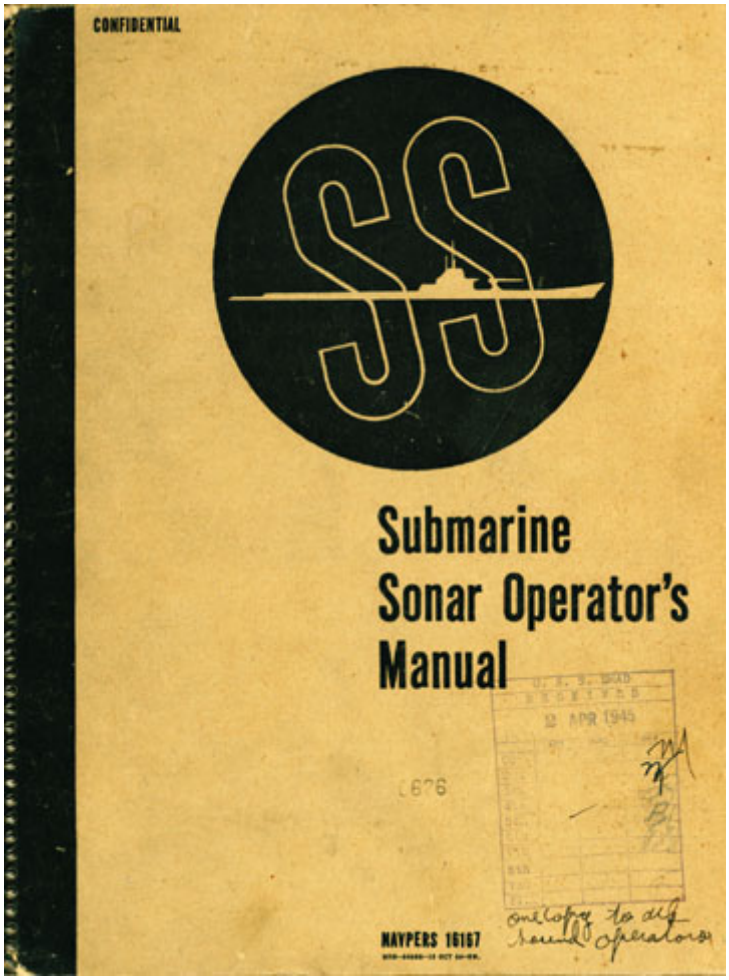
The Fleet Type Submarine Online Submarine Sonar Operator's Manual



Folks,

Submarine Sonar Operator's Manual, Navpers 16167, is one of a series of submarine training manuals that was completed just after WW II. The series describes the peak of WW II US submarine technology.

In this online version of the manual we have attempted to keep the flavor of the original layout while taking advantage of the Web's universal accessibility. Different browsers and fonts will cause the text to move, but the text will remain roughly where it is in the original manual. In addition to errors we have attempted to preserve from the original (for example, it was H.L. Hunley, not CS Huntley), this text was captured by optical character recognition. This process creates

errors that are compounded while encoding for the Web. Please report any typos, or particularly annoying layout issues with the Mail Feedback Form for correction.

Our thanks to IKON Office Solutions (now Ricoh USA http://www.ricoh-usa.com) for scanning services.

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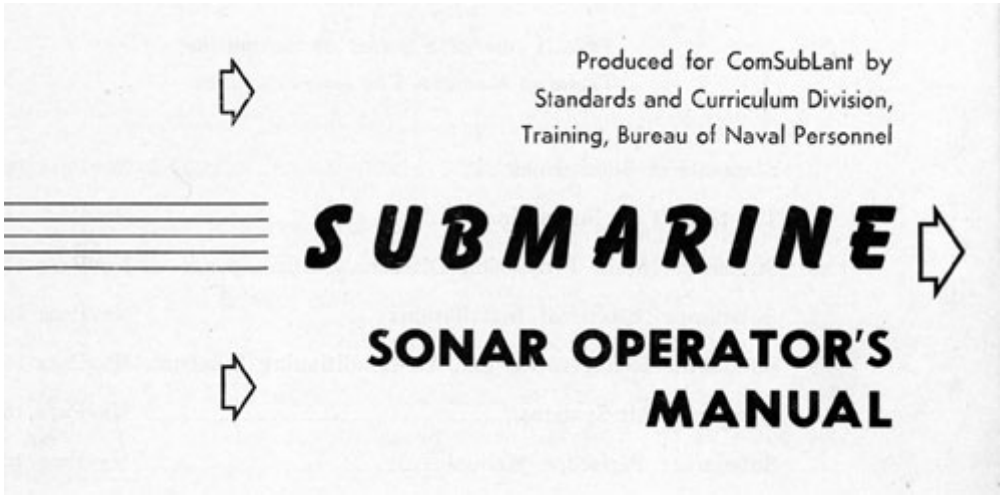
NavPers 16167



June 1944

~~CONFIDENTIAL~~

This is one of a series of Submarine Training Manuals. The series includes:

1. The Fleet Type Submarine	NavPers 16160
2. Submarine Main Propulsion Diesels	NavPers 16161
3. Submarine Electrical Installations	NavPers 16162
4. Submarine Refrigerating and Air-Conditioning Systems	NavPers 16163
5. Submarine Distilling Systems	Navpers 16163A
6. Submarine Air Systems	NavPers

		16164
7.	Submarine Periscope Manual	NavPers 16165
8.	Submarine Trim and Drain Systems	NavPers 16166
9.	Submarine Sonar Operator's Manual	NavPers 16167
10.	Submarine Underwater Log Systems	NavPers 16168
11.	Submarine Hydraulic Systems	NavPers 16169
12.	Torpedo Tubes, 21-Inch submerged, Mks 32 to 39	O.P. 1085

PREFACE

As a sonar operator, you will have a most important job. On a patrol in enemy waters the lives of your shipmates may be in your hands.

You must know your gear and what it can do. You must be able to recognize and interpret the sounds that you hear. You must be able to operate the controls the way you drive a car - automatically without thinking.

Most of these things you cannot learn from books. Only long hours of practice on the gear itself will make you proficient. There is, however, a certain amount of background knowledge which will prepare you to make the most of your practice time.

This manual supplies that background knowledge. It is all solid meat. You can well afford to know every bit of it by heart. Study it thoroughly from cover to cover.

The manuscript for this publication was prepared by Columbia University Division of War Research, at the U. S. Navy Underwater Sound Laboratory, Fort Trumbull, New London, Connecticut. Illustrations were prepared by the U. S. Naval Training Aids Development Center.

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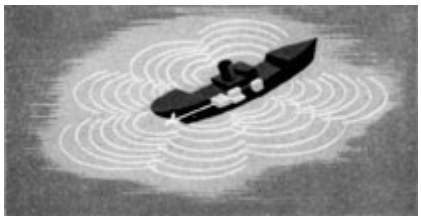
1
SONAR GEAR

SONAR is the name applied to all underwater sound gear. Like radar, it is a coined name, taken from the words SOund Navigation And Ranging.

When a submarine submerges, radar becomes useless and no lookouts remain on deck. The periscope and the sonar gear are now the eyes and ears of the submarine. But in the vicinity of enemy ships, it may by dangerous to use the periscope very often. Then the submarine must depend chiefly on listening. The sonar operators become the main channel of information about the maneuvers of the enemy.

Ships make sounds

Any ship moving through the water makes a certain amount of sound. Most important to the sonar operator is the sound of enemy propellers as they churn through the water.



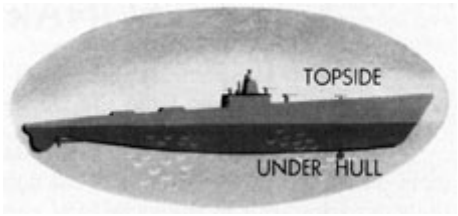
Next in importance to the sonar operator are the noises from various pieces of machinery within the ship. These sounds go through the hull and out into the water.

With the ship stopped dead in the water, propellers and machinery may both be silent. But even then some sound may come from the slapping of the waves against the ship's hull.

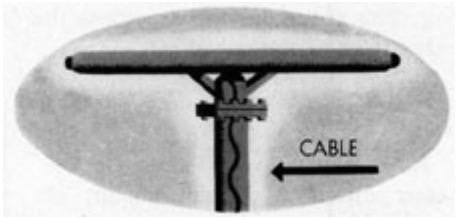
The purpose of sonar gear is to detect these various sounds

Sonar listening gear has 5 essential parts

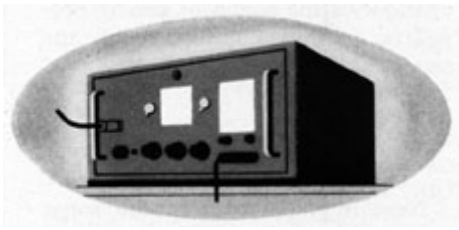
1. Hydrophones. On a modern submarine there are three hydrophones: one topside and two just below the level of the keel.



2. Cables. A cable runs from each hydrophone through the submarine's hull.

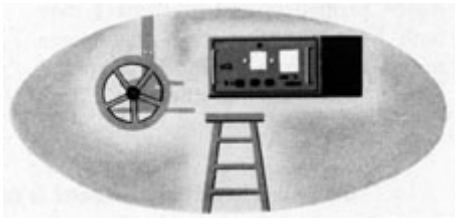


3. Receiver-Amplifiers. The other end of each cable is connected to a receiver-amplifier, which looks something like a radio.



4. Headphones. A pair of head phones can be plugged into the phone jack of each receiver-amplifier.

5. Training Mechanisms. Hand-operated and electrically controlled mechanisms turn the hydrophones in any desired direction.



The principles of sonar listening are simple

3

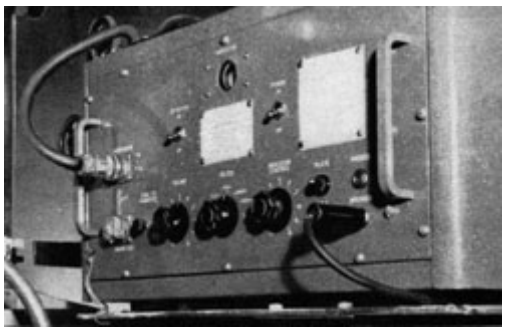
There are two main types

Sonic gear picks up sound you could hear with your own ears if you stuck your head out into the water.

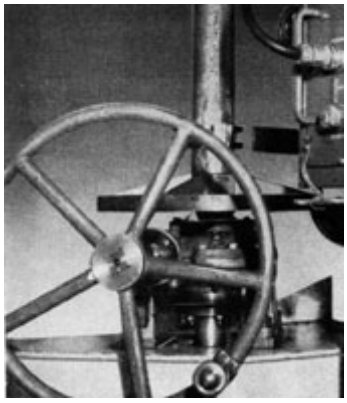
The Hydrophone in sonic gear resembles a long bar and is mounted topside, either port or starboard, forward of the conning tower.

The Amplifier at the other end of the connecting cable from the

hydrophone is located in the forward torpedo room.



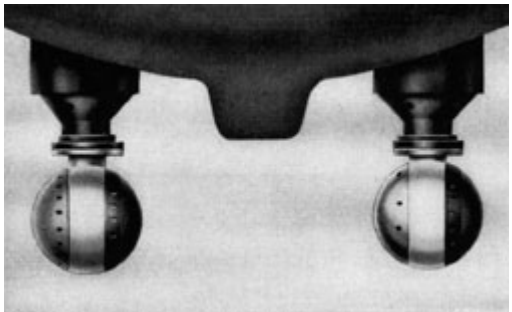
The Training Mechanism alongside the amplifier consists of a handwheel which turns the shaft on which the hydrophone is mounted. There is also a pointer and dial marked off in degrees.

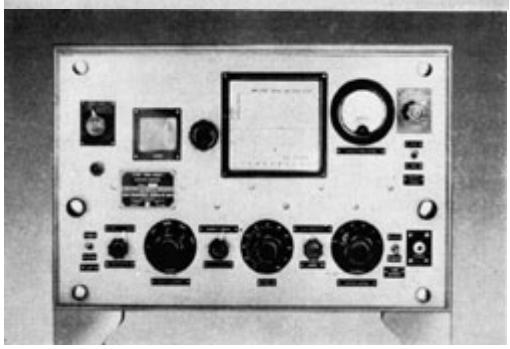


JP is the Navy term for sonic listening gear. The J means that it can be used for listening only. The second letter P merely indicates the model.

of sonar listening gear

Supersonic gear picks up sounds too high for the human ear to hear and changes them into sounds which can be heard.





The Two Hydrophones (Projectors) are mounted at the bottom of shafts, which extend through the hull under the forward torpedo room. Lowering these shafts puts the two projectors below the keel.

The Receiver-Amplifiers, one for each projector, are located in the conning tower. They look alike and they both operate in the same way.

The Remote-Control Units, one for training each projector, are also in the conning tower, on top

of the receiver-amplifiers. Actually the projector shafts are turned in the forward torpedo room, by training mechanisms run by electric motors.

JK/QC is the Navy term for one type of supersonic gear. The JK half of the combination projector is for listening only; the QC half can also be used for sending out sounds into the water.

QB designates the other type. As indicated by the letter Q, the QB projector can send as well as receive sounds.

Comparison of sonic and supersonic listening

Since enemy ships make sonic and supersonic sounds, both types of gear are necessary for efficient listening. Each has its own particular advantages one is incomplete without the other.

Sonic gear is useful for picking up targets at great distances because sonic sounds travel farther. Also, on the JP gear sounds appear more natural and are more easily recognized. Therefore, you can identify not only the machinery noises of enemy ships, but also any telltale noises your own submarine is making.

Supersonic gear is useful for picking up the important supersonic noises that sonic cannot get. Supersonic gear is especially superior for catching the bursts of supersonic sound used by enemy escort vessels in searching for our submarines. (In addition, QB and QC gear can be used to send out sounds into the water to determine the range of an enemy ship.)

The WCA Installation

The WCA Installation on a submarine includes all the sonar gear that handles supersonic sounds. Much of this equipment is grouped in the conning tower, where it is known as the "WCA Stack." To locate all the various units, let us subdivide WCA into its two main parts:

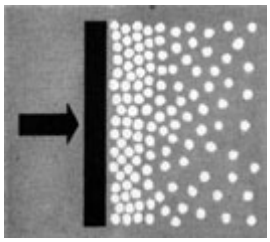
QB Gear has its receiver-amplifier and remote-control unit in the conning tower. The projector is mounted on the starboard shaft and extends just below the keel under the forward torpedo room. The electric training mechanism for turning the projector is in the forward torpedo room.

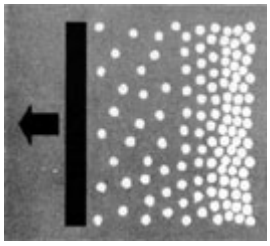
JK/QC Gear also has its receiver-amplifier and remote-control unit in the conning tower, and its training mechanism in the forward torpedo room. The double-faced projector extends just below the keel on the port side, opposite the QB projector. A range indicator, used with either QB or QC, is also part of the WCA stack in the conning tower.

NOTE: The WCA Installation also includes NM gear (in the control room), which is used for determining the depth of the water beneath the keel.

3
SOUND IN WATER

Sound can travel through any medium, such as air or steel or water. As a sonar operator, you are concerned with water as the medium.



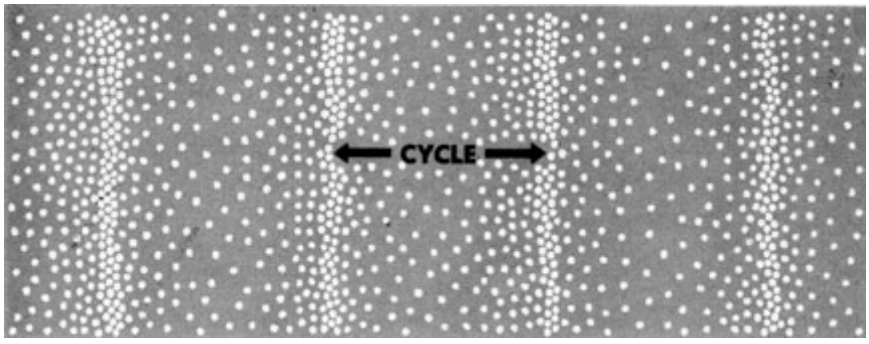


How sound waves get started

Imagine an object vibrating back and forth in water. As it moves forward, the particles of water directly in front of it are pressed closer together. Each particle then passes this pressure along to the one ahead of it. Thus a state of compression moves away from the object in all directions.

But when the object moves backward, this pressure is removed and the particles are thinned out. Thus a state of rarefaction follows after each compression.

The vibrating object continues to send out compressions and rarefactions one after the other. Each compression plus - rarefaction is a sound wave.



Cycle. A single back-and-forth movement of the vibrating object is called a cycle. A single sound wave (as shown in the drawing above)

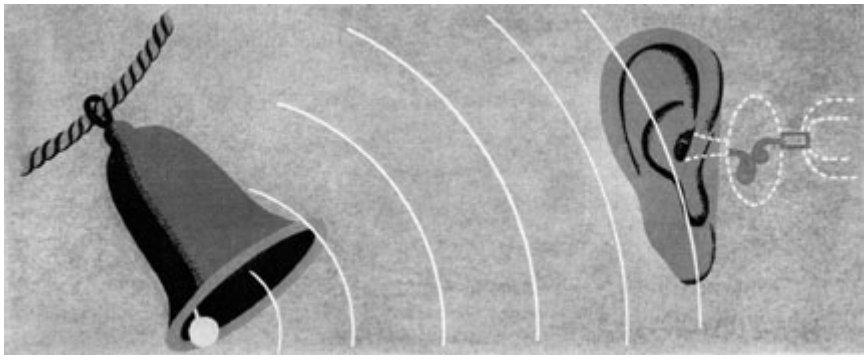
is also called a cycle.

Frequency. The number of cycles per second is the frequency. For convenience, this is sometimes expressed in kilocycles (1000 cycles). A frequency of 16 kilocycles (16 kc), for example, means 16,000 cycles per second.

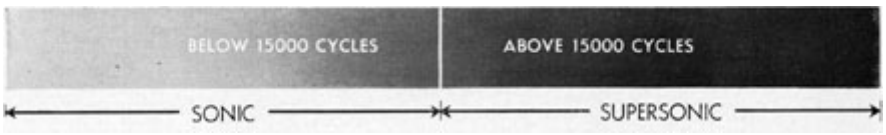
How we hear sounds

When sound waves reach us through the air, their alternate compressions and rarefactions cause the eardrum to move in and out at the same frequency. By a chain of tiny bones, this vibration is transferred to the inner ear. Here it is changed into nerve impulses, which pass to the brain and produce the sensation of hearing.

But for the sonar operator, the process includes some additional steps. The sound waves in the water must be picked up by some sort of hydrophone and changed into electric currents. These electric currents are then strengthened and sometimes changed, so that they can by heard through the headphones.



Sonic and supersonic frequencies



SONIC FREQUENCIES are those below 15,000 cycles per second. They can be heard by the normal human ear.

SUPERSONIC FREQUENCIES are those above 15,000 cycles per second - beyond the range of normal human hearing.

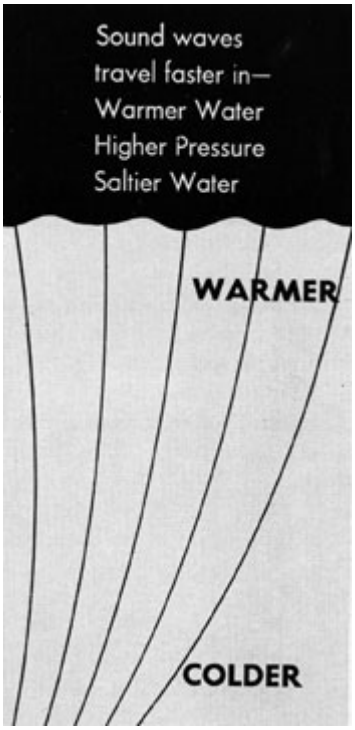
Supersonic frequencies must be changed to sonic frequencies before the operator can hear them in his headphones or loudspeaker. Within the sonic range, the pitch of a sound depends mainly upon its frequency. A high-frequency sound has a high pitch; a low-frequency sound, a low pitch. The loudness of a sound depends mainly upon the strength of the compressions. The more powerful they are, the louder the sound. But loudness is also somewhat dependent upon

frequency. The normal ear hears best between 1000 and 2000 cycles, and sounds in this frequency range generally seem louder than sounds of extremely high pitch.

How sound waves behave in water

The behavior of sound waves in water is a rather complicated subject. Here are some of the most important features to remember.

Velocity



Sound waves travel very rapidly in water-about 4800 feet per second, as compared with 1100 feet per second in air. Weak sounds and strong sounds, high frequencies and low frequencies, all travel at the same speed. But their speed is affected by the temperature, pressure, and salinity of the water, as shown at the right.

Refraction

The fact that the speed of sound varies, especially with temperature, explains why sound waves are bent out of their normal paths. This bending is called refraction. Usually water is warmer near its surface than at lower depths. As shown in the diagram at the right, the upper part of a sound wave in the warmer water travels faster than the lower part in the colder water. This makes the sound wave bend downward.

Transmission loss

The sound that reaches the hydrophone is very much weaker than it was when it left its source. Two main factors explain this loss during transmission.

1. Spreading. As a sound wave goes out from its source in all directions, it spreads over a larger and larger area. Thus a given amount of sound has to cover an increasingly large space, and it gets thinner and thinner.

2. Attenuation. This term covers the weakening of the sound from a number of other causes. As the water particles move back and forth in the compressions and rarefactions of sound waves, they rub against one another. Some of their original strength is used up in friction. Also, during their travel, sound waves may hit air bubbles, seaweed, fish, the ocean surface, or other obstacles. Some of the strength of the sound waves is absorbed by these obstacles; some is scattered in other directions so that it never reaches the hydrophone.

Most important to sonar is the fact that attenuation is greater with higher frequencies. For this reason, supersonic sounds lose strength more quickly than sonic sounds and therefore cannot travel as far.

Sonic and supersonic sounds from ships

It has already been mentioned that submarines are equipped with sonic and supersonic listening gear. Both kinds are necessary to pick up all the sounds we are interested in hearing.

Propellers generate a wide band of sonic and supersonic frequencies. Consequently, they can be detected with either type of gear.

Ship machinery noises are mainly in the sonic range. Sonic listening is necessary, not only to catch these sounds from enemy ships, but also to locate and identify noises from your own submarine that might give you away to enemy escort vessels.

Enemy echo-ranging, that is, sound signals sent out by enemy escort vessels in searching for submarines, is supersonic, and can be heard clearly with supersonic gear.

Slapping of waves and the sounds of surf pounding on a beach are largely in the sonic range. This is also true of most sounds made by fish and marine animals.

Only with a combination of sonic and supersonic listening can we be sure of hearing all of these sounds.

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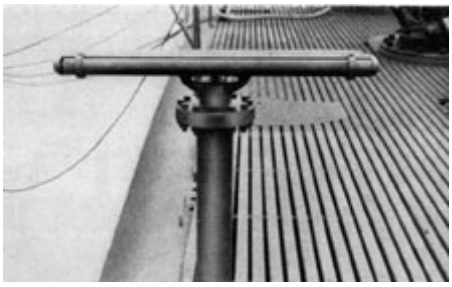
4

SONIC LISTENING

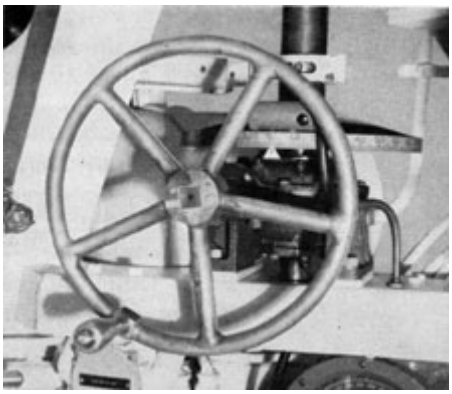
The essential parts of JP gear

1. Hydrophone



When a sound wave hits the front of the hydrophone, the long metal tube changes slightly in size. This sets up an electric current in wires coiled around its wooden core. Sound cannot hit the back, of the tube very strongly because it is protected by a rubber bale.

2. Training mechanism



The shaft on which the hydrophone is mounted goes down through the pressure hull into the forward torpedo room. Inside the shaft a cable carries the electric current to the amplifier. Geared to the shaft is a training handwheel. One full turn of this wheel turns the hydrophone about 33 degrees. On the circular scale, the target's relative bearing is read opposite the pointer.

3. Amplifier

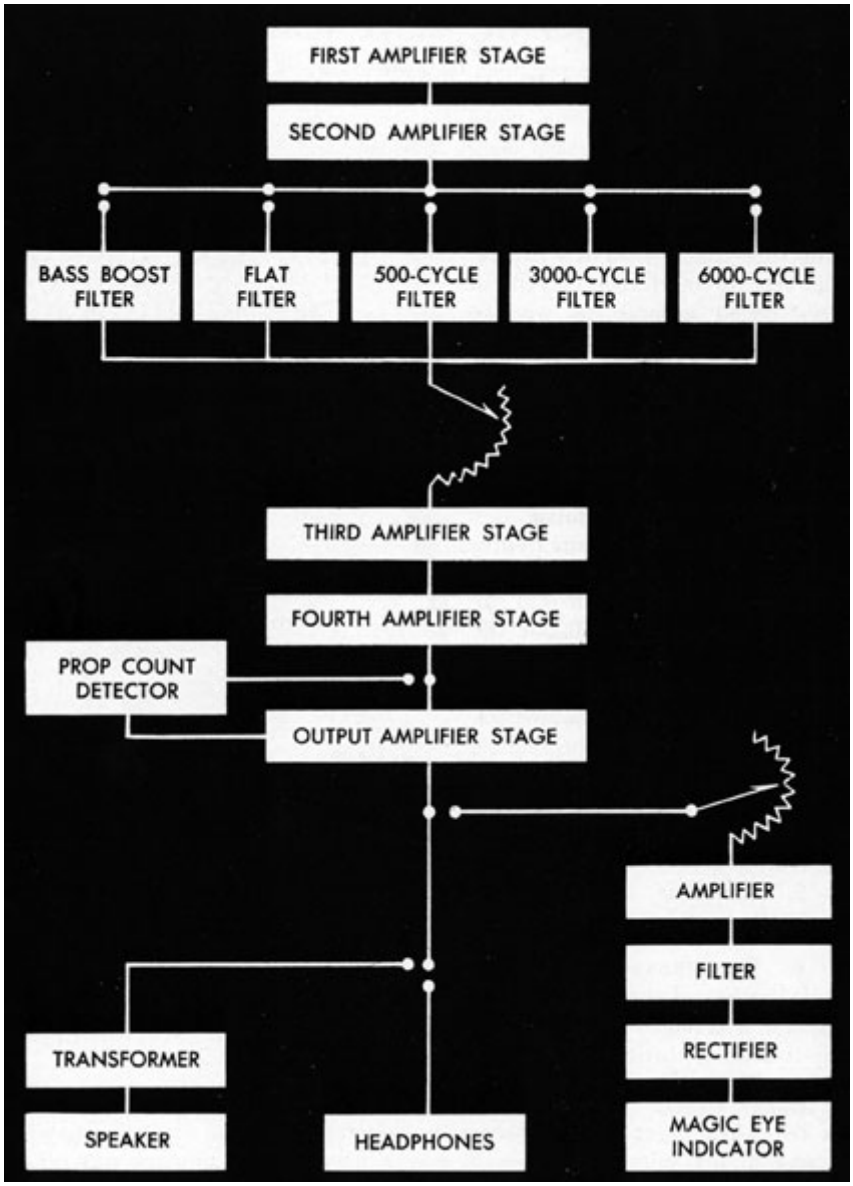
In the amplifier the electric current from the hydrophone is made stronger.

4. Headphones

By means of the headphones, or loudspeaker, the electric current from the amplifier is changed back into sound. Thus the operator can hear and identify sounds coming through the water.

Power supply. JP gets its power from the submarine's batteries. This has two advantages: First, there is no generator to make noise during silent running of the submarine. Second, even if depth-charge damage cuts off the submarine's main power supply, the JP operator can still tell what is happening on the surface.

This is the way



the JP amplifier works

1st amplifier stage receives the incoming electric current from the hydrophone and makes it stronger.

2nd amplifier stage makes this amplified current still stronger.

Bass-boost filter weakens frequencies above 1500 cycles, making the low frequencies seem stronger.

Flat filter passes all frequencies equally well.

500-cycle filter cuts out frequencies below 500 cycles it weakens frequencies from 500 to 2500 cycles, making the higher frequencies seem stronger.

3000-cycle filter weakens frequencies below 3000 cycles, making the higher frequencies seem stronger.

6000-cycle filter makes 6000 cycles stand out by weakening frequencies lower and higher than this.

3rd amplifier stage makes the filtered current stronger. How much stronger is determined by the volume-control setting.

4th amplifier stage makes this amplified current still stronger.

Prop-count detector changes the current so that the propeller beats stand out.

Output amplifier stage makes the current strong enough for the headphones.

Transformer changes the current so that the

Headphones change the electrical current into sound.

Amplifier strengthens a small portion of the current. How much it is

loud speaker can handle it.

Loudspeaker changes the electrical current into sound.

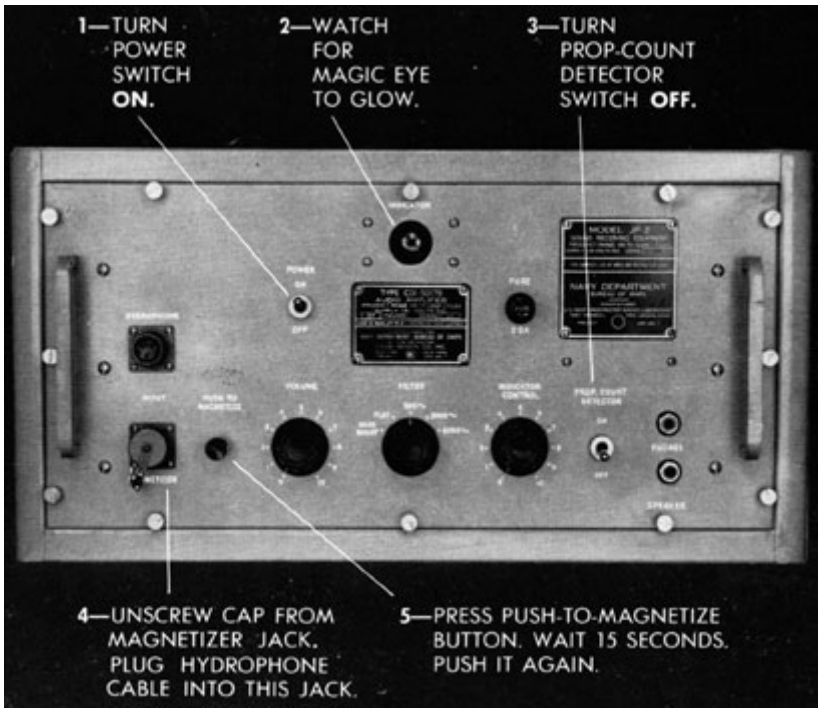
strengthened is determined by the indicator control setting.

Filter cuts out all frequencies below 6000.

Rectifier changes the current so that the indicator can handle it.

Magic eye indicator lets the operator's eye see what his ears hear. The eye closes when current is strongest.

These are the steps to take



Power switch when ON, allows power to be supplied to the amplifier.

Input jacks. When the cable is connected to the hydrophone jack, the current from the hydrophone goes into the amplifier. When the cable is connected to the magnetizer jack, power from the amplifier

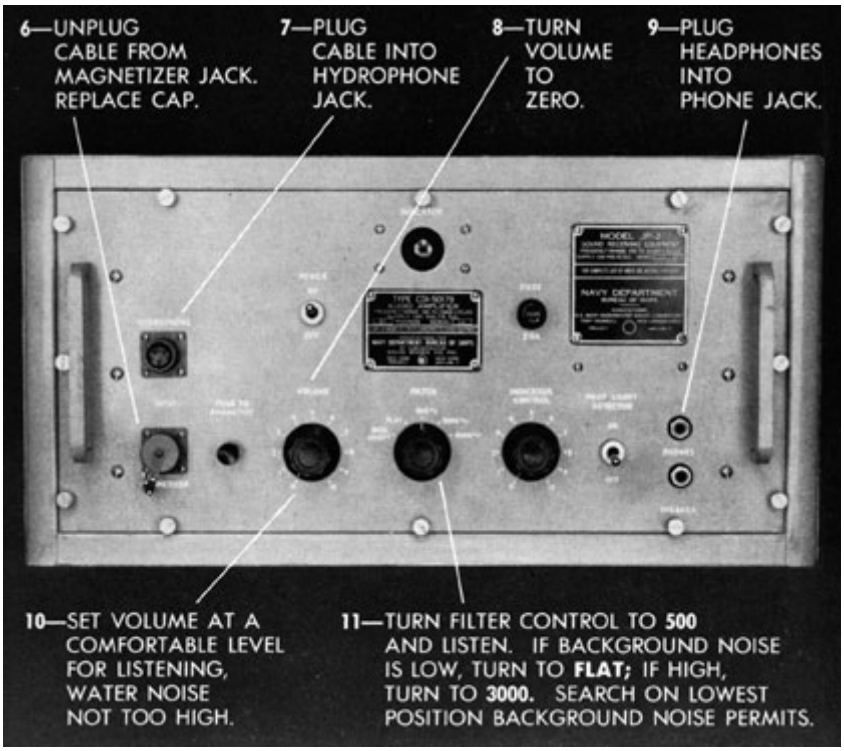
Push-to-magnetize button sends the magnetizing power into the hydrophone.

Prop-count detector. Sometimes you can get a better turn count with this ON.

Magic eye indicator. The eye closes when the hydrophone is trained exactly on the loudest sound.

can be sent into the hydrophone, magnetizing it to make it more sensitive.

in starting JP sonic listening gear



Phones jack. Headphones are plugged in here for normal operation.

Speaker jack. If speaker is used, it is plugged in here.

Fuse. If a fuse burns out, your gear will go dead. Call the radio technician.

Volume control. As this is turned clockwise, the sound is made louder.

Filter control selects whichever of the five filters you want to use.

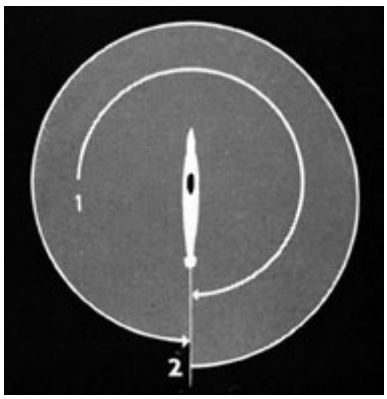
Indicator control. Turned clockwise, this increases the strength of the current going to the magic eye.

JP Search Procedures

When you are on sonar watch, until you get a contact, your time will be spent in routine searching. To get the proper rate of sweep, you will have to turn the handwheel rapidly. When you take over the watch, you first carry out ...

Rapid search

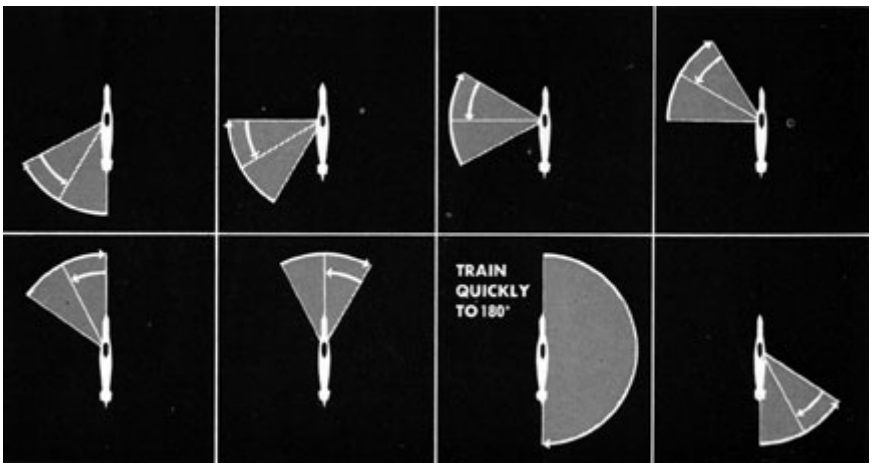
1. From the bearing at which the hydrophone was left by the previous watch, sweep through 000 degrees and continue on to 180 degrees.



2. Then, reversing direction, sweep back around the full circle to 180 degrees. If no suspicious sounds are heard, shift to ...

Progressive search

Sweep forward two full turns of the handwheel and then one turn back. Continue up the same side, two turns forward and one turn back, until you have crossed the bow. Then train rapidly down the opposite side to 180 degrees. Reverse direction and train two turns forward, one back, two forward, one back, until you have crossed the bow again. Then train rapidly down the other side ... and so on. Continue this procedure for the duration of your watch, unless ordered to do otherwise.

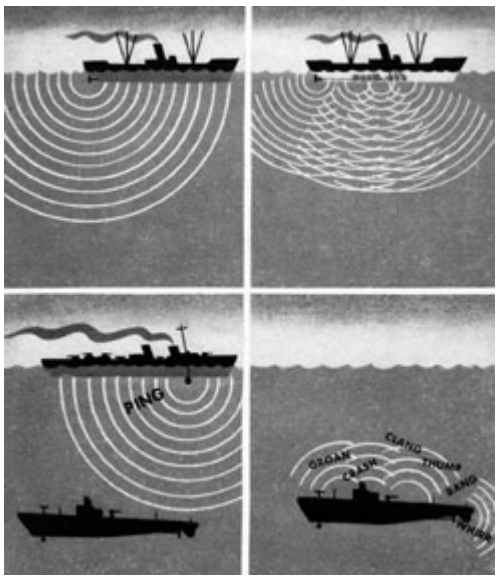


These are some of the sounds you are likely to hear

Report these sounds

1. Enemy ships' propellers have rhythmic, swishing beats. PT boats whine and freighters chug.

2. Enemy ships' machinery noise is not rhythmic like propellers. For example, generators sound just as you would expect.



3. Enemy echo-ranging (pinging) produces dull thuds or sometimes shrill peeps on JP.

4. On your own submarine, electric motors have a smooth hum; bow planes grate; the TDC whirrs; blowing tanks make a roaring sound.

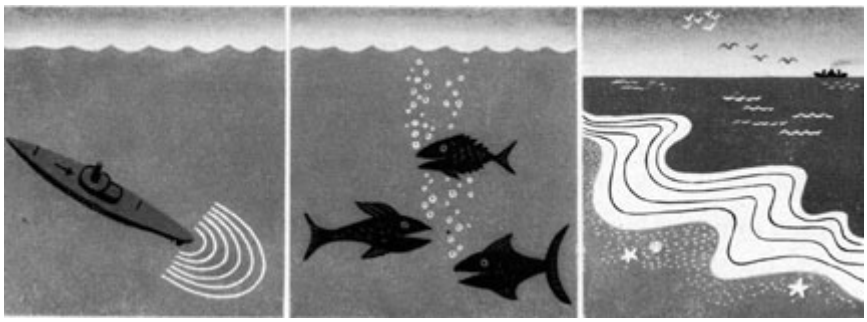
The only way to learn to know these sounds is to listen to them repeatedly on the JP training records. Every submarine has these records.

Learn to recognize these other sounds

1. Own ship's screws are heard at 180 degrees, except during silent running.

2. Shrimp snap; porpoise bark and whistle; drumfish sound like a drum; croakers croak.

3. The roaring pound of surf against a beach sounds quite natural.



Contact !

When your searching picks up a suspicious sound, your real job begins. The conning officer needs all the information you can give him. Here is what you must do - and do quickly.

1. Check the reciprocal bearing

Suppose you pick up a contact when the hydrophone is trained on 090 degrees. Immediately train halfway around the bearing circle to 270 degrees. If the sound is weaker here, then you know 090 degrees is the correct contact bearing. But if the sound is stronger on 270

degrees, then 270 degrees is the right bearing to report, because the sound you heard on 090 degrees came through the baffle at the back of the hydrophone.

2. Report the contact

Immediately give the approximate bearing: "JP, contact, bearing ze-ro niner ze-ro." If you are not sure it is a ship, report: "JP, doubtful contact, bearing ze-ro niner ze-ro."

3. Adjust the amplifier controls

While you are reporting, set your amplifier controls to sharpen the target sound:

1. Set volume low enough to make the target distinct from the background noise.

2. Turn filter to the highest setting on which the target can still be heard.

3. As soon as you can hear on the 3000-cycle position, adjust the indicator control so that the magic eye just closes as the hydrophone is swung across the target.

4. Keep reporting accurate bearings

Make your eyes and ears work together. Use both the magic eye and the sound from your headphones to get the best bearings you can. Report every bearing you read. Keep adjusting your volume and filter controls to narrow the arc of the target.

5. Identify the target

As soon as possible, decide the probable kind of target. If it is a ship, notice the speed of the screws (slow, medium, or fast) and the weight of the sound (light or heavy). Report the nature of the target: "JP, bearing two eight eight. Sounds like a destroyer."

6. Keep information going to the conning tower

Get the turn count. Watch for any changes in the speed of the screws or in the loudness of the sound. Report every fact right away.

How to get accurate bearings

Read when sweeping from target's bow through target's stern

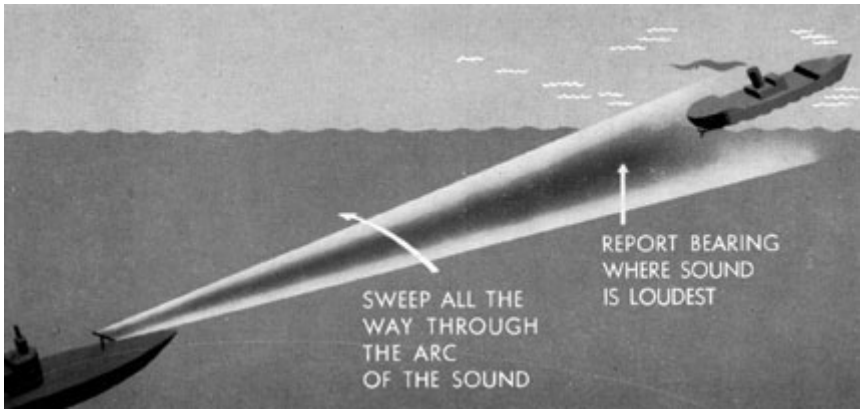
To get good bearings and to avoid losing contact, keep crossing the target. Sweep all the way through the screw noise. Then sweep back.

Sweep all the way through again and all the way back. Determine which way the target is heading as quickly as possible. Then read the bearing only when sweeping in one direction: from the target's bow through the target's stern. Continue to sweep and to report bearings every time you cross the target in this one direction.

Read the bearing at maximum loudness

As you sweep across the target, the propeller noise increases to maximum loudness, and then dies away. There is also a change in the nature of the sound. Near the bearing of the propellers it has more of a hissing quality. With some experience, you will learn to combine the change in loudness and the change in quality to pick out the maximum point accurately.

If the sound is of equal loudness over a wide arc, proper use of the gain and filters will nearly always narrow it enough to give you a distinct maximum. Also, the more rapidly you sweep, the more noticeable the changes become - and the more accurately you can determine the peak.



Use the magic eye

The eye can be brought into operation as soon as you are able to listen on the 3000-cycle filter position. Adjust the indicator control until the eye just closes on each sweep through the target. Read the bearing the instant the eye closes. This should check with the bearing obtained by listening. When ever you change the volume setting, you may have to reset the indicator control.

Use volume and filters wisely

Low volume narrows the target.

As soon as you get a contact, turn the volume control to the lowest setting at which the target can be heard. By cutting down the background noise level, this makes the propeller sounds stand out

more clearly. With low volume, the arc of the target noise narrows. This allows you to get more accurate bearings.

Filters can define and narrow the target

Propeller noise is made up of all frequencies. But background noise, from the water and the submarine, is mostly low-frequency sounds. Therefore, by operating with a high-frequency filter you can get rid of the background noise, yet still hear the screws. Also at higher frequencies the target is heard over a narrower arc. So it is wise to use the highest filter setting on which the target can be heard.

How to take a turn count

1. Train the hydrophone directly on the bearing where the prop beats are loudest.

2. Turn the prop-count detector ON. It may bring out the beats more clearly. (If it does not, turn it OFF.)

3. Notice whether the beats are accented or unaccented. Accented beats go CHUG, chug, chug (three-bladed propeller)-or CHUG, chug, chug, chug (four-bladed propeller). Unaccented beats go chug, chug, chug, chug, chug.

4. Get in rhythm with the beats by pumping your arm up and down. If there is an accented beat, let your hand come down with every accented CHUG -or if the beats are all the same, on every chug.

5. Count the number of times you pump your hand down in 15 seconds.

6. Multiply this count by 4 to get the number of rpm (revolutions per minute). Report the rpm immediately. For example, if your 15-second count is 24, the rpm will be 96, and you will report: "JP, turn count is ze-ro nines six. Good count." If the beats are so rapid that you are not sure of the accuracy of your count, report: "Poor count."

7. After you have reported, make sure that the prop-count detector switch is OFF.

During approach and attack

Give the conning officer every scrap of information you can about the target. Be alert to catch and report:

. . . if it changes its course, turn count, or pinging rate.
. . . if it crosses your own bow or stern.
. . . if another ship comes between you and the target.
. . . if you lose contact.

Listen carefully to all orders from the conning officer. He may direct you to track the target. Or he may tell you to continue searching all around to keep in touch with the escort vessels in the screen, while another sonar operator stays on the target. If he fires torpedoes, he may order you to track them-to give bearings continuously on their whining sound as they run, and to report the crash as they explode.

During evasive maneuvers

In escaping from the enemy, the JP gear is frequently used to keep track of the attacking ship. Because of its topside mounting it can be operated even when you are lying on the bottom. It is also valuable for detecting telltale noises your own machinery may be making, using the bass-boost filter to bring out the low frequencies. If a doubtful sound remains on the same bearing when your own ship changes course, it is almost certainly from your own machinery. You should study our own ship's sounds so that you learn to recognize them quickly.

After depth charges - remagnetize

If depth charges are dropped near you, you probably will have to remagnetize the hydrophone. Plug the cable into the magnetizer jack, and press the push-to-magnetize button just once. Then plug the cable into the hydrophone jack and listen. If you cannot hear anything, magnetize the hydrophone again. Continue this procedure until the hydrophone is able to pick up sounds.

Securing JP gear

As soon as your submarine surfaces, secure the JP gear,

1. Turn the power switch off.

2.Train the hydrophone to 090 degrees if it is installed on the port side, or to 270 degrees if it is on the starboard side.

3. Hang up the headphones carefully. They are a special kind that cannot be replaced while you are on patrol. Other headphones do not work as well on JP gear.

Enemy echo-ranging

If in searching you hear the dull thuds or shrill peeps of enemy pinging (echo-ranging), quickly check the reciprocal bearing, and then report the approximate bearing of the pinging immediately. Estimate the time between pings. If it is over 2 seconds, report "long scale." If it is definitely less than this, report "short scale." Be alert to catch and report any change in the pinging rate.

5
SUPERSONIC LISTENING

The WCA system of sonar gear is used for supersonic listening, and also for echo-ranging and depth-sounding. It consists of three main divisions: QB, JK/QC, and NM. In this chapter we shall be concerned with the use of QB and JK/QC for supersonic listening. However, to keep things straight, we shall start with a brief description of the whole WCA system.

Projectors

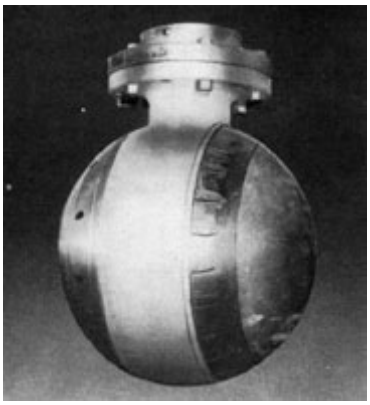
The QB projector is a spherical hydrophone mounted on the lower end of the starboard training shaft. One face contains rochelle salt crystals, which change shape when a sound wave strikes this face of the projector. The other side is empty.

The JK/QC combination projector is mounted portside. The JK face is just like QB. The QC face contains small nickel tubes, which change size when a sound wave strikes this face. (The NM projector, mounted on the hull centerline in the forward trim tank, is used only for echo sounding.)

Change in shape of the salt crystals (QB, JK) or in the size of the metal tubes (QC, NM) generates a small electric current in connecting cables.

Receiver-amplifiers

In the receiver-amplifier, the small electric current is



Hoist-lower-train mechanisms

Both shafts are equipped with hydraulic mechanisms for raising and lowering the projectors. Training motors and reduction gears turn the shafts and projectors. Power is supplied by two motor generators. All of these units are in the forward torpedo room.

Other parts

The remaining parts of the WCA are concerned with echo-ranging or depth sounding. For echo-ranging there is a QB driver and a QC driver in the forward torpedo room, and a range indicator in the conning tower. For echo-sounding, there is a depth indicator in the control room. (The QC driver is

strengthened and changed so that it is heard as sound in the phones or speaker. Two receiver-amplifiers, QB and JK/QC, are in the conning tower. There is also a receiver-amplifier in the forward torpedo room for emergency use with either system.

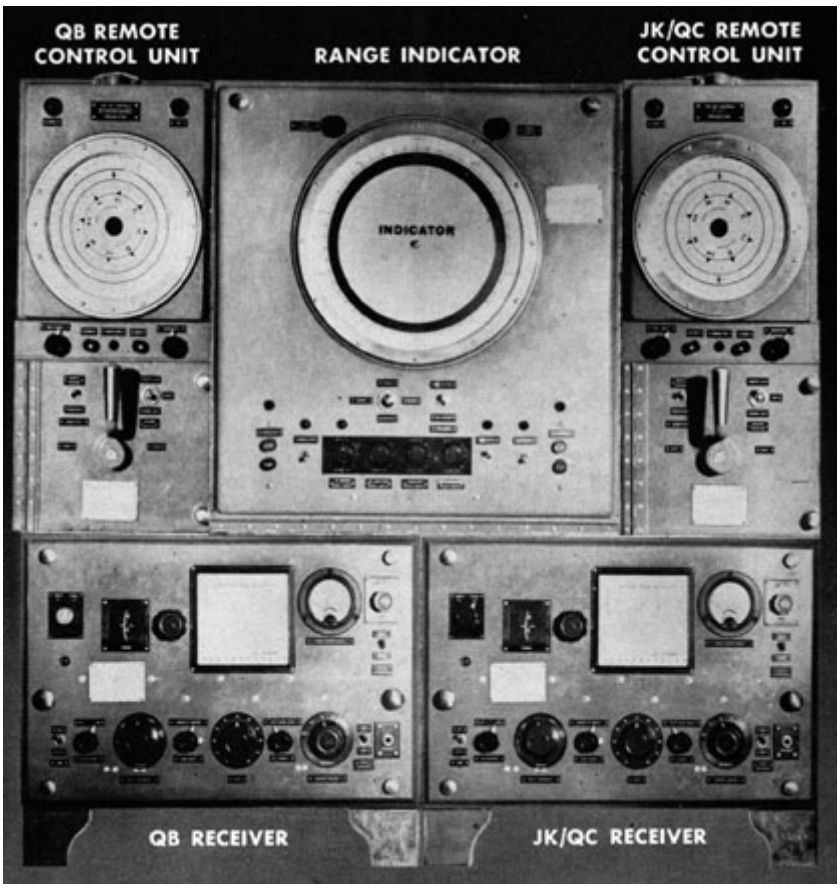
Remote-control units

In the conning tower are two remote control units, one for the QB, the other for the JK/QC projector. These operate the training motors, and also show the direction in which each projector is trained.

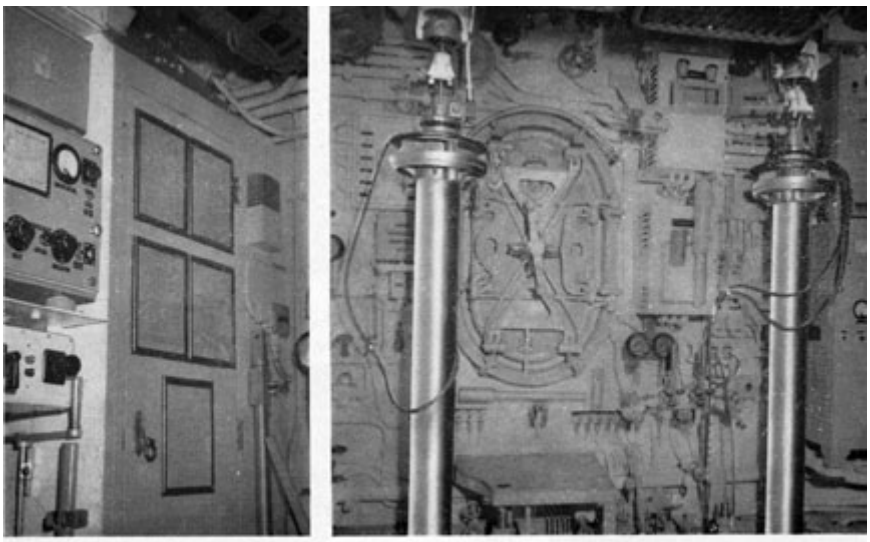
also used for NM in depth sounding.)

In the conning tower

The photograph below shows a WCA stack, in which five units are grouped for efficient supersonic operation. There are separate remote-control units for the starboard (QB) and port (JK/QC) projectors, each with its receiver-amplifier. During routine search only one type of supersonic gear is manned. But when a contact is reported, QB is taken over by the sonar operator whose battle station is at the stack, and a second operator mans JK/QC. Normally during an attack, QB tracks the target, while JK searches for other ships. The range indicator is not used for listening.



In the forward torpedo room



The spare receiver-amplifier and training control.

General view looking aft showing training shafts for both projectors.

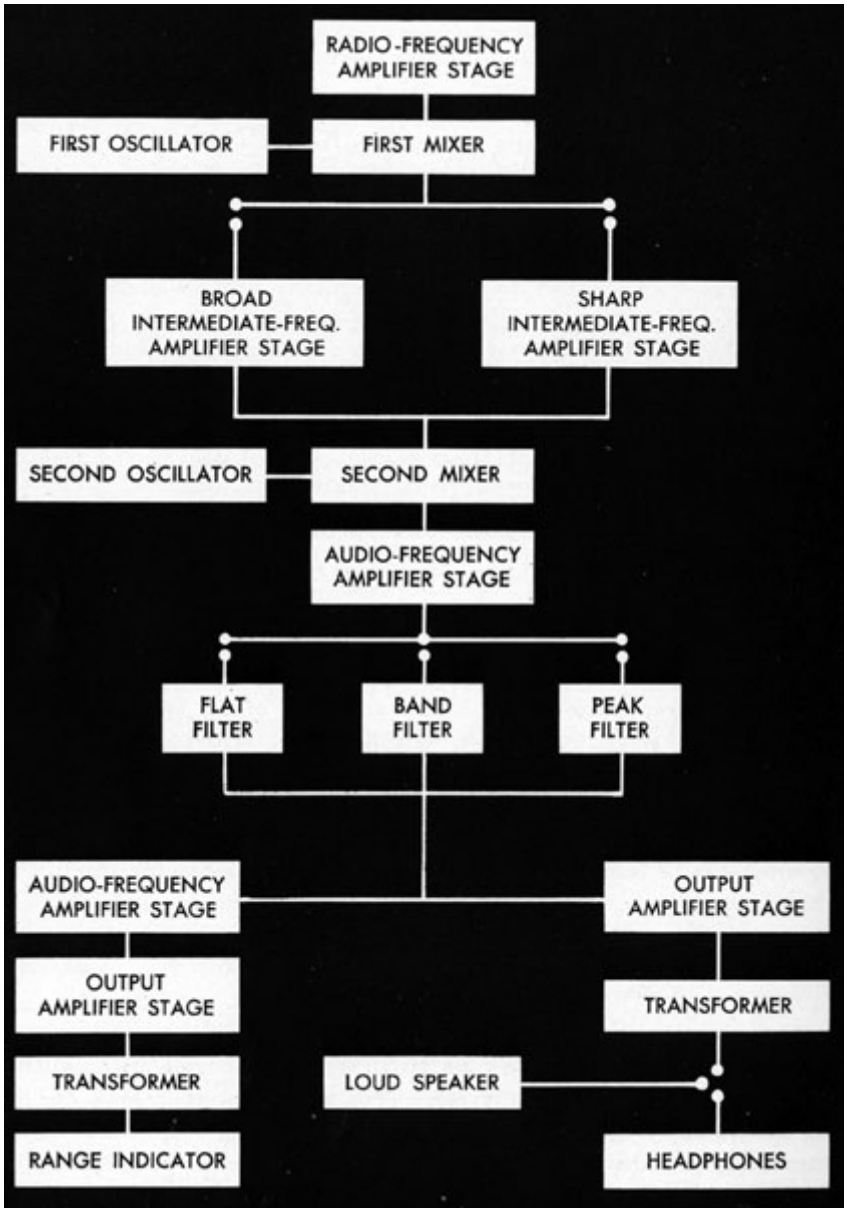
The photographs above give a general picture of the WCA gear in the forward torpedo room, looking aft, with projectors raised. These are lowered by a torpedoman, operating the hoist-lower mechanisms. If for any reason, the conning tower has to be abandoned, supersonic listening can still be carried on from the spare units in this room. These include a receiver-amplifier, which can be connected to either JK or QB, and a training control for turning either shaft. Relative

bearings can be read directly from the scale and pointer on each hoist-train shaft. True bearings cannot be read.

Limit switches prevent training either shaft more than 2 1/4 turns, as a protection to the cables. If you train far enough to hit one of these switches, the training motor automatically stops. You must then train back one full turn. Where slip rings have been installed, the training shaft can be turned continuously in either direction without damage to the cables - eliminating the need for limit switches.

29

This is how the



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receiver-amplifier works

First oscillator produces a

Radio-frequency-amplifier stage

current whose frequency is 60 kc higher than that of the incoming current. For example, with an incoming current mainly of 17 kc, this oscillator would develop 77 kc (17 plus 60).

increases the strength of the current coming from the projector.

First mixer combines these two currents to get a frequency that is mainly 60 kc (77 minus 17). The frequency obtained by mixing is always equal to the difference between the frequencies that are mixed.

BROAD Intermediate-frequency-amplifier stage strengthens a broad band of frequencies centered around 60 kc.

SHARP Intermediate-frequency-amplifier stage strengthens a narrow band of frequencies centered around 60 kc.

Second oscillator, as normally set, produces a current whose frequency is 60,800 cycles.

Second mixer combines this 60,800-cycle current with the amplified 60,000-cycle (60 kc) current to get a frequency that is mainly 800 cycles (60,800 minus 60,000).

Audio frequency amplifier stage makes the current from the second mixer stronger.

Flat filter passes frequencies from 200 to 3000 cycles.

Band filter passes frequencies from 600 to 1000 cycles.

Audio-frequency-amplifier stage makes the filtered current still stronger.

Peak filter passes practically only 800 cycles.

Output - amplifier stage makes this current strong enough to operate the red light on the range indicator.

Output-amplifier stage makes the filtered current strong enough for the head phones or loudspeaker.

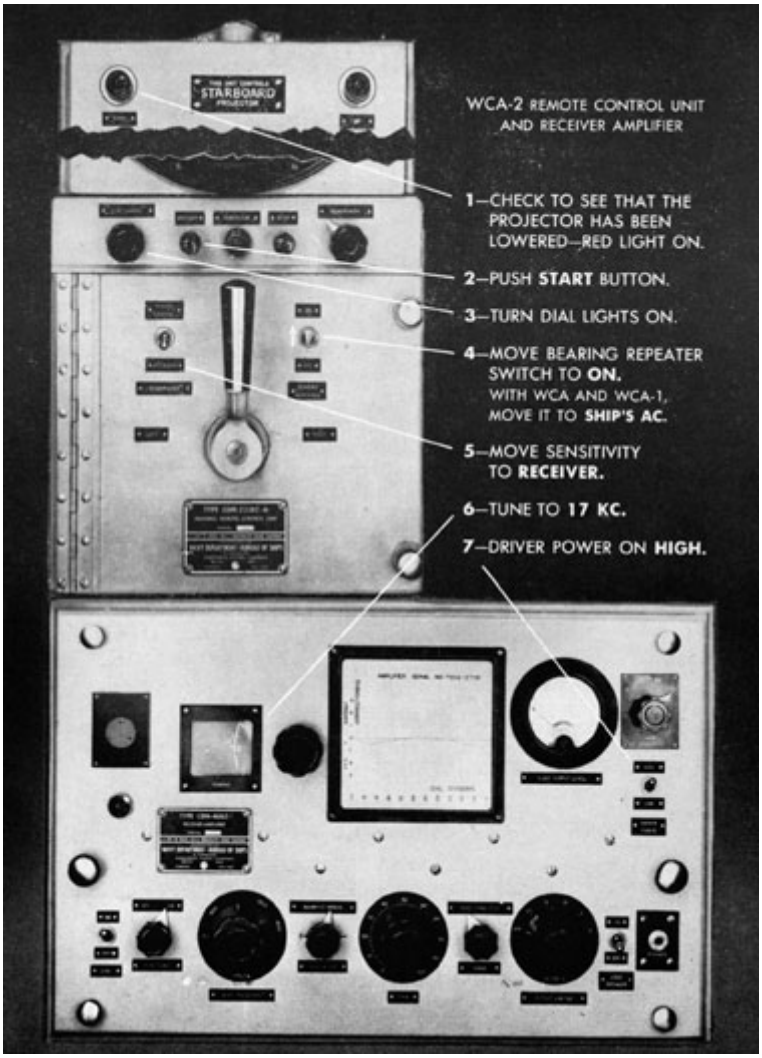
Transformer changes the amplified current so that the range indicator can handle it.

Transformer changes this amplified current so that the headphones or loudspeaker can handle it. **Loudspeaker** changes the electrical current into sound.

Range indicator. Here the current makes a red neon light flash. This indicator is not used for listening.

Headphones change the electrical current into sound.

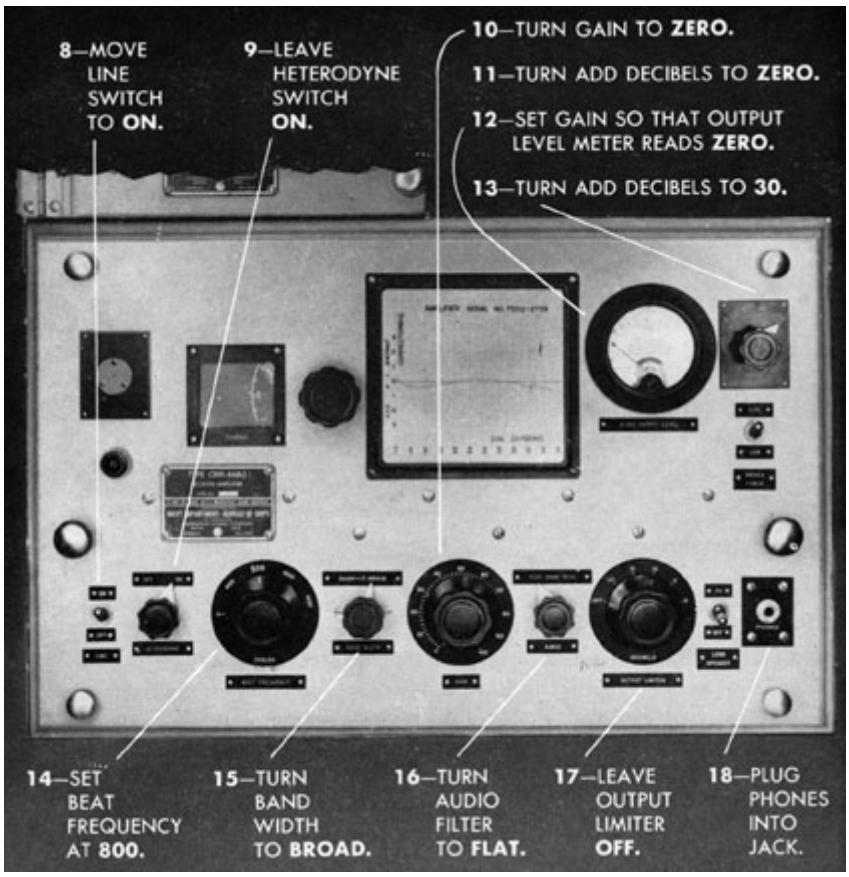
These are the steps to take



Heterodyne switch. When this switch is off, the second oscillator does not work. Some times propeller beats can be heard with it off. But almost always you should operate with it ON.

Output limiter cuts off part of the sound. Once in a while, when background noise is very high, you may use it. But to avoid losing the target, you will almost always keep it OFF.

in starting WCA listening gear



Audio-output-level meter shows the strength of the electric current going to the head phones or loudspeaker.

Add-decibels switch protects this meter from breaking. Always keep it set at 30, except when determining the proper setting for the gain control.

Beat-frequency control. The radio technician uses this control when he adjusts the gear. But for listening, it must always be set at the red 800. Otherwise the target may be lost when the PEAK filter is being used.

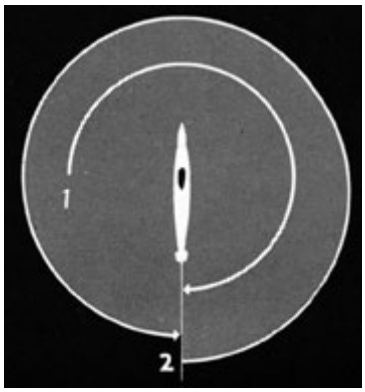
Driver-power switch should be left on HIGH. It is set at LOW only when the radioman uses the echo-ranging gear to send underwater signals in code to another vessel.

Gain control, when turned clockwise, increases the volume of sound. There is an other gain control on the remote-control unit, labeled "Sensitivity." If you wish to regulate gain from the remote-control unit, move the sensitivity switch to REMOTE CONTROL.

Tuning dial tunes the receiver to whatever frequency is desired. At the same time it automatically adjusts the first oscillator to send whatever frequency is needed to produce 60 kc in the first mixer.

When you take over the watch on the WCA stack, check all controls. If necessary, retune to 17 kc. Start with...

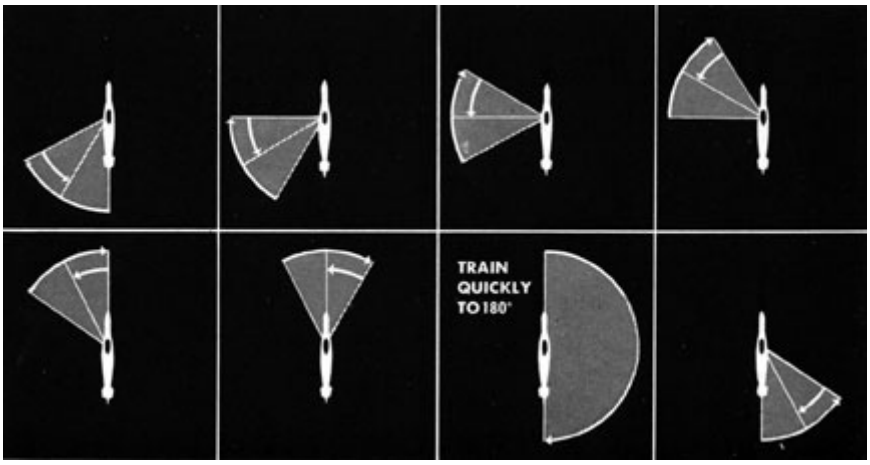
Rapid search



Swing the remote-control lever so that the bug passes through 000 degrees and continues down the other side to 180 degrees. Then reverse the lever until the bug makes a complete circle to 180 degrees. If you hear no suspicious sounds, shift to

Progressive search

Reversing direction, sweep 60 degrees forward, then 30 degrees back, 60 degrees forward, 30 degrees back - until you have crossed the bow. Then train quickly down the opposite side to 180 degrees. Again reverse direction and sweep 60 degrees forward, 30 degrees back, 60 degrees forward, 30 degrees back - until you have crossed the bow. Then train quickly down the opposite side to 180 degrees. This completes one full double-cycle (720 degrees).



Frequency search

Every fifteen minutes during a sonar watch, you make a frequency search to try to pick up enemy pinging. This is the sequence for a frequency search:

20 kc - one complete double cycle of progressive search.
23 kc - one complete double cycle of progressive search.
26 kc - one complete double cycle of progressive search.
29 kc - one complete double cycle of progressive search.

32 kc - one complete double cycle of progressive search.
14 kc - one complete double cycle of progressive search.

Then return to 17 kc and continue with the normal search plan.

Rate of sweep

In searching, the proper rate of sweep is somewhat less than the maximum obtained when the remote-control lever is swung all the way over. The position of the lever to get the proper rate has to be determined by experience, since the speed steps vary on different remote-control units.

Reporting enemy echo-ranging

Sometimes a ship's pinging can be picked up before you can hear its screws. Any ship that is pinging is out searching for submarines. Merchant vessels are not equipped for echo-ranging.

So-if you hear pinging report it at once. For example "QB, contact, echo-ranging bearing one one ze-ro." Set your tuning dial to make the pinging come in loud and clear. Estimate the time between pings and report whether the ship is using long scale or short-scale pinging.

Also notice carefully whether you hear the pinging without interruption. If it comes in for a few pings and disappears for a minute or more, comes in again and disappears - the ship is probably still searching. But if it comes in continuously or with only brief interruptions, the ship has probably picked you up as a contact and is likely to attack. This is important information and should be reported immediately.

Contact !

Maybe your whole watch will be spent in just routine searching. But at any moment you may pick up enemy propellers. Then you must quickly do six things:

1. Immediately report the approximate relative bearing of the contact: "QB, contact, bearing thuh-ree ze-ro ze-ro." Even if this bearing is incorrect by 20 degrees or 30 degrees, it lets the conning officer know the general direction of the target. If you are not sure your contact is a ship, report it anyway: "QB, doubtful contact, bearing thuh-ree ze-ro ze-ro."

2. Reset your amplifier controls to get better bearings. Turn the gain down to the lowest possible setting on which the target can be clearly heard.

Turn the tuning control to the highest frequency on which the target can be clearly heard.

Shift the audio switch to BAND. If you cannot hear the target, return the switch to FLAT.

3. Keep sweeping across the targetall the time you are making these adjustments. Keep reading accurate bearings and reporting them. Report relative bearings, but note the true bearing at the same time. If your submarine changes course, you can maintain contact with the target by following its true bearing during the turn. Get in the habit of noticing the true bearing every time you read and report a relative bearing.

4. Identify the target. Describe its screws as heavy or light, slow or medium or fast. Tell what type of ship it is. "QB, bearing thuh-ree thuh-ree fo-wer. Heavy, slow screws. Sounds like a tanker."

5. Take a turn count and report the number of rpm. Whenever the target's speed changes, report that fact at once: "QB, bearing thuh-ree fo-wer niner. Heavy screws speeding up." Then get the new turn count and report the rpm.

6. Try new filter settings from time to time. If you are on BROAD-BAND, shift to BROAD-PEAK and then to SHARP-PEAK. Be ready to shift back instantly if on the new setting you lose the target. When you change filters, you may have to change your gain setting. But keep the gain as low as possible at all times.

Using tuning, gain, and filters to narrow the target

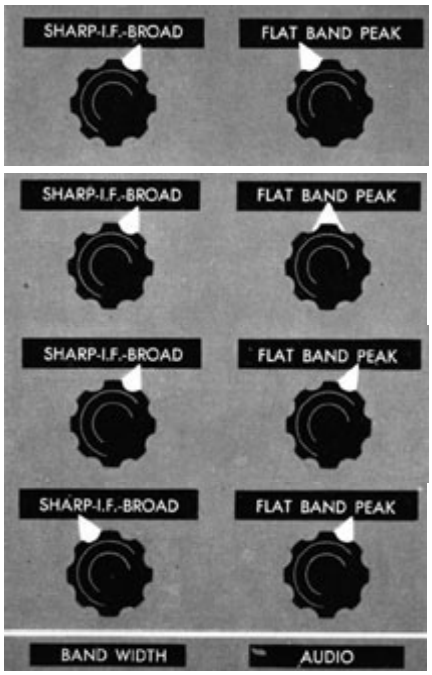
These three controls must work as a team. They must be handled with skill and with a complete understanding of the way they work together.

Tuning high. As the frequency of a sound increases, a hydrophone becomes more and more directional. That is, it picks up sounds over a narrower arc. So it is good practice to take the bearings of a target with the tuning dial set high. Remember, however, that the attenuation is greater at higher frequencies. So if you turn the tuning knob too far, you may not be able to hear the target at all. But always track a target at the highest frequency on which it can be heard.

Gain low. After contact, keep your gain as low as possible. This will make the target's screws stand out from the background noise. Also,

because low gain narrows the arc over which you hear the target sounds, you will get better bearings.

Filters help by cutting out most of the background noise, allowing mainly the screw sounds to come through. Sweeping a narrower arc of noise gives more accurate bearings. Below is the order in which you are most likely to use these filters.



Because this combination gives a wide listening arc, it is good for searching, but poor for getting bearings.
Shift to BAND as soon as you can after contact. It gives better bearings.

PEAK narrows the arc considerably. It gives even better bearings.

This is the best combination of all. Reach it, if possible, during an approach.

Accurate and continuous bearings

Accurate bearings must be continuously supplied to the conning officer. With some experience, you will learn to get accurate bearings if you follow the proper procedure.

Keep crossing the target completely. Sweep all the way through the arc of propeller noise. Continue until it dies out completely. Then reverse direction and sweep through until it dies out on the other side.

Read when sweeping from bow through stern. As quickly as possible determine which way the target is moving. Then read the bearing on the sweep that goes from the target's bow to the target's stern.

Read the bearing at maximum loudness. Usually you can determine easily a point of maximum loudness. This is the bearing. If the sound is of equal loudness over a wide are, adjust tuning, gain, and filters to narrow it enough to give a distinct maximum.

Securing WCA gear

When your submarine surfaces, you will continue searching. While it is running at a slow speed, you will be able to listen efficiently. But at higher speeds the noise becomes so great that you will have to report to the conning officer: "QB, listening conditions poor." Probably you will then be ordered to secure the gear. Here is the way to secure:

1. Bring the bug either to 000 degrees or 180 degrees, whichever is required by the cable arrangement on your ship. (Ask the radio technician.)

2. Unplug the headphones and hang them up carefully.

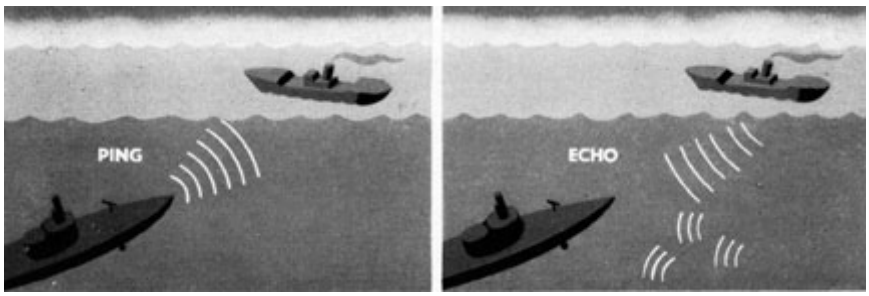
3. Push the STOP button on the remote-control unit; the training-motor generator light will go out.

4. Turn the line switch on the receiver-amplifier OFF.

5. The conning officer will order a torpedoman in the forward torpedo room to raise the projectors. Watch the green light in the upper right-hand corner of the remote-control unit. When it glows, you know that the projector has been raised.

6
SINGLE-PING ECHO-RANGING

If the conning officer requires a range more accurate than his periscope can give, he may order, "QB, get a single-ping range." The sonar operator then aims his projector at the target and shoots out a single burst of supersonic sound called a ping. The time until the echo returns gives a measure of the target's range. There will be a series of small echoes, called reverberations, but the clear note of the main echo from the target can generally be distinguished.



This requires two additional units of equipment, different from those which have been discussed so far.

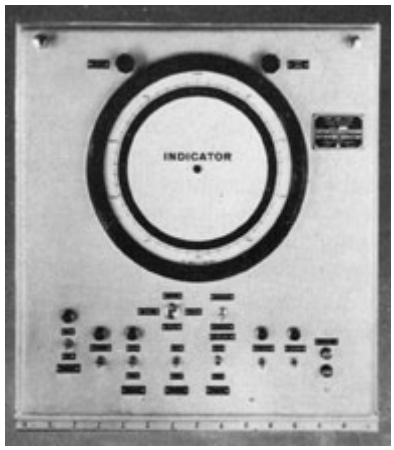
The Driver sends a pulse of current of supersonic frequency to the projector, which projects a ping into the water. There are two drivers, both located in the forward torpedo room. One is connected to the QB projector; the other is used with either the QC projector (echo-ranging) or the NM projector (echo-sounding to get the depth of water beneath the keel).

The Range Indicator is a giant electric stop-watch which measures the time between the ping and the return of the echo. Its dial is marked off in yards so that the range can be read directly.

WCA, WCA-1, and WCA-2 Range Indicators

WCA and WCA-1

The black panel containing four screw driver adjustments appears only on WCA and WCA-1 range indicators. Power can be obtained from a generator or from the ship's AC.



WCA-2

In WCA-2 the screwdriver adjustments have been replaced by hand switches. There are no generator buttons because this model operates entirely on ship's AC.

Advantages of QB for single-ping echo-ranging

Although either QB or QC can be used to get a single-ping range, QB is better for several reasons:

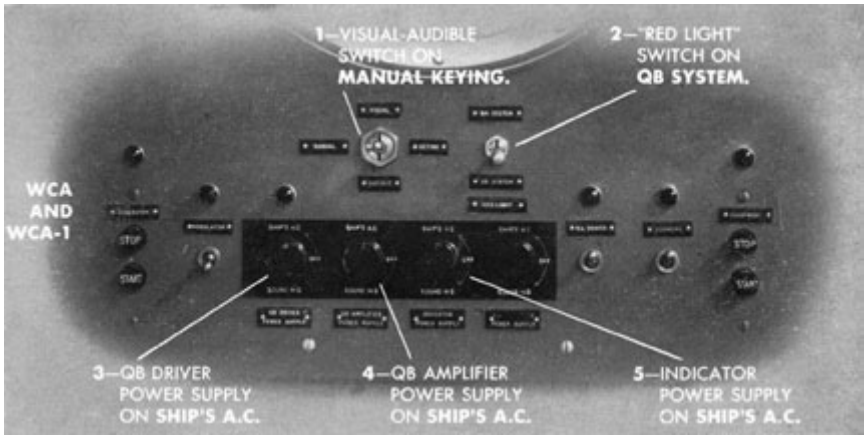
1. You are more certain of getting a good range on a single ping. Although both send out about the same strength of sound, QB can pick up a weaker echo.

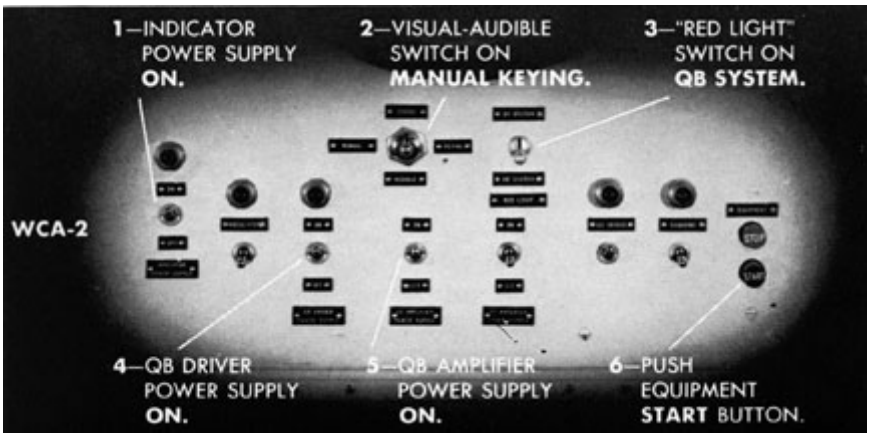
2. You do not have to be so exact in setting the tuning dial when using QB. With QC, it is necessary to tune to an exact frequency.

3. If you have been using JK for listening, before you can use QC, it is necessary to turn the input switch to QC and train the QC bug halfway around the bearing circle. With QB you are ready to ping instantly.

QC must be used when the target bears between 250 degrees and 290 degrees relative. At these bearings the QB projector is blanked out by the JK/QC projector, which is then between it and the target.

How to set the controls for a single-ping range on QB





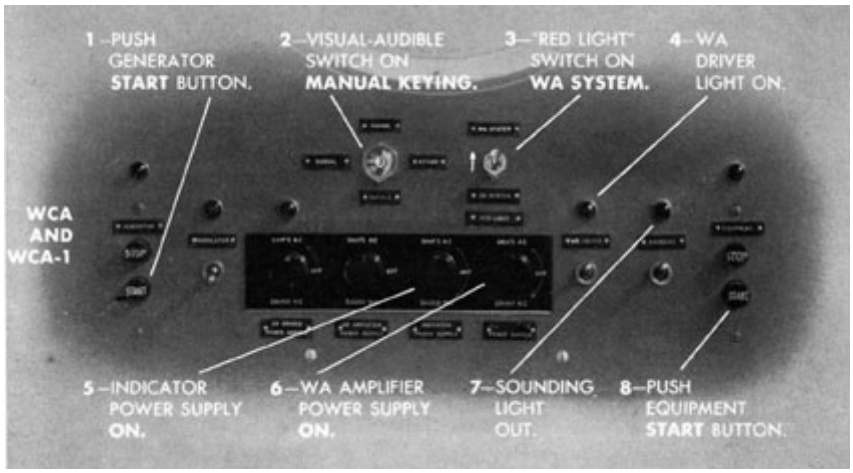
On the QB receiver-amplifier

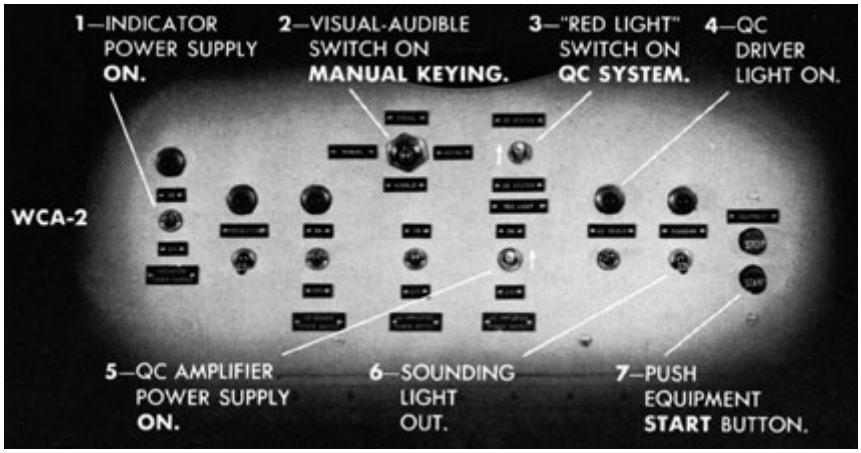
1. Use the frequency on which you have been listening, which should be about 28 kc, because you have raised the tuning to narrow the target.

2. Be sure filters are on BROAD-FLAT.

3. Be sure the driver-power switch is on HIGH.

How to set the controls for a single-ping range on QC





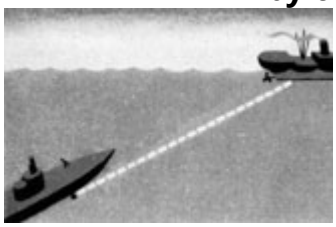
On the QC receiver-amplifier

1. Turn input switch to QC. Train the projector through half a circle so that the QC bug is on the bearing of the target.

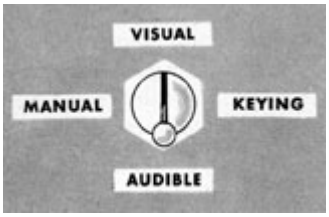
2. Tune exactly to the frequency written above the tuning dial. Very accurate tuning is extremely important.

3. Be sure filters are on BROAD-FLAT.

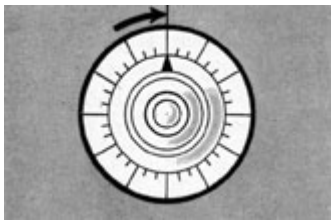
How to get a single-ping range by the audible method



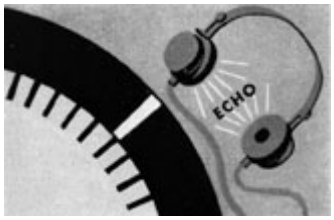
1. Train the bug 2 degrees toward, the target's bow from the bearing where the sound is loudest. Turn the gain down to protect your ears.



2. Just before the white light slit reaches zero, move the switch to AUDIBLE, keeping one hand on this switch.

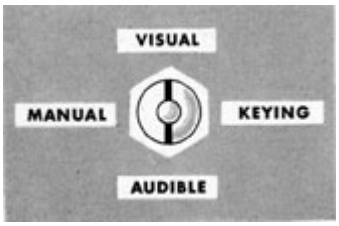


3. When the slit has passed 300 yards, return the gain to its former level in order to get a louder echo.



4. Keep your eyes on the revolving slit and listen intently for the echo. Disregard the rolling reverberations, and concentrate on catching the clear note of the returning echo from the target. At

the instant it comes, note the reading on the scale. This is the range.



5. When the slit reaches 4000 yards, return the switch to MANUAL KEYING.

When and how to use the visual method

Sometimes when your submarine is within 1500 yards of the target, the visual method may be used instead of the audible method. This requires two changes:

1. Instead of setting the switch at AUDIBLE, above it to VISUAL.

2. When the light slit arrives at zero, an arc of red light will flash, indicating that the ping is going out. Following this there will usually be a series of little red flashes caused by the reverberations. Then a good solid red flash will come at the same time that you hear the target echo. Read the range at the trailing edge of this flash.

This visual method involves two serious dangers. First, if the gain on the receiver-amplifier is set too high, you will get a confusing series of red flashes all over the dial from the reverberations. Second, to flash the red light requires more current than to produce an echo in the headphones; so you are likely to get no flash at all from a weak echo.

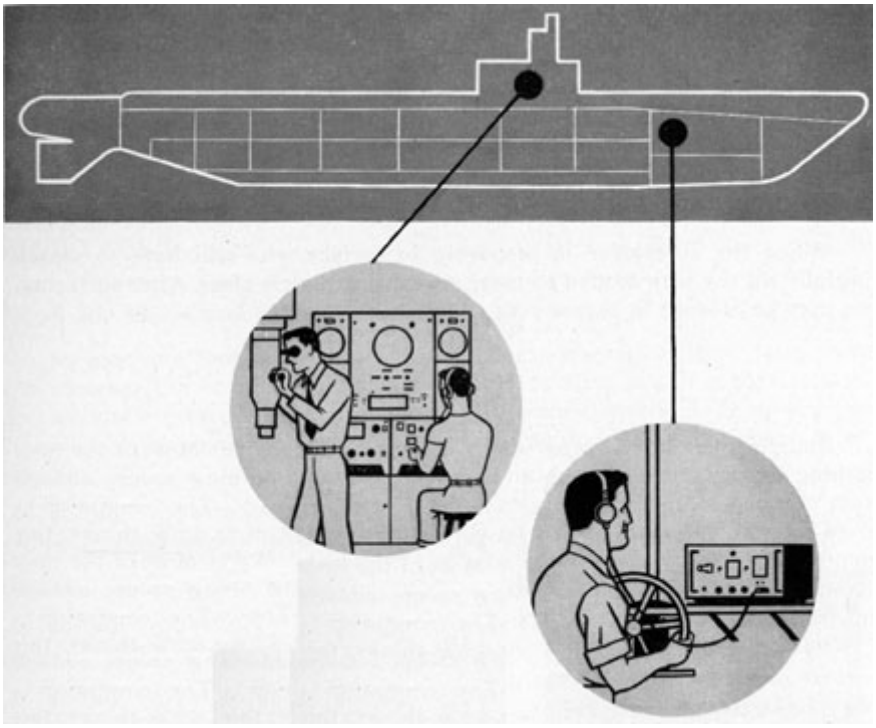
Why submarines do not echo-range continuously

Since the speed of surface escort ships produces a noise level too high for efficient listening, they depend heavily on echo-ranging to detect submarines. In fact, surface escorts echo-range continuously. But submarines hardly ever echo-range, because a submarine has to keep its location secret from the enemy. Continuous pinging would be a dead giveaway.

When the submarine conning officer needs a sonar range, he allows the operator only a single ping. For the submarine's purpose a successful single ping range is sufficient -- and it's fairly safe.

Version 1.11, 19 Oct 07

7
STANDING A SONAR WATCH



When a submarine is running submerged, normally two men are on sonar watch. One is on the JP in the forward torpedo room. The other is at the WCA stack in the conning tower. The conning officer is at the periscope.

Before taking over, get information

When you are about to go on watch, it is important for you to have a clear picture of all essential conditions. Take the time necessary to find out all the things you should know.

About sound conditions. The communication officer can tell you about sound conditions. He gets the information from the bathythermograph, an instrument which tells how water temperature varies with depth. Particularly you will want to know what maximum echo-range can be expected, if you are ordered to get a single ping echo-range.

your submarine, the depth of the water, and the bearing of the nearest land.

About the previous watch. From the sonar operator you relieve, obtain a concise account of everything that occurred while he was on duty. This includes: any targets picked up and their bearings, the bearings of any other noises (fish, surf, etc.), and any

About your submarine. From your quartermaster you can learn the speed, course, position, and depth of telltale noises from aboard your own submarine.

Upon taking over the watch

1. Report. As soon as you take over, report: "JK (or JP or QB) operator relieved. Smith has the watch."

2. Check settings. Take nothing for granted. Check every setting on the gear. If you are operating JP, be sure to magnetize the hydrophone.

3. Start the search. Unless you receive specific orders to search a particular area, go through the routine search plan for the gear you are working on.

If the submarine surfaces

When the submarine is preparing to surface, you will have to search carefully all the way around to make sure everything is clear. After surfacing, you may be ordered to secure your gear.

BE ALERT!

Standing a routine sonar watch is a most difficult job. Most of the time nothing happens. You search and search, but hear nothing except sounds from your own ship or possibly from fish. You get weary. The temptation is to go through the motions and let your mind wander off to other things. But you must keep your mind on the job. You must be alert. You are the ears of the ship. Your skipper and your shipmates depend on you to do the listening for all of them when you are on sonar watch.

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8
CORRECT REPORTING

Importance

The sonar operator gets a lot of important information from his gear, but it is useless unless he reports it properly. In fact, experience proves that attacks have been hindered by the inability of sonar operators to report clearly. Every bit of information should be reported at once. If you are not sure of your data, report anyway and say that you are uncertain. The conning officer needs correct data, it is true. But he must have all information as soon as sonar gets it.

Need for standard forms

As soon as a contact is made and battle stations sounded, the captain himself becomes the conning officer. During the exciting minutes that follow, the captain will be giving orders to many different stations on the submarine. He will also be receiving reports from various sources - coming in one after another.

During an attack communication lines become heavily burdened. The conning officer cannot afford to waste precious seconds trying to figure out the meaning of your own particular brand of wording. Therefore, to save his time and to prevent tragic mistakes, you must learn to use simple, standard forms of phraseology for all reports.

Pronunciation of numerals

Since your reports will usually include numbers, it is extremely important that you learn a standard pronunciation for the numerals. At first, the exaggerated pronunciations shown in the box at the right may seem strange, but there is a logical reason for every one of them. For instance, the usual "nine" may be confused with "five," but "niner" doesn't sound at all like "fi-yiv." Drill yourself in these pronunciations until you use them automatically.

Call letters in orders and reports

In giving orders, the conning officer avoids confusion by addressing each sonar operator according to the gear he is on. For example, if you happen to be stationed at the QB gear he will call you "QB." The same goes for JP. However, if you are on the JK/QC gear, he will call you simply "JK" -even if you happen to be using the QC side at the moment. In acknowledging orders and in giving reports, you always start with your call letters. Then the conning officer will know instantly what gear the information is coming from.

Bearings and turn counts

Always report a bearing or turn count as three separate numerals. If necessary, add zeroes at the beginning. For example:

"QB, bearing ze-ro ze-ro six."

"JP, turn count is ze-ro eight fo-wer."

Unless specifically ordered to do otherwise, you will always report relative bearings. Therefore you leave out the word "relative" from such bearing reports. But if you are instructed to give true bearings, you must add the word "true" after the numerals. For example: "JK, bearing one two nines, TRUE."

Ranges

In reporting a range, use "oh" and "double oh", instead of zero and zero zero. For example:

"QB, range one thuh-see double oh."

"QB, range two oh double oh."

Brevity

In giving reports, you will leave out the usual courtesies such as "sir," "please," "thank you," etc. These expressions are good manners, but they are pure waste when every word should give information. Stick to the simple, standard forms- using the fewest words possible.

Insuring accuracy

If the conning officer cannot understand you, or if you misunderstand him, the consequences may be serious. Therefore, it is important for you know by heart, and practice constantly, the following standard procedure

1. Repeat every order word-for-word as soon as you receive it.

For example:

Order: "JP, make a rapid search."
You say: "JP, make a rapid search."

2. If you do not understand every word of an order, say "Repeat." For example:

Order: "JP, pick up target bearing ugg ugg ugg"
You say; "Repeat."
Repeated order: "JP, pick up target bearing two thuh-ree ze-ro."

3. If you make a mistake in your report, say "Belay that," and then give the corrected message. For example:

"JP, bearing one two niner. Belay that. JP, bearing one one niner."

4. Listen while the man at the other end repeats your report. If he makes a mistake, say "Belay that" then repeat the correct information. For example:

Your report: "JK, bearing thuh-ree fo-wer fi-yiv."
Repeated as "JK, bearing, two fo-wer fi-yiv."
You say: "Belay that. JK, bearing thuh-ree fo-wer fi-yiv."

Typical orders

The examples below are typical of the kind of orders you are likely to receive:

"JP, monitor ship's noise."
"JK, pick up target bearing one two ze-ro."
"QB, report bearings every two degrees."
"JP, give me a mark on bearing two one fo-wer."
"QB, shift to fast screws, bearing ze-ro eight one."

Typical reports

Study the examples of reports given below. Model your reports after these:

"JP, sound conditions poor."
"QB, contact echo-ranging. Long scale."
"JP, target bearing one six ze-ro going down starboard side."
"JP, lost contact. Last bearing was two thuh-ree fi-yiv."
"QB, fast screws crossing target."
"QB, torpedoes running at thuh-ree fo-wer fi-yiv."
"JP, high noise level, bearing ze-ro eight fi-yiv. Sounds like generator."

Of course, a sample of every possible report cannot be given here, but you can get the general idea. Every report is given in the

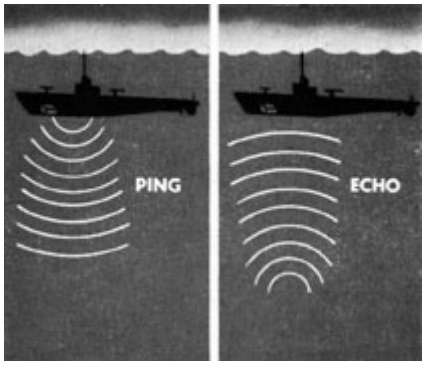
minimum of necessary words, using standard forms whenever possible.

Reports must be understood

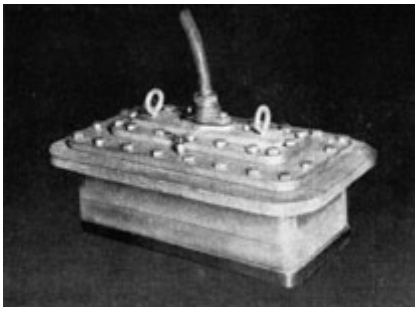
Finally, you must learn to speak clearly enough and slowly enough to be easily understood. Also, make your voice loud enough to be heard-with out unnecessary shouting.

Keep this in mind: All the finest information your sonar gear can give will do no good unless you report it in a clear and understandable manner.

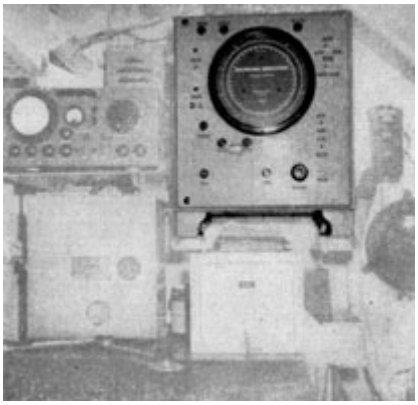
9
ECHO-SOUNDING



The depth of enemy waters in which our submarines patrol has been fairly well charted. Nevertheless, it will often be necessary to determine accurately how deep the water is beneath your keel. This is done on the NM gear by echo-sounding, which is merely echo-ranging with the ocean bottom as the reflecting surface. Instead of sending signals straight out, the NM projector sends them straight down.



The NM Projector looks some thing like a small steel coffin. It is bolted flush with the bottom of the submarine in the forward trim tank. The NM projector gets the current needed to send out pings from the same driver that is used with the. QC system.



The NM Fathometer. From the projector, a cable runs up to the depth-sounding indicator, which is located in the control room. This is called a fathometer, because it is marked off in fathoms instead of yards. It is practically the same as the range indicator used in echo ranging. A receiver-amplifier is in side the lower part of the unit.

Set the remaining switches according to the table below:

Approx. depth of water	Visual-audible switch	Signal interval switch	Shoal-deep switch
Less than 300 fathoms	Visual	Standard	Shoal
Between 300 and 700 fathoms	Visual	Alternate	Shoal
Between 700 and 1800 fathoms	Audible	Standard	Deep
More than 1800 fathoms	Audible	Alternate	Deep

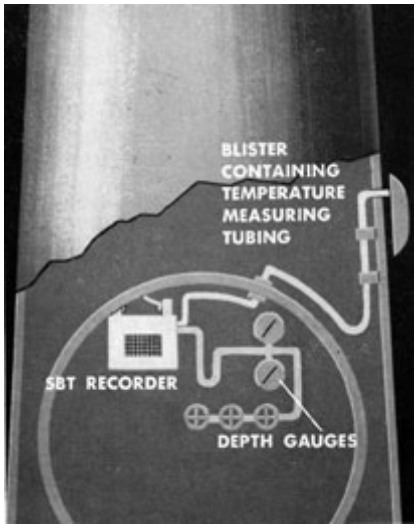
Important: Echo-sounding pings are likely to be picked up by the enemy.

Do not take unnecessary risks. Return the signal interval switch to its center position as soon as the depth has been obtained.

10
THE SBT AND THE TDC

What the SBT is

SBT stands for submarine bathythermograph, which is a device for recording the variation of temperature with depth. The recording unit hangs from the bulkhead of the control room near the ladder leading to the conning tower. As the submarine changes depth, the bathythermograph traces on a smoked card the curve that represents the thermal gradient of the water.



Reading the SBT records

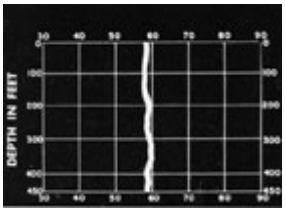
1. If, during a dive, the temperature of the water increases with depth, the chart records a positive thermal gradient.

2. If the temperature decreases with depth, the curve shows a negative thermal gradient.

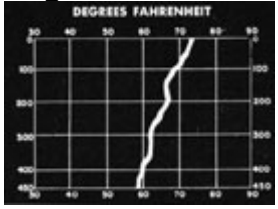
3. If the temperature remains the same with change in depth, the curve shows you are in isothermal water. Isothermal means uniform temperature.

In many cases, the chart may reveal a combination of two or more of these conditions at different levels.

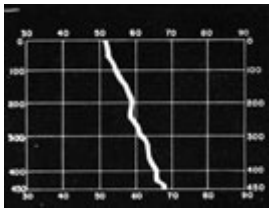
Isothermal



Negative Gradient



Positive Gradient



The value of SBT data to the sonar operator

Although the sonar operator may not read the SBT charts himself, he can get their information from the communication officer. As you already know, water temperature conditions affect the efficiency of sonar listening and echo-ranging. Here are some of the points you can learn from SBT data:

1. You can have some idea how safe your boat is from detection by enemy listening and echo-ranging. For instance, if it is below a layer of sharp temperature gradient (a thermocline), there is less danger of enemy sonar contact.

2. You can judge whether conditions are good or bad for your own listening. Isothermal water is best for listening. Sharp negative gradients are likely to be bad.

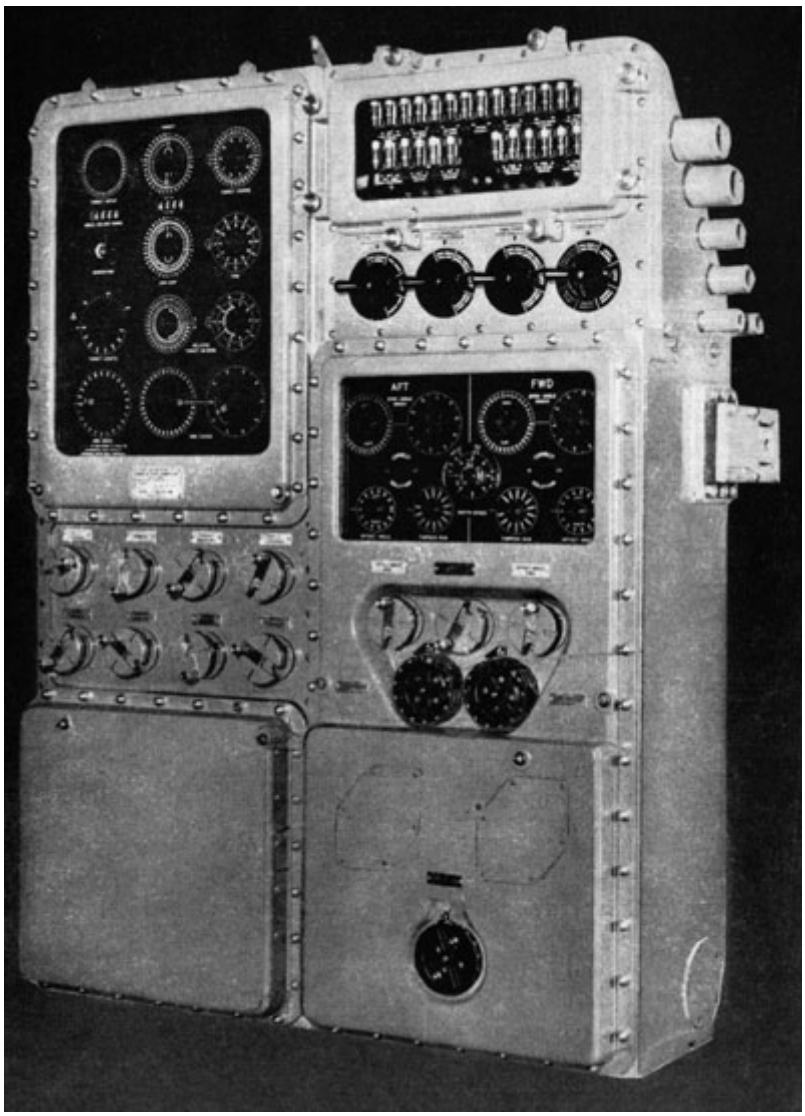
3. You can estimate the chances of getting a single-ping echo-range on an enemy target. Again, isothermal water is good; sharp gradients bad.

What the TDC is

TDC stands for torpedo data computer. It is located in the conning tower usually close to the WCA sonar stack. As shown in the photograph on the opposite page, it has many dials. Six of these dials show six main types of data: own ship's course, own ship's speed, target's course, target's speed, target's range, and target's bearings. The TDC takes in all these pieces of data and shows on its face a solution, in terms of relative bearings. Since some of the dial settings can be only approximate (like target's course and target's speed), the TDC operator checks the TDC solution with the bearings reported by sonar. As long as the sonar bearings and the bearings of the TDC solution agree, he assumes that his other settings are correct. But as soon as they begin to differ, he tries changing the settings on some of his dials, until the two bearings agree again.

If it will help any, you may think of the TDC as an oversized cash register. The sum of the various bits of information pops up on the front panel. If the sum proves incorrect (does not check with sonar bearings), then one or more of the figures used in the computing must be inaccurate. The TDC officer then changes the settings he judges are incorrect, thereby changing the solution. An accurate solution gives the correct data needed for firing. So upon the accuracy of the TDC depends the entire success of the torpedo attack.

General view of the TDC



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The value of the sonar operator to the TDC

By this time it should be apparent why the sonar operator is so important to the TDC. The essential information for TDC comes from various sources:

1. Own ship's course is registered AUTOMATICALLY from the master gyrocompass in the control room.

2. Own ship's speed is also fed AUTOMATICALLY, from the submarine's "log" (actually a speedometer at the keel).

3. Target's course is either estimated by PERISCOPE observation of the angle at which the target ship is traveling, or by plotting from other data. Since this information is only approximate, it is modified as the problem progresses.

4. Target's speed is estimated principally from the turn count obtained by the SONAR operator, or from the periscope identification of the target. This information also is approximate. Therefore, it too is corrected as the problem demands.

5. Target's range can be accurately determined by SONAR single-ping echo-ranging. However, this is used only to supplement estimates from periscope observation,

6. Target's relative bearings can be determined spottily by brief periscope observation. But for a continuous flow of relative bearings, the TDC operator depends on SONAR.

This is why the sonar operator must give bearings continuously after contact. If he fails to do so, TDC operations are seriously handicapped.

A continuous flow of accurate sonar bearings is important for TDC operation and for a successful torpedo attack.

APPENDIX

Definitions relating to sound and sonar gear

Absorption. The loss of energy by a sound wave when it strikes an obstacle which does not reflect it completely.

Alternating current (A C). Electric current which flows first in one direction and then in the other.

Amplifier. A device which builds up a weak electric current into a stronger one.

Amplitude. The maximum extent of a vibrating movement. With sound, the greater the amplitude, the louder the sound.

Attenuation. The weakening of a sound wave as it travels, caused by losses due to friction, absorption, and scattering.

Audio frequency. Another-term for sonic frequency; that is, below 15,000 cycles per second. Compare Radio frequency.

Audio-frequency-amplifier. An amplifier for use with alternating currents of frequencies less than 15,000 cycles per second.

Background noise. Noise that tends to mask the sounds you want to hear. Chiefly water noise and noise from the receiver itself.

Band filter. An audio filter which suppresses all frequencies except those between a given high and low limit. For example, the band

Cycle. A complete sound wave compression-plus-rarefaction.

Decibel. A unit of measurement of intensity of sounds.

Detector. Generally, anything that enables sound to be heard; e.g. the ear. Specifically, in the receiver-amplifier, the detector mixes two supersonic frequencies to give a frequency that can be heard. Also called a "mixer."

Diffraction. The tendency of sound waves to bend around an obstacle in their path and meet somewhere beyond. This accounts for your being able to hear sounds around a corner. (Do not confuse with "refraction.")

Direct current (DC). Electric current that flows continuously in the same direction. A storage battery gives direct current.

Driver. An electrical device used to send a burst of supersonic sound (ping) into the water by means of the projector. In the WCA gear, there are a QB and a QC driver.

Frequency. Number of cycles per second.

Gyrocompass repeater. A device which repeats the movement of the master gyrocompass. The inner dial on the bearing indicator is a gyrocompass repeater dial.

filter on the WCA gear suppresses all frequencies below 600 cycles and above 1,000 cycles.

Beam. A cone of sound waves, such as is used in echo-ranging. Normally, a beam can be obtained only by using supersonic frequencies.

Beat frequency. The frequency obtained by mixing two different frequencies. For example, by mixing 60,800 and 60,000 cycles, we obtain a beat frequency equal to their difference of 800 cycles. This is called heterodyning.

Cavitation. The formation of a series of vacuums when propellers are turning so rapidly that the water does not flow in immediately as the blade passes through. Propeller noise is greatly increased when cavitation occurs.

Compression. The part of a sound wave where the particles are packed together more closely than normal.

The main gyrocompass on a submarine is in the control room.

Heterodyning. The mixing of two frequencies to obtain the beat frequency, which is the difference between them.

Homogeneous water. Water in which the temperature does not change with depth.

Hydrophone. Any device for picking up sound waves from water. It is called a projector only when it also sends sounds out into the water.

Intermediate frequency (IF). The frequency into which the energy entering the superheterodyne receiver is converted in the intermediate stage. In WCA gear, this is 60 kilocycles.

Isothermal. Uniform in temperature. Homogeneous water is isothermal.

Kilocycle (kc). One thousand cycles.

Magnetostriction. Change in size of a metal tube when subjected to an electric current. This principle is used in the JP hydrophone and in the QC and NM projectors.

Modulator. A device which causes a sound to change in pitch continuously. Sometimes used by surface ships in echo-ranging, when an echo is difficult to distinguish.

Reverberations. The multiple echoes reflected from the surface, bottom, and many small irregularities in the water. In echo ranging, distinguished from the echo, which comes from the target.

Salinity. The saltiness of water. Normal salinity of sea water is 35 parts of salt per thousand.

Scattering. The loss of energy by a sound wave caused by its striking

Negative thermal gradient. Decrease in temperature of water with depth.

Noise level. The volume of background noise heard in the headphones or on the loudspeaker.

Oscillator. A device that produces an alternating current at a particular frequency.

Piezoelectric effect. The development of an electric current when a Rochelle salt crystal changes in size. This principle is used in JK and QB projectors. Compare Magnetostriction.

Positive thermal gradient. Increase in temperature of water with depth.

Projector. The hydrophone portion of QC, QB, and NM gear. Although called a "projector," in submarines it is principally used to pick up sounds. In echo-ranging, it projects the ping into the water.

Quick beating. Bearing of the maximum loudness in sweeping across the target. Also called "Maximum bearing."

Radio frequency. Frequency above 15,000 cycles per second, Compare Audio frequency.
Radio-frequency amplifier. An amplifier for use with alternating currents of frequencies higher than 15,000 per second.

Range rate. The rate in knots at which a target's range is changing. Useful in determining the speed of the target.

such irregularities in the water as seaweed, fish, and en trapped air bubbles.

Screen. The antisubmarine escort craft which are protecting a convoy.

Sonic frequencies. Frequencies less than 15,000 cycles per second.

Sound shadow. The region beyond an obstruction where a sound is not heard. See Diffraction.

Split bearing. A bearing obtained by computing the middle point between where the signal comes in and where it goes out in sweeping across the target. Split bearings are used only when quick bearing cannot be obtained.

Sweeping. Turning the projector or hydrophone so that it goes through the entire arc of the target's propeller sounds.

TDC. The Torpedo Data Computer-a device in the conning tower which figures out the correct firing data, using the facts of bearings, ranges, course, and speed.

Transducer. The technical term for what is generally called a "projector." A transducer operates both as a hydrophone (picking up sound vibrations and converting them into electric current pulses) - and as a projector (transforming electric current pulses into sound vibrations and projecting them into the water).

Vibration. A continuous back - and - forth movement, producing sound waves in the medium.

Wake. The ribbon of churned-up water astern of a moving ship or

Rarefaction. The part of a sound wave where the particles are thinned out to less than normal density.

Resonance. The tendency of an object or an electrical circuit to respond well to a particular frequency, but poorly to other frequencies.

submarine. It consists of small currents, eddies and entrapped air bubbles.

Wave length. The distance from a given point on one compression to the corresponding point of the next compression of a sound wave.

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