0.53}$	10,000
$\overset{75}{0.26}$	$\overset{79}{0.13}$	$\overset{84}{0.60}$	$\overset{88}{0.29}$	$\overset{92}{0.14}$	$\overset{97}{0.66}$	20,000
$\overset{111}{0.31}$	$\overset{116}{0.10}$	$\overset{123}{0.33}$	$\overset{129}{0.11}$	$\overset{136}{0.34}$	$\overset{142}{0.11}$	30,000
80	85	90	95	100	105	x m / a $10^{-4}m^{-1}$

NOTE

1. $\overset{5}{0.63} = 0.0000063$
0.63×10^{-5}



EXPLANATION OF USE OF MAPS

General Explanation

The following charts shows the state of attemua
underwater sound waves (except for those going throug
surface and bottom) which are propagateu directly fro
sound to the hydrophone. The attemuation of acoustic
horizontal distances on the requisite sea surface is
ing maps (Map #1 for summer and Map #2 for winter) an
Table I if the value of "a" is known for said sea sur
matter how good the sensitivity of the hydrophone wit
broken red line on Map 1, the distance of acoustic po
numerical value shown on the solid red line. Neverth
limit of this distance of acoustic power is influence
source of the sound and of the hydrophone. The numer
are for cases where the depth of the source of the so
the hydrophone 10 meters (or vice versa). If these d
numerical values do not increase even though the maxi
power increases.

"Generally in wintertime the ratio of successiv
of sound waves from the surface to depth decreases m
there is a maximum speed of the sound waves as the pr
waves improves over the whole surface moves lower, an
an absolute limit to the audible distance of direct s
disappears or is limited to very special water surfac
there are points where there is a lack of data on the
northern Pacific, areas like those mentioned above pr
the numerical values in solid blue writing are the va
various points recorded.

"In these charts it is necessary to pay attentio
they are for sound force which is propagated for the
sometimes the force of waves reflected from the botto
of direct waves. This is particularly so in deep wat

Example of Use

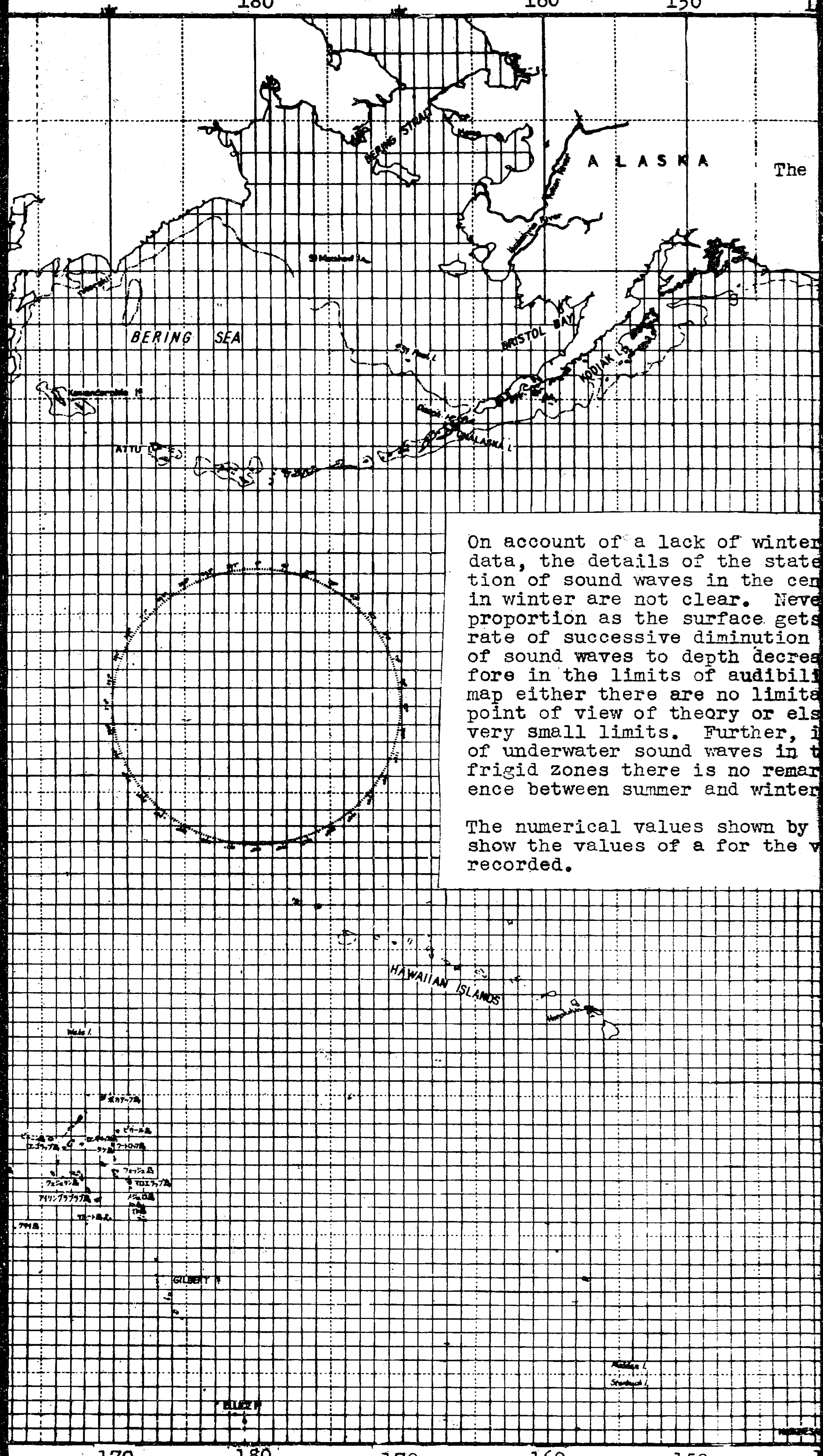
(a) Comparison of the state of attemuation of t
the OGASAWARA Islands and DAITO SHIMA in the summer f

Because according to Map #1 a=50 in the vi
Islands and a=10 in the vicinity of DAITO SHIMA, in t
in Table 1 the force of sound at points where the hor
source of sound is 900 meters decreases 69 decibles w
unit distance from the source of the sound. In contr
vicinity of DAITO SHIMA at first a decrease of 69 dec
meters. Accordingly, in sound detection at both the
detection is possible near the OGASAWARA Islands up t
distance when the strength of the source of sound, th
hydrophone and the strength of miscellaneous sounds a
be extended to 2,000 meters near the DAITO SHIMA.

(b) Assumption of feasible pick-up distance for
cussed in the following.

When the depth of the source of the sound i
hydrophone 10 meters on the sea at 166° East, 45° Nor
Map #1 that you cannot pick up direct sounds at a hor
than 1 kilometer. In this case, if by increasing the
20 meters (making its actual depth 30 meters) you cal
the increase of possible sound detection distance and
260 meters, the possible sound detection distance doe
the numbers entered on the map within the area of the
without relation to the depth of the hydrophone and o
sound.

CHART FOR SONIC RANGING - ATTENUATION & MAXIMUM AUDIBLE RANGE
(JAPANESE HYDROGRAPHIC CHART NO. 2775 - 20 FEB. 1945)
MAP #2 - DISTRIBUTION OF a IN WINTER



MAPS

ttenuation of acoustic power of
through reflection on the
tly from the source of the
coustic power to the various
ace is based on the accompany-
ter) and may be obtained from
sea surface. However, no
one within the area of the
stic power is limited to the
Nevertheless, the maximum
fluenced by the depth of the
e numerical values on the map
the sound is 5 meters and of
these depths increase, the
he maximum distance of acoustic

cessive diminution of the speed
ases markedly; the layer where
the propagation of sound
ver, and the area where there is
irect sound waves either
surfaces. In Map #2 although
on the central part of the
bove probably do not exist and
the values of "a" for the

ttention because, although
r the most part under water,
bottom is greater than that
ep water.

n of the force of sound near
mmer follows.
the vicinity of the OGASAWARA
, in the case of the former,
he horizontal distance of the
bles when compared with the
contrast to this, in the
69 decibles is shown at 2000
th these points, if sound
s up to 900 meters horizontal
nd, the sensitivity of the
unds are the same, this should
A.
ce for direct sounds is dis-

ound is 5 meters and of the
5° North, it is known by
a horizontal distance greater
ng the depth of the hydrophone
ou calculate from formula (3)
ce and if it is merely about
ce does not differ greatly from
of the broken red line and
and of the source of the

Theory

The attenuation of the forc
is determined primarily by the v
sound waves under water (the att
medium is extremely slight). Mo
tribution of underwater sound wa
represented by V and the depth b

$$V = A \cos (az + b) .$$

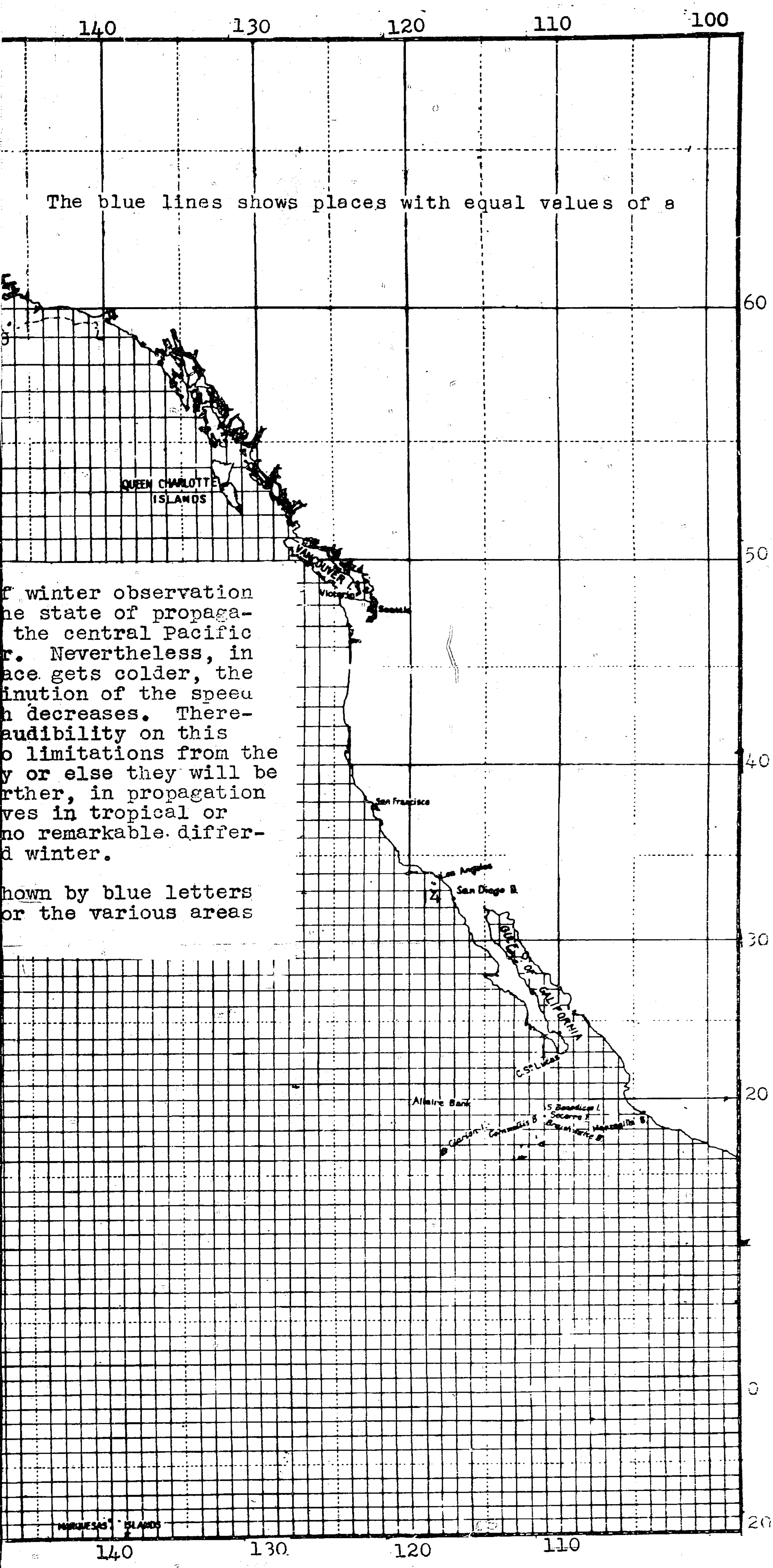
In the above A, a and b are cons
When we get from (1) the ve
waves, I/Io, which is the attenu
directly from the source of the
which is the horizontal distance
hydrophone, and with h which is
with z which is the depth of the
relation with h or z. We get

$$I/Io = \frac{}{S \quad \sin (h}$$

If we show the numerical va
shown in Table II, while Table I
because the direct waves in the
not exceed a certain fixed dista
waves is greater the closer to t
to hear sufficiently with the at
cannot pick up these direct wave
for direct waves, X_1, is as foll

$$X_1 = \frac{1}{a} \log \quad \frac{\sin (ah}{\sin (az}$$

ANGE



f winter observation
e state of propaga-
the central Pacific
r. Nevertheless, in
ace gets colder, the
inution of the speed
h decreases. There-
audibility on this
o limitations from the
y or else they will be
rther, in propagation
ves in tropical or
no remarkable differ-
d winter.

hown by blue letters
or the various areas

the force of sound which is propagated under water
by the vertical distribution of the speed of the
(the attenuation based on the absorption of the
ght). Moreover, if the speed of the vertical dis-
sound waves at a layer 10 meters from the surface is
e depth by z we get

(az + b) ....(1)

are constants for the places.
(1) the vertical distribution of the speed of the sound
he attenuation of the force of sound propagated
e of the sound to the hydrophone, is compared with X,
distance of the source of the sound and the
which is the depth of the source of the sound and
th of the hydrophone. When it is great it has no
We get

$$\frac{a}{\quad \sin (h)\ ax} \ \ldots (2)$$

erical value for each horizontal distance, it is as
Table I shows this in decibel units. However,
s in the area of the broken red line in Map #1 do
xed distance (in this area the speed of the sound
loser to the surface), and even when you should be abl
ith the attenuation of force shown in Table II, you
irect waves. The maximum feasible pick-up distance
is as follows:

$$\frac{\sin (ah + b) + \sin (ah) \sin (ah + 2b)}{\sin (az + b) - \sin (az) \sin (az + 2b)} \ \ldots\ldots (3)$$

100° 110°

A. Explanation:

Sound waves generated by underwater sound sources will reach a hydrophone either directly, or after having been reflected from the sea surface or from the bottom of the sea. The density distribution of sea water varies. Consequently the waves received (by the hydrophone) will vary in force depending on the path each wave has traveled.

These tables and chart will show the "geometric and optical" attenuation of the force of sound whose direct waves, surface reflected waves, and sea-floor reflected waves are received in accordance with the vertical distribution of the density of sea water. With this chart, if one knows the constant -a- (represented by a blue line of uniform value) dealing with the density distribution of sea water, and -b- (represented by a red line of uniform value) then one can determine from Table I the attenuation of direct waves and surface reflected waves at those places. This table standardized the force of sound at a distance of one meter from the sound source, and indicates in decibels the attenuation of the force of sound as the distance increases.

The attenuation of direct waves is determined at long ranges by -a- and the distance, and is independent of a value of -b- as well as of the depth of the sound source and the hydrophone. However the attenuation of surface reflected waves will vary with the depth of the sound source and the hydrophone. Table I will show several values in cases where the depth of the sound source is 10 meters and that of the hydrophone is 5 meters. In cases when the depth of the sound source is -h- meters and ah/10 plus b is less than 0, then attenuation will not vary uniformly with distance, and at a certain distance will be irreduceably small. This distance will fluctuate depending on the distribution of the density of sea water. In Table I the figure shows the minimum attenuation value; the numerals within the parentheses s
cases where b is less than 0 the force of th
waves will be much smaller than the force of
this case, even though the sensitivity of th
there will be definite limits to the distanc
pick up direct sounds and surface reflected
the maximum limitations are related to the d
source and the hydrophone. Table II shows i
range for cases where the depths of the soun
phone are respectively 10 and 5 meters. If
sound source and the hydrophone are greater
will increase somewhat. Sea floor reflected
characteristics.

In shallow waters sea floor reflected w
same attenuation as surface reflected waves.
depth increases, the effect of a and b on th
force of sound gradually diminishes. In dee
mitted as spherical surface waves. Such att
of the depth of the sound source, hydrophone
order to conveniently compare the attenuatio
waves with that of direct waves respectively
end of Table I for depths of 1000 meters and
waters if the distance between the sound sou
more than several thousand meters, the force
flected wave will exceed that of all others.
mission of sound waves is accompanied by att
losses due to reflection and absorption of
medium. For this reason in using these tabl
points in mind. The amount, in most cases,

Distance	a Direct Waves	b Direct Waves	Sea Surface Reflected Waves -50	-10	0	10	Direct Waves	Sea Surface Reflected Waves -50	-10	0	10	Direct Waves	Sea Surface Reflected Waves -50	-10	0	10	Direct Waves
100	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
200	46	46	46	46	46	46	46	46	46	46	46	46	45	46	46	47	47
300	50	50	49	50	50	50	50	49	49	50	50	50	49	50	50	51	51
400	52	52	52	52	52	52	52	51	52	52	52	53	51	52	53	54	55
500	54	54	54	54	54	54	54	53	54	54	55	56	52	55	56	57	58
600	56	56	55	56	56	56	56	54	55	56	56	58	54	56	58	59	61
700	57	57	57	57	57	57	57	55	57	57	58	60	56	58	60	62	64
800	58	58	58	58	58	58	59	56	58	59	59	62	58	60	62	65	66
900	59	59	59	59	59	59	60	57	59	60	61	63	60	61	63	67	69
1000	60	60	59	60	60	60	61	[illegible]	60	61	62	65	62	62	65	70	72
													*56 (1390)				
1500	64	64	62	63	64	64	65	64	63	65	69	74	60	67	74		84
								*53 (1790)									
2000	66	66	64	66	66	67	69	62	65	69	76	81	68	72	81		96
3000	70	70	67	69	70	71	75	70	69	75		96	77	80	96		120
4000	72	72	70	70	72	75	80	73	[illegible]	80		110	84	87	110		143
5000	74	74	73	72	74	78	86	77	[illegible]	[illegible]		124	92	94	124		166
			*69 (5460)														
6000	76	76	72	73	76	82	91	80	85	[illegible]		138	99	101	138		188
7000	77	77	75	74	77	85	96	83	90	96		152	107	108	152		210
8000	78	79	76	76	79		101	86	95	101		165	114	115	165		233
9000	79	80	77	77	80		106	88	100	106		179	121	122	179		255
10000	80	81	79	78	81		110	91	104	110		193	128	129	193		277
				*73 (12020)													
20000	86	89	91	84	[illegible]		157	118	153	157		326	199	199	326		[illegible]
30000	90	95	104	88	95		202	145	201	202		458	270	269	458		[illegible]

TABLE II

AUDIBLE RANGE FOR DIRECT WAVES AND SEA SURFACE REFLECTED WAVES (METERS)

a \ b	10	20	30	40	50	60	70	80	90	100
5	3310	2380	1950	1690	1520	1390	1280	1200	1130	1080
10	2280	1660	1370	1190	1070	980	900	850	800	760
15	1810	1330	1100	960	870	790	730	690	650	620
20	1540	1140	950	830	740	680	630	590	560	530
30	1210	910	760	670	600	550	510	480	450	430
40	1010	770	650	570	520	470	440	410	390	370
50	880	680	570	500	460	420	390	370	350	330

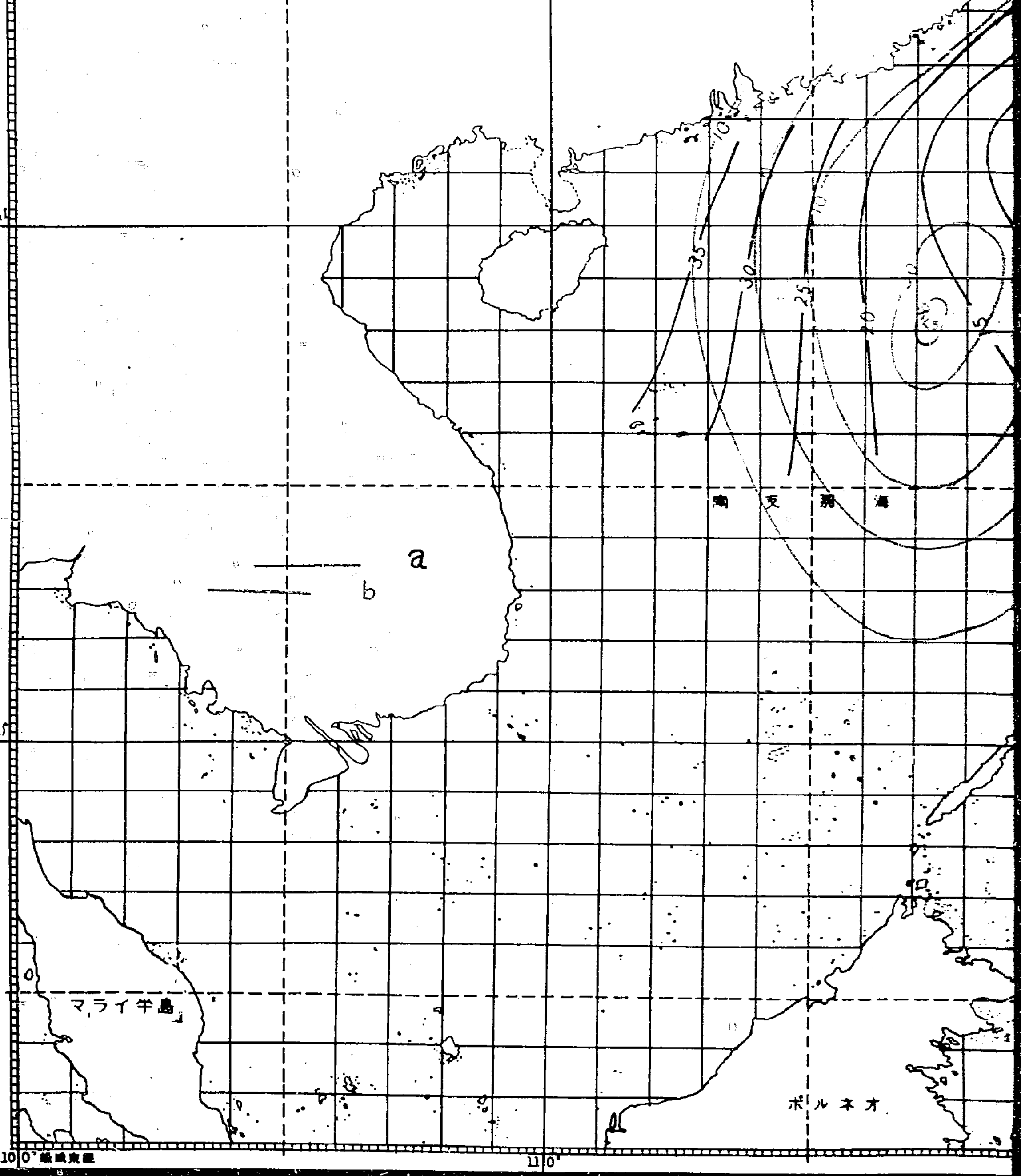


CHART FOR SONIC RANGING - ATTENUATI… SEAS ADJACENT T… (JAPANESE HYDROGRAPHIC CHART NO…

…the parentheses shows the distance. In …0 the force of the surface reflected …than the force of the direct waves. In …sensitivity of the hydrophone is good …its to the distance at which one can …surface reflected sounds. Furthermore …e related to the depths of the sound … Table II shows in units of meters the …depths of the sound source and the hydro-…and 5 meters. If the depths of the …phone are greater than this the range …ea floor reflected waves have no such

… floor reflected waves exhibit roughly the …e reflected waves. Nevertheless as the …t of a and b on the attenuation of the …iminishes. In deep waters it is trans-…e waves. Such attenuation is independent …source, hydrophone, a as well as b. In …are the attenuation of sea floor reflected …waves respectively values are given at the …of 1000 meters and 5000 meters. In deep …ween the sound source and the hydrophone is … meters, the force of the sea floor re-…hat of all others. Of course the trans-…accompanied by attenuation resulting from …nd absorption of … er according to the …n using these tables and chart bear these …t, in most cases, is very small.

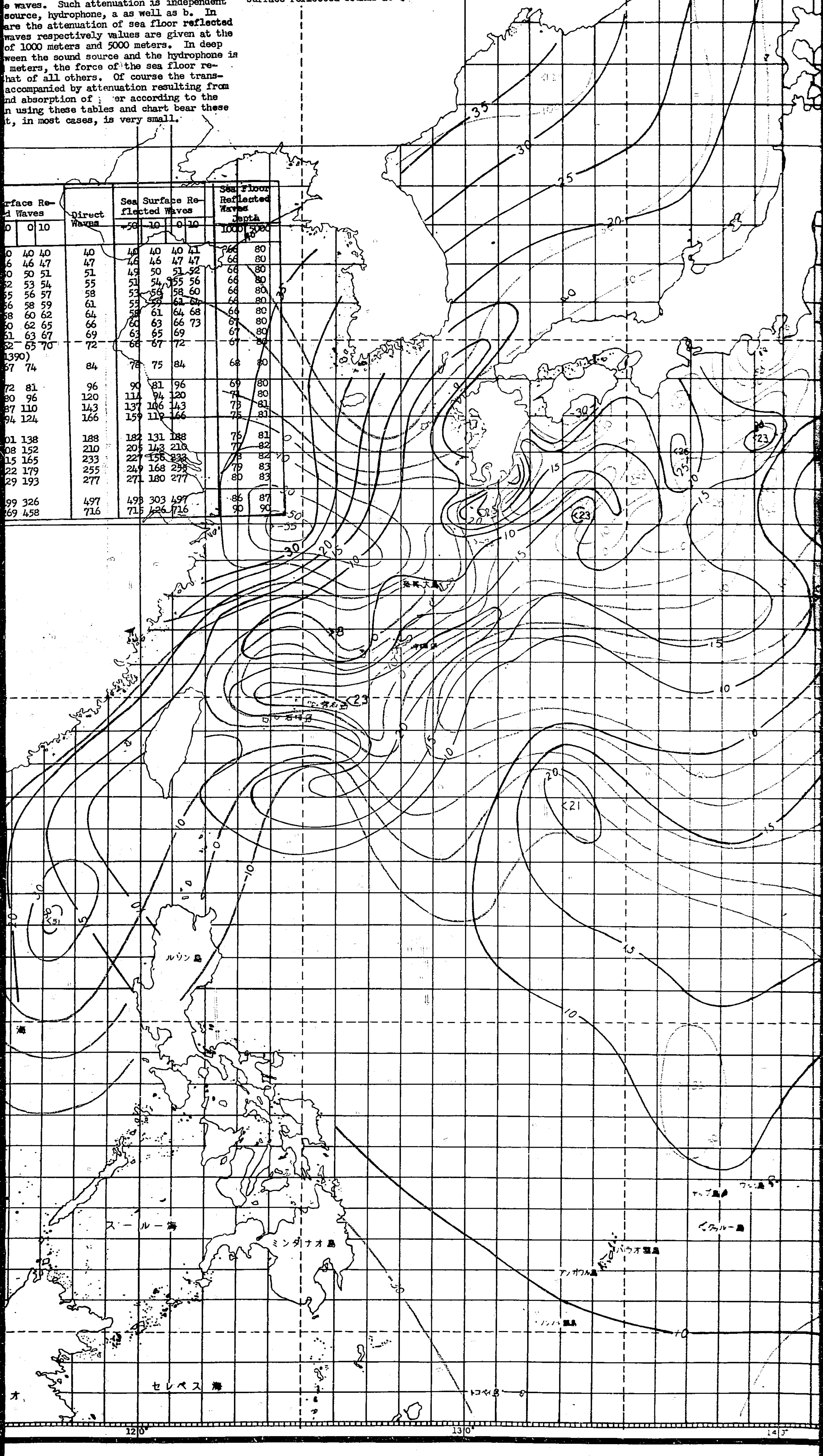
B. Illustration:

Comparison of the attenuation of the force of sound in June in the Ogasawara area 140° E 29° N — depth 1000 meters (temporarily called P) with an area SE of the Kuriles 160° E 45° N — depth 5000 meters (temporarily called Q).

According to the distribution chart the values of a and b at P and Q are respectively: at P. a equals 10 and b equals 25; at Q. a equals 30 and b equals minus 25. According to Table I, at P the attenuation of the force of sea floor reflected waves and direct waves at a horizontal distance of 3000 meters from the sound source is 75 and 71 decibels respectively. According to Table II at horizontal ranges above 1500 meters, sea surface reflected waves are inaudible.

At Q direct waves are attenuated to 74 decibles at 1500 meters; sea floor reflected waves are attenuated to more than 80 decibels. At 2000 meters sea surface reflected waves attenuated to 71 decibels. When the strength of the sound source, the sensitivity of the hydrophone and the strength of miscellaneious noises are completely the same, if at P they are audible up to 3000 meters, at Q the audible range will decrease to 2000 meters. In such cases it is evident that the most effective sounds for listening to will be sea floor reflected sounds at P and sea surface reflected sounds at Q

…rface Reflected Waves			Direct Waves	Sea Surface Reflected Waves				Sea Floor Reflected Waves Depth	
…0	0	10		-50	-10	0	10	1000	5000
…0	40	40	40	40	40	40	41	66	80
…6	46	47	47	46	46	47	47	66	80
…0	50	51	51	49	50	51	52	66	80
…2	53	54	55	51	54	55	56	66	80
…5	56	57	58	53	56	58	60	66	80
…6	58	59	61	55	59	61	64	66	80
…8	60	62	64	58	61	64	68	66	80
…0	62	65	66	60	63	66	73	67	80
…1	63	67	69	63	65	69		67	80
…2	65	70	72	66	67	72		67	80
…1390)									
…67	74		84	78	75	84		68	80
…72	81		96	90	81	96		69	80
…80	96		120	114	94	120		71	80
…87	110		143	137	106	143		73	81
…94	124		166	159	119	166		75	81
…01	138		188	182	131	188		76	81
…08	152		210	205	143	210		77	82
…15	165		233	227	156	233		78	82
…22	179		255	249	168	255		79	83
…29	193		277	271	180	277		80	83
…99	326		497	493	303	497		86	87
…69	458		716	715	426	716		90	90



URE (B), continued

ATTENUATION & MAXIMUM AUDIBLE RANGE
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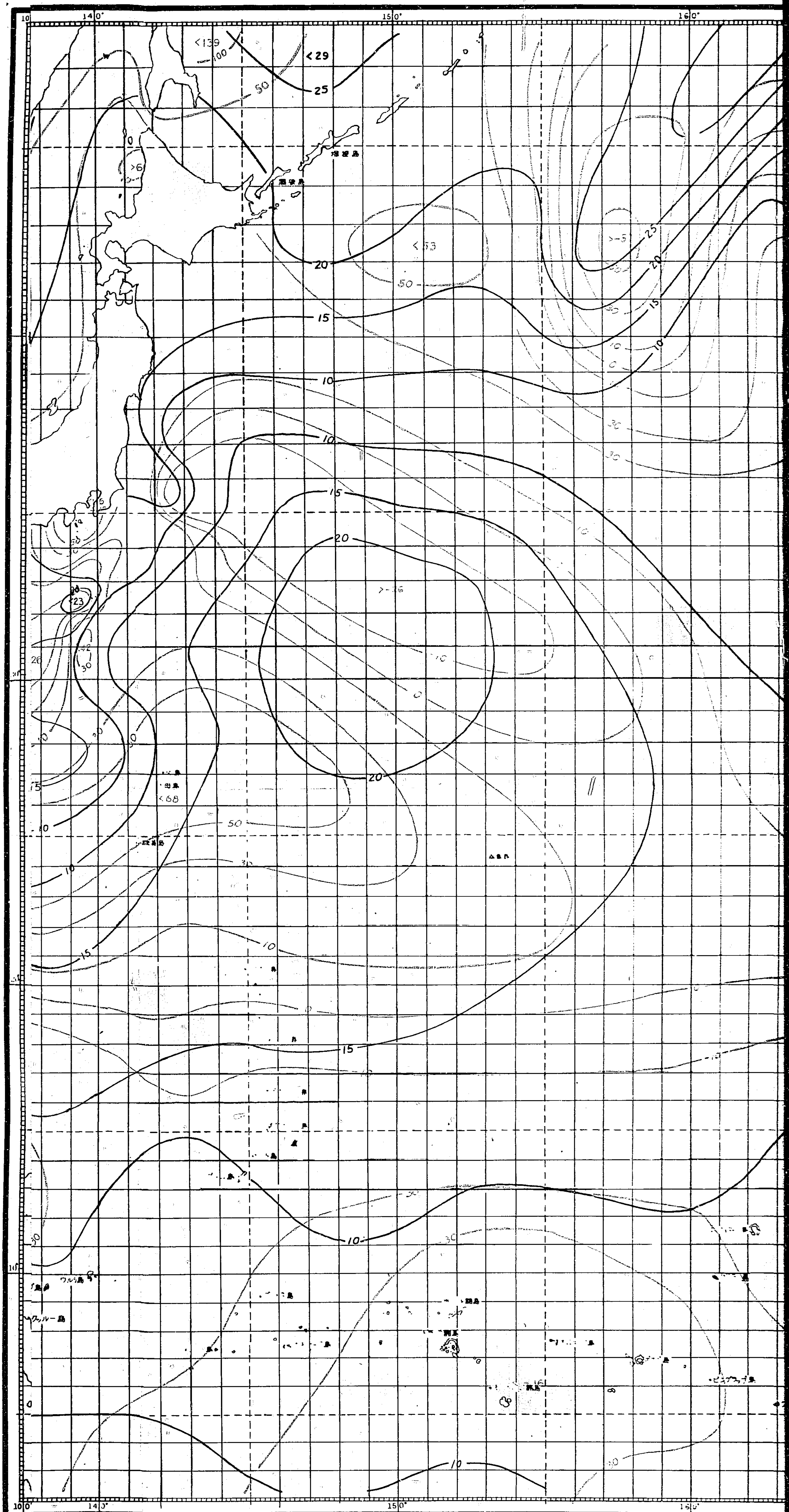

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