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Section 1. Study of Vibrations and Waves.

Sound may be difined as the sensation resulting from the action of the external stimulus on the sensitive nerve apparatus of the ear.

Sound may also be defined as a disturbance in a medium consisting of alternate regions of condensations and rarefactions.

SOURCE OF SOUND. An investigation of various types of sound producing apparatus shows that emitted sound arises from some vibrating body. The wall of a bell or the diaphragm of a megaphone or oscillator will be found to be in rapid vibration when emitting sound. More generally it will be found that any body will emit sound if it be caused to vibrate with sufficient force and rapidity.

MEDIUM IN WHICH SOUND TRAVELS. Sound requires some ponderable medium as air or water for its propagation. This may be demonstrated by placing an electric bell under the receiver of an air pump. Sound will diminish as air is removed and increase as air is restored, From this we can conclude that not only is the presence of air necessary for the transmission of the sound, but that its intensity or loudness depends upon the amount or density of the air in the pump.

WATER WAVE ANALOGY. Condensations and rarefactions of sound waves are exactly analogous to the familiar crests and troughs of water waves. Thus the wave length of such a series of waves as that shown in figure 3 is defined as the distance between two crests (bf) or the distance dh, or ae, or og, or mn between any two points which are in the same conditon or phase of the disturbance. The crests, that is, the shaded parts, which are above the natural level of the water, correspond exactly to the condensation of sound waves, that is, to the portions of air which are above the natural density. The troughs that is, the dotted portions, correspond to the rarefactions of sound waves, that is, the portions of air which are below the natural density. But while the water waves are like heat, light and electric waves, transverse to the direction of propagation, in sound waves the particles move back and forth in the line of propagation of the wave.

Water waves are called transverse waves, while sound waves are called longitudinal waves.

We find that the velocity V of sound was equal to the square root of the elasticity E divided by the density D of the medium. For our purpose we are most interested in the velocity of sound in water. It enters essentially into the construction of acoustical instruments and in the design of the retardation values of the recurrent sections of electrical compensators. We must therefore have an exact knowledge of the velocity of sound in water to understand the theory of any sound apparatus.

The velocity of sound in water is about 1,590 yards per second at a temperature of 40 degrees Fahrenheit and about 1,630 yards at a temperature of 62 degrees Fahrenheit. For use in design of most of our sound apparatus the value of 1,600 yards per second was used as an average value.

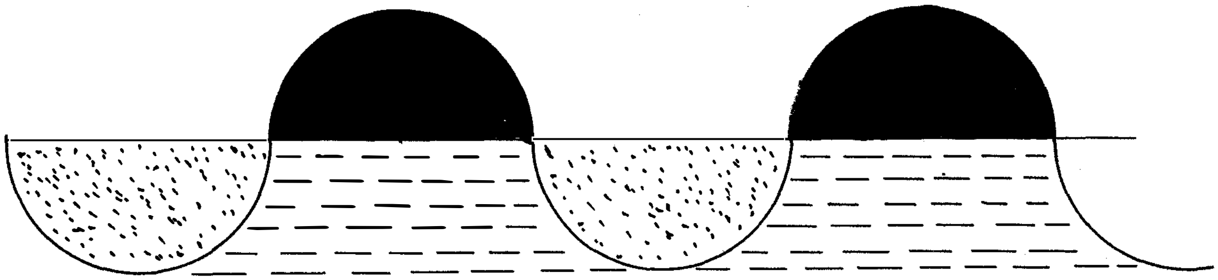


Fig. 3:- Anology of water waves to the sine wave generally used to illustrate the compressions and rarefactions of sound waves.

Effect of Temperature upon the Velocity of Sound.

The speed of sound in air and water and in fact all medii is found to increase with an increase in temperature.

If the pressure is changed without a change in temperature, the density is proportional to the pressure change; that is, $\frac{P}{D}$ equals constant. Hence the velocity of sound is wholly in- dependent of pressure.

Ratio of velocity of sound in water to velocity of sound in air. In studying the theory of design of acoustical instruments it is important to know the ratio of the velocity of sound in air to the velocity in water. It has been assumed in the construction of such instruments that the ratio 0.23 is suitable for average conditions.

Characteristics of Sound:- All sound may be divided roughly into two classes, namely, noises and musical sounds. Noise is a sound resulting from irregular and practically unanalyzable vibrations.

Musical tones are distinguished by:-

(a) Their force, intensity, or loudness, determined by the amplitude and by the frequency of the vibration.
(b) Their pitch, determined by the frequency of the vibration.
(c) Their quality, determined by the harmonics and overtones present.

The extreme minuteness of a motion which may be perceived as sound makes it evident why sound may be detected at such great ranges in water.

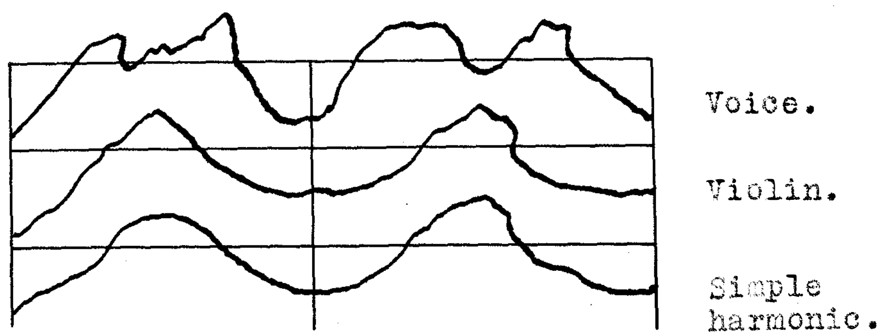
In case of strictly spherical waves spreading radially from a point of source the intensity will vary inversely as the square of the distance.

PITCH:- The pitch of a sound depends on the frequency of the vibrations in the sound wave. We have already seen that there is a simple relation between frequency and wave length in a medium; they are inversely proportional; that is, the longer the wave the less the frequency. Hence we may also say that the pitch of a sound depends on the length of a sound wave. It must not be concluded that a regular succession of sound waves produce the sensation of sound, no matter what the frequency. To produce sound, the frequency or pitch must not be less than 30 per second nor more than 30,000 per second. The upper limits of frequency is different for different people and is lowered by age and by disease of the ear.

Quality.

The quality of a sound depends on the shape of the curve representing the vibration; and the shape of the curve depends solely upon the number and relative strength of its partial simple tones or harmonics and overtones.

If the sound of a bell be analyzed, it will be found that it consists of several sounds of different pitches. The deepest or lowest of these is called the fundamental of the bell and the others are called overtones.



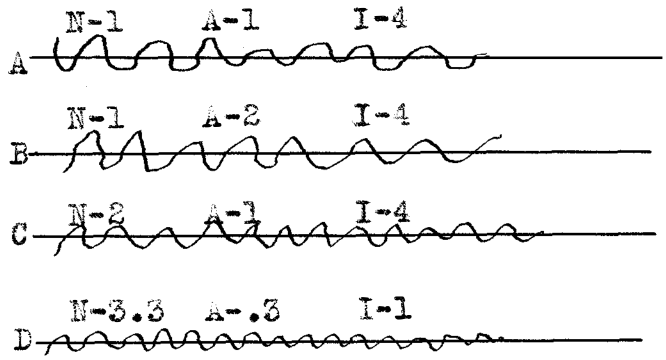
Sketch:- Wave forms of sound having different quality.

When we are given the frequency of a fundamental, we can at once calculate the frequencies of its harmonics by multiplying by 2, 3, 4, etc. Overtones may not be harmonics, and usually refer to some particular instrument.

The sketch above shows three curves of the same amplitude and length, but of different forms. The lower is what we call a simple harmonic curve, and is the form given off by the tuning fork.

The second is more like the wave from a violin string, and the third like the wave from the human voice.

The sketch below represents simple sounds of various degrees of loudness. The curve b has a frequency the same as that of curve a, but its amplitude is twice as great; hence it represents a sound four times as loud. The curve c has an amplitude the same as that of a, but its frequency is twice as great, and again its loudness is four times as much as that of a.



Sketch:- Curves representing simple sounds of various degrees of loudness.

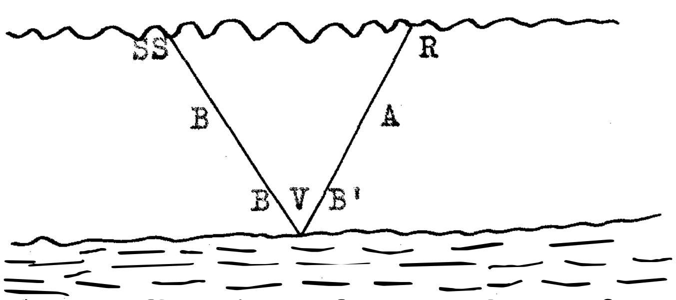
The curve d has a frequency of 3.5 and an amplitude of 0.3, and it represents a loudness equal to that of A. Then the sounds represented by a and d are equal loudness; and those represented by b and c are equal, but four times as loud as a or d.

Most people can distinguish a single sound from a mixture of sounds; thus one may distinguish a single sound from a tuning fork through a mixture of sounds.

A well trained ear is capable of doing more than this. For instance, it can detect the slightest discord when a piano is being played; similarly a trained sound observer can detect the sound of a motor boat through a mixture of subaqueous sound

SOUND WAVE:- A sound wave consists of pulse of condensation followed by a pulse of rarefaction. In a pulse of condensation the particles are more dense than normal and in a pulse of rarefaction the particles are less dense than normal. In a pulse of condensation the particles are always moving in the same direction as the pulse, whereas in a pulse of rarefaction, the motion of the particles is always opposite to the direction of propagation of the pulse.

The angle of reflection is equal to the angle of incidence In the sketch below, let SS represent a sound source, R a receiver and the reflecting surface B'. Let B represent the incident wave and A the reflected wave. Then, according to the above, the angle B that the incident wave makes with the reflecting surface. An echo is the repetition of a sound caused by its reflection from some surface transverse to its line of propagation.

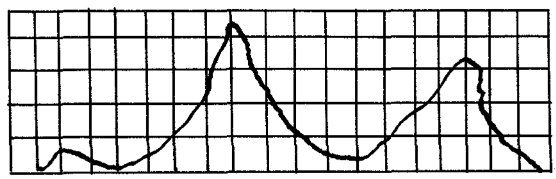


Sketch:- Reflection of a sound ray from the bottom of a body of liquid, ie., the ocean bottom.

Reverberation consists of a prolongation of sound due to repeated reflections from all reflecting surfaces. Almost everone has experienced this phenomenon when walking thry a tunnel.

RESONANCE:- Every vibrating body has one or more natural periods in which it vibrates easily. If a body capable of vibrations is excited by any means whatever and the exciting cause is removed, the body will usually vibrate freely in its natural frequency, or with its free period. If the exciting cause operates in this same frequency, the two are in resonance.

Under these conditions the response of the body receiving the vibration is a maximum . If the exciting cause differs in frequency but slightly from that natural to the other body, there will still be response, but in a lesser degree, that is, the resonance or tuning is not so sharp.



Sketch:-

When the two bodies are quite out of tune there will be very little resonance, and while the second body may still be made to vibrate the response will be small. These conditions are well illustrated by the curves in the above sketch.

When the receiver is out of tune with the transmitter it is often made to vibrate with the transmitter, and it is then said to be forced vibration. In such forced vibration, the two having different natural frequencies, the resulting forced frequency is in general not that natural to either, each drawing the other more or less to a common intermediate frequency. When a receiver or body is exactly in tune with the transmitter that is, when it is in resonance, it may take up the vibrations with great ease and vigor, such a response is often called sympathetic vibration.

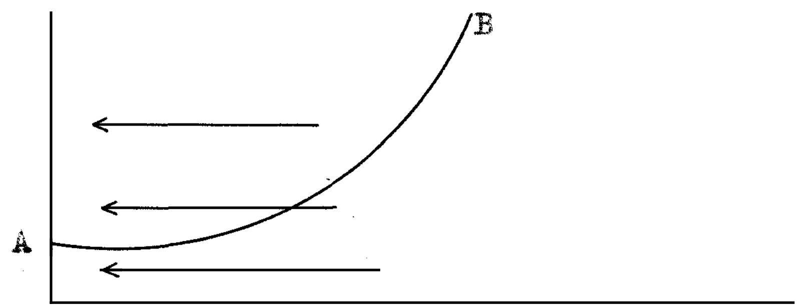
There are two distinct kinds of resonators. One having no definite vibration frequency of its own to tones of any frequency and to combinations of these; it can produce a two gradations of tone quality. The second type of resonator possesses a more or less definite natural frequency, and, because of selective control, it reproduces sounds of particular quality only. Such a resonator will respond not only to tones corresponding to its fundamental, but also to tones in unison with its overtones and harmonics.

Refraction of Sound:- Waves are refracted, or their line of propagation is bent when they pass obliquely from medium into another in which the velocity is different. The chief causes of rarefaction of sounds in air are winds and variations of temperature in the atmosphere. The chief cause of rarefaction of sound in water is variation of temperature. The velocity of wind is less nearer the surface of the earth than higher up, since near the surface it is retarded by the firctional resistance of the surface. When sound is traveling in the same direction as the wind its resultant velocity is greater above than below. Hence, the waves, which always travel at right angles to their fronts, are tilted forward, or the direction of their motion is deflected downward. The opposite effect takes place when the sound is traveling against the wind.

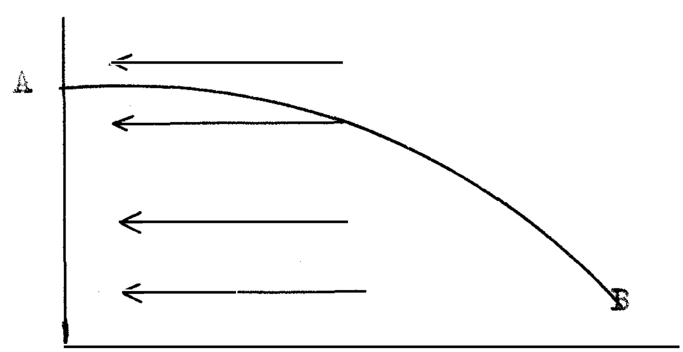
Similar effects result from the temperature being different at different depths of water. (See sketch below). The temperature is lower as the depth increases and the velocity of sound is less there. Thus the waves are reflected downward.

Defraction of sound:- Defraction of sound means the bending of waves around obstacles.

The amount of defraction in any case depends on the linear dimensions of the obstacles compared with the wavelength of the sound. A bank or hill in the ocean casts a fairly definite sound shadow because it is large in comparison with the wavelength. Cases have been known in which houses in the shadow of a hill have suffered no damage from very large sounds, such as the explosion of a powder magazine, while the windows of more distant houses have been broken by the impact of the waves



Sketch:- Bending upward of a sound ray traveling against the wind.



Sketch:- Bending downward of a sound ray traveling with the wind.

Methods used in collecting sound energy.

Forward:- The use of the term receivers in connection with sound is often misleading to the layman in that it is sometimes used in referring to an entire installation, and, at other times to a certain part. Strictly speaking in referring to an assembly of sound-receiving apparatus, the mission of which is to pick up sound energy and, by manipulation, to determine its bearing, the term receiver should be used; and the terms receiving unit or receiving line should be applied to that part or section of the receiver whose function is actually to pick up sound energy and to transmit it to the compensation mechanism of the receiver.

Various Methods used in the Navy are as follows:

Sound transmission thru water:
- Oscillators (KC or KA)
- Submarine Bells.
- Supersonic.

Sound Reception in water:
- Acoustic:-
- S.C. Tube and M.B. Tube.
- M.F. Tube and D.M.F. Tube.
- Model J.E. Receivers.
- Acoustical Electrical, Y-5 Tube.

Electrical:
- Models JA, JB, JC, and JD sound receivers.
- Microphone tank set.
- Navigational six spot.
- Supersonic.

Special Apparatus:
- Sonic range and depth finder.
- Indicating trawl or sweep.
- Magnetic detector.

The presence of a vessel at sea may be detected by the following means:
- (a) Visually.
- (b) By intercepting Radio signals.
- (c) By intercepting sound energy radiating from the vessel.
- (d) By the presence of a magnetic field surrounding that body.
- (e) By means of stray electric currents.
- (f) By acting as a reflecting medium of controlled sound waves.

Reasoning from a military standpoint the above may be divided into main divisions: (1) Means under control of an enemy vessel (2) Means over which the enemy has no control.

Possibility of control by enemy vessel:

Visually:- Control by submerging, producing smoke screen darkness, intercepting sound energy radiating from vessel. Control, by stopping source of sound (engine auxiliary machinery, etc) running at silent speed, Intercepting radio signals. Direct control by stopping source. Launching interfering sound source.

Means over which enemy has no control:

The presence of a magnetic field surrounding the body. Strength of field depends upon the shape and size of vessel, material of hull, and amount of iron in hull; direction of stray currents; By acting as a reflecting medium of controlled sound waves; directly under control of attacking vessel.

Resonance receivers:- Two serious weaknesses of this type of receiver are that they do not reproduce quality faithfully, therefore all sounds sound alike and it is difficult to distinguish one vessel from another. They also do not reproduce phase faithfully.

The use of non-resonant receivers by the Navy is considered more selective than the resonant receivers. The non-resonant receivers have a natural period above or below the loudest signals heard. Shape of the intensity curve is flat or should be

Types of receivers:- Six types of sound receivers have been developed for sound work, (a) Acoustic, (b) Microphone, (c) Piezo electric.

The acoustic receiver is a water-tight chamber and is connected by a tube to the ears of the operator. Pure gum rubber was found to be the best suited in the construction of such a receiver.

The receiving capabilities of the above receiver depends on the area, shape of receivers, diameter, ratio of length to diameter, and also the thickness of the walls.

Thomas Edison devised an instrument which, instead of generating the undulatory current, depended on the action of causing variation in the length of a current generated by some different source. This instrument consisted of a pencil of carbon, bearing against a small platinum disk secured to a diaphragm. As pressure was imposed against the carbon pencil and so caused changes in resistance and current in the circuit.

In 1881 Hunnings made a transmitter but instead of using a carbon pencil as Edison did, used finely granulated carbon granules which were placed between two electrodes. One of the electrodes was connected to a diaphragm and when vibrations were sent against it, it caused the pressure against the carbon granules to vary, thus also varying the flow of current thru it. This works on the same principle as the above transmitter, but, there being more surface on the carbon granules to make contact. more current could be carried without heating.

Pressure type of microphones: These microphones are not good for sound work as they are too sensitive to high frequency and local sounds.

Inertia type microphones: The movable diaphragm is attached to the diaphragm fastened to the housing. The opposite electrode is held in place by the microphone diaphragm, and is not fastened to the housing. The microphone electrode possesses enough inertia to hold this electrode stationary compared to the movable electrode when the frequency of vibration is within the audible.

Piezo-Electric Receivers: Piezo electric effect is an electro-elastic property possessed by certain hemihedral crystals, such as tourmaline and quartz (mineral). When these are subjected to stress in certain regions they liberate electrons of an alternating character (or generate electricity) and of a frequency peculiar to the resonance period of the crystal. As the current output of such a generator is but a few microamperes and the frequency of the current generated is above audible range, it is necessary to heterodyne and amplify the Piezo-Electric current before it passes thru the telephone receivers and is converted to sound energy to the ears of the observers.

-: Practical Sound :-

Binaural Sense:- Binaural sense is the ability of an operator to determine the direction of a sound source by the difference in the time of arrival of the sound at the two ears.

The binaural Center is the spot in the head where a sound from a forward source seems to center. It differs for every person, but should be actually located and taken into consideration when taking bearings.

Sound Receivers in the Navy are non-resonant and function on the difference in hydrostatic pressure between the dense and rare portions of a sound wave.

Microphone circuits:- Microphone circuits containing impedance are used where the total resistance of the line is small in comparison with the resistance of the microphones.

Microphone circuits containing induction coils; repeating coil or transformer are used when the total resistance of the circuit is large compared to the resistance of the microphone. This circuit is used with all electrical compensators.

Frequencies of Microphones now in use:

	CYCLES
Submarine Signal Company - Mica diaphragm, type G....	800
Western Electric-Type H double mica diaphragm........	800
Navy Type 1877-FD-Felt diaphragm....................	300

Theory of action of carbon in a microphone:- Changes in resistance are due to the variation of the contact between the electrodes. To illustrate this: If a ball was pressed against a hard surface covered with graphite, the spot touching the graphite would leave a spot. If the ball was thrown ciolently against the graphite, a larger spot would be produced showing that the ball had slightly flattened by the force of the impact If the two bodies mentioned were electrodes when pressed tightly together there would be a variation of resistance according to the amount of pressure put upon them.

Microphone Packing.

The chief cause of microphone trouble lies in packing of the carbon granules in the microphone button.

This packing is of two kinds:- (1) Electrical and (2) Mechanical.

Electrical packing is the result of the breaking down of lines of force in the compensator circuit. Which is caused by an arc across the battery switch.

In modern electrical compensators, the battery switch is protected by a condenser to take up the arc.

Microphone Readings.

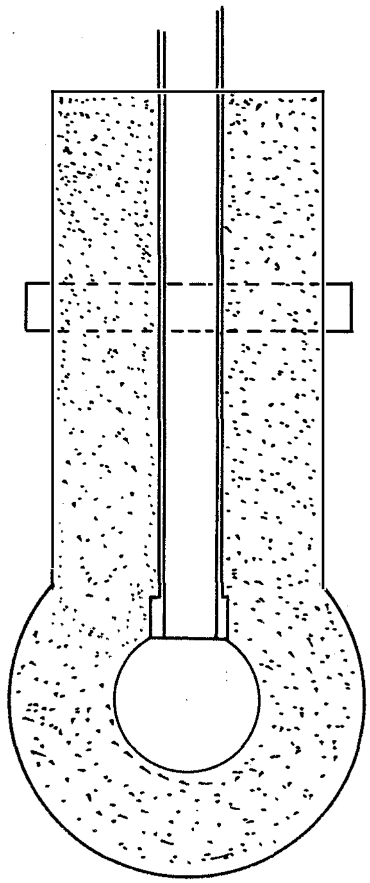
7 to 15	Good.
15 to 25	Fair.
25 to 40	Bad.
Above 40	Pack.

If the very best of results is expected of an oscillator. or compensator, the following should be observed daily:- Make sure sound batteries are fully charged at all times, in the morning put the battery switch on microphones and keep a log of the mike readings every few minutes to notice condition of carbon granules in the mike.

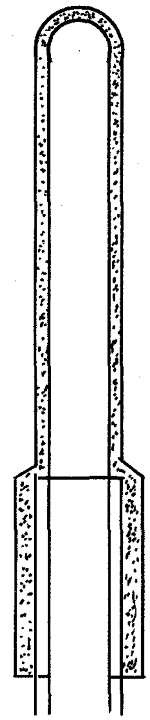
Sound the oscillator for five minutes to notice any possible trouble, take readings of the mike again. The longer juice is kept on the microphones, the better and more sensitive they become, if the microphones are allowed to lay idle for any length of time packing is bound to give trouble.

The average length of time a microphone can be used is about two years and should then be renewed. If a microphone shows a high reading above 40, the only remedy is a new one.

Sound Acoustic Receivers.



Globular acoustic sound-receiving unit designed for use with the type SE 4214 and (Form I)-(SC) rotatable sound receivers.



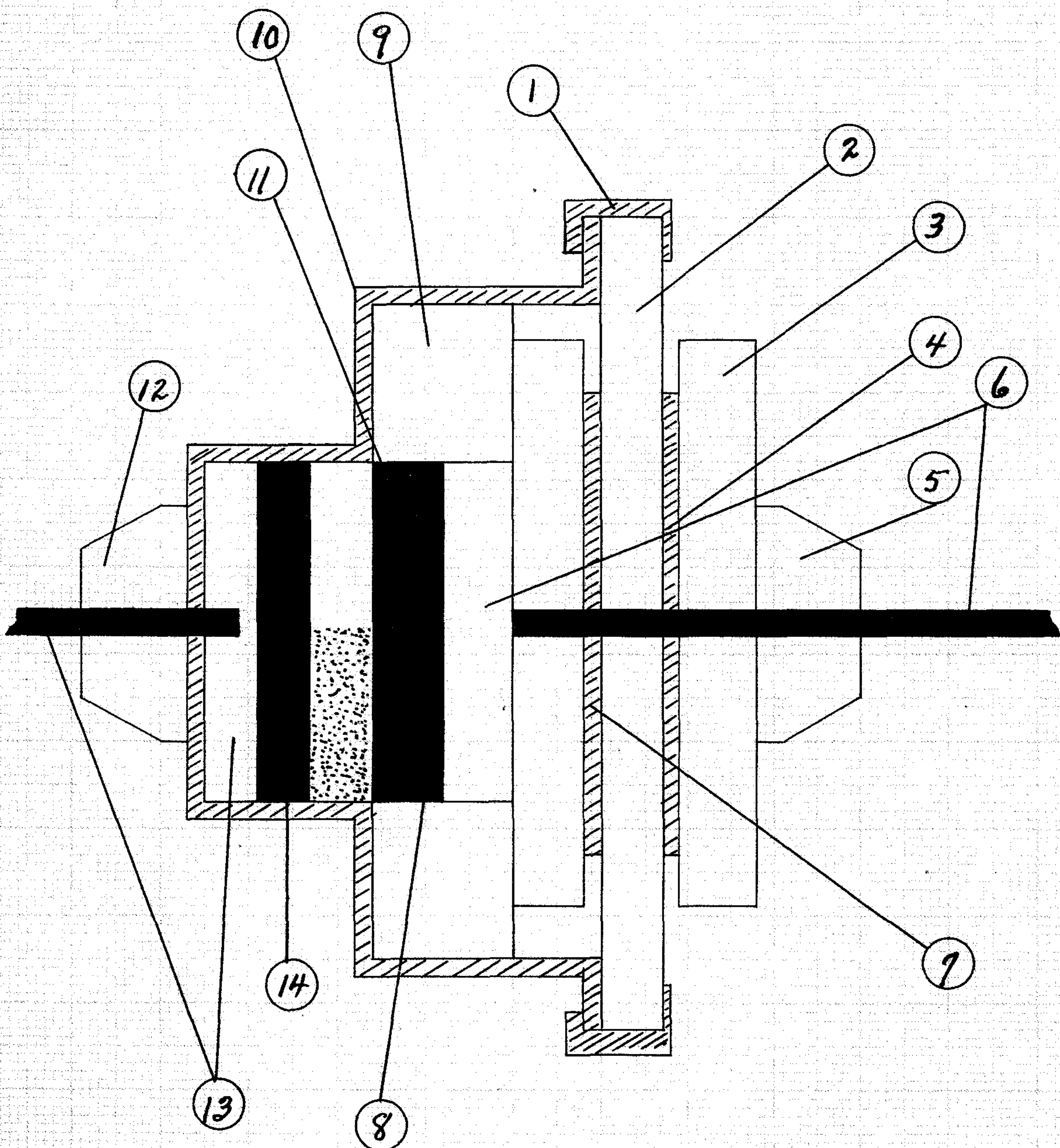
Type SE 4207

Acoustic Sound Receiver Nipple, sectional view. A group of these nipples, (8) constitutes an acoustic unit for the model JE (MV-I6B) Sound Receiver.

Nomenclature For Microphone-Type

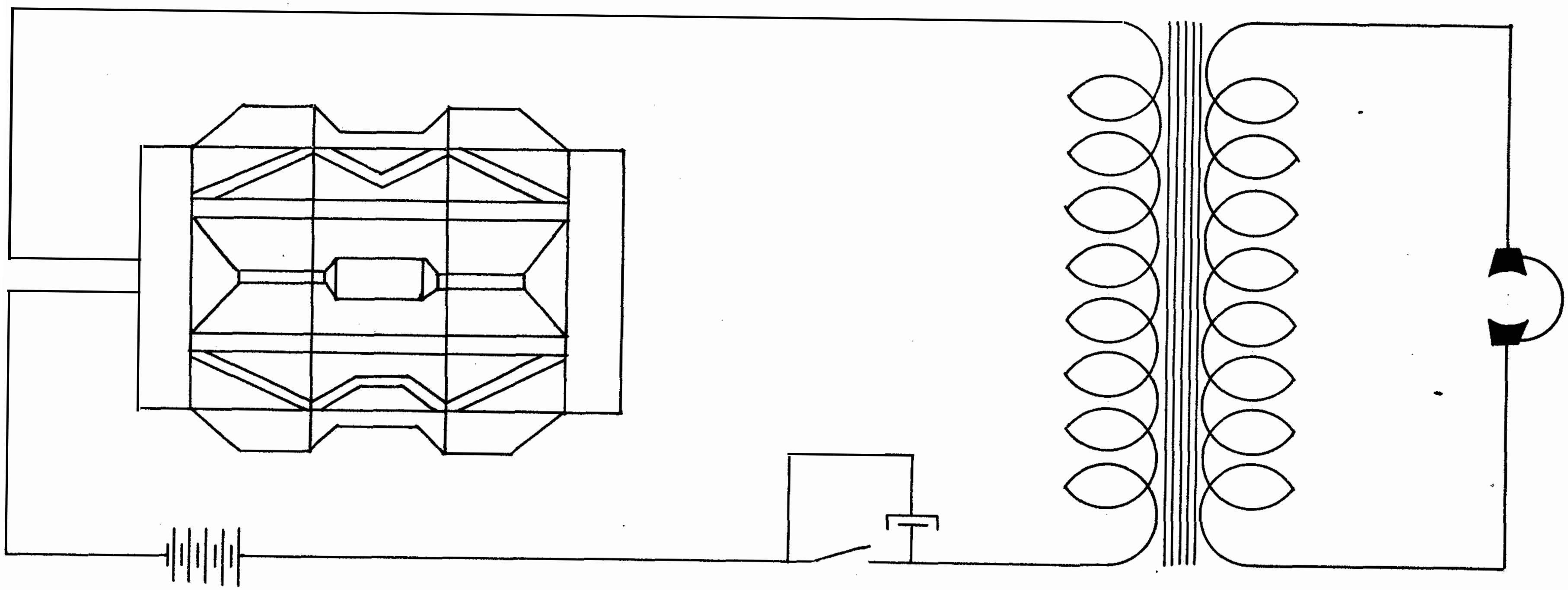
SE-1877-F.D.

No.	Part	Material
1.	Clamping Ring	Aluminum
2.	Microphone Diaphragm	Felt
3.	Diaphragm washer	Brass
4.	Spacing Washer	Aluminum
5.	Assembly Nut	Brass
6.	Threaded Stud Movable Electrode Backing Piece	Brass
7.	Diaphragm Washer	Brass
8.	Granulated Carbon	Carbon
9.	Insulating Washer	Felt
10.	Casing	Aluminum
11.	Inertia Electrode	Carbon
12.	Follower Nut	Brass
13.	Threaded attachment Stud and Electrode Backing Piece	Brass
14.	Movable Electrode	Carbon



MICROPHONE BUTTON TYPE SE 1877-F.D.

(NAVY TYPE)



SCHEMATIC DIAGRAM OF MICROPHONE CIRCUIT CONTAINING INDUCTANCE COIL OR TRANSFORMER.

Sound Screens and Inertia Plates.

A sound screen may be anything that would cast a sound shadow.

The term "Sound Screen" is used to designate any object that would cause a reduction in the intensity of the sound heard in a receiving unit when placed between it and the source of the sound. In other words, a sound screen is anything which produces a sound shadow. The screening effect may be due to either to absorption or to reflection.

Numerous experiments have shown that solid objects such as a plate of iron or steel or lead, are not entirely effective as screens. A plate of lead an inch thick and twelve inches square produces no effect except in the case of extremely high pitch components of the sound, which are slightly increased in intensity on front of it. The plates of an iron vessel, even with the added stiffness and inertia of the frames and bulkheads permit sound waves to pass so freely that sound receivers may be used in the water or oil tanks. The extremely small screening effect observed in such cases is doubtless due to the fact that the thickness of the metal is always small compared to the wave-length of the sound. With sounds whose pitch is above the audible limit so that the wave length in water is only a few inches, the screening effect of such metal plates is undoubtedly great.

If, however, materials are used which modify the sound waves not because of their rigidity and inertia but because of their ability to yield freely to the pressure of the waves, very effective screens are made. A bubble of air or a toy balloon of thin rubber is perhaps the simplest form of illustrating a screen of this type. When sound waves fall upon the balloon or bubble, the surface yields so freely that no appreciable increase in pressure can be produced. In the immediate vicinity of the surface the pressure of the water is unaffected by the sound waves, and a receiver whose action depends upon pressure changes will give no response. Thus air bubbles on the diaphragm of an underwater microphone reduces very greatly the intensity of the sound heard. A toy balloon placed in front of a Fessenden oscillator will greatly reduce its range both as sender and as a receiver.

Screens which possess the property of yielding freely to pressure may be made in a great variety of ways. For example, a thin rubber pad filled with air is a good screen and can be made in any form desired. To make it remains in its shape, and to prevent collapsing, the bag may be loosely filled with felt or some similar material. Spongy rubber makes a good screen and can be used to good advantage providing the little bubbles which give its spongy character are water tight, so that the material cannot get water soaked. Flat air filled boxes with metal walls make screens that are apparently as good as rubber pads, provided the metal is not too thick. It is surprising, however, how thick and heavy the walls may be without seriously affecting the yielding and screening action. The hull of a vessel, even when the plates are as thick as three fourths of an inch, forms a yielding or pressure release surface for sound waves, as is demonstrated by the fact that the intensity of the sound heard in a receiver placed near the hull is greatly reduced. Some reduction in intensity can be noticed when the hull of the receiver is at a distance of 18 inches or more from the receiver.

The SC Sound Receiver.

Type SE-4214

The SC tube is a two unit rotatable receiver, operating on the binaural principle. The natural period is approximately 900 cycles. Therefore above normal range of subaqueous sound.

The tube itself consists of a key shaped arrangement of brass pipes fitted with pure gum rubber acoustic receiving units on the two extreme ends of the "t".

Brass tubes lead from the acoustic receivers thru the leg of the "T", down into the boat.

Directly inside the hull and secured to it is a bronze housing containing ball bearings to permit easy rotation of the device. It also contains a flapper valve, which insures water integrity in case of accident when the tube is not in use.

Directly below the bearing housing is an illuminated dial calibrated in degrees. Also a stop which keeps the SC tube in a fore and aft position when not in use. The pointer is attached directly to SC below the dial and indicates zero degrees, when at a right angle to the center line to the ship. The lower ends of the tubes leading from the acoustic receivers are slightly belled. Upper end of the tubes contained in the handle are slightly tapered.

One necessary precaution when getting the tube ready to take bearings is to make sure that the stethoscopes are of equal length and are pushed on the tubes the same length, thus making sure that the air pass to both ears is equal.

The Type SE 4214 (SC) receiver is of the acoustical rotatable type.

Description:-

This receiver is for submarines only. Riveted to the pressure hull is a filler plate to which is fastened a heavy stuffing body containing the stuffing gland for making the set watertight. This gland contains standard flux packing and a recessed ring filled with graphite grease. This graphite grease is forced into the gland by the means of a forced feed lubricating cup, thus making a lubricated water-tight joint.

Mounted on this heavy stuffing body is a composition outer housing which extends to the super-structure deck. Bolted to the underside of the heavy stuffing body is the supporting bearing frame or spider housing a ball thrust bearing for supporting the sound receiving apparatus proper.

The sound receiving apparatus proper consists of two hollow spherical rubber receivers fixed at the ends of brass tubes. The brass tubes are suitably mounted and protected in a "T" shaped pipe frame which elevates the receivers to a position between fourteen inches and twenty inches above the super-structure deck. The lower end of the vertical column is threaded into the flapper valve body, which in turn is secured to a bearing spindle which freely rotates in the ball thrust bearing.

This vertical column rotates within the heavy stuffing body and outer housing. The receivers and their respective brass tubes are extended beyond the end of the horizontal arm of the "T" shaped arm. These tubes are held central in the frame by means of a rubber packing plug, those at the outer ends of each pipe of the frame being compressed to make a watertight joint. These tubes terminate at the lower end of the vertical column and have ends shamfered on the inside and slightly flared out.

Accurately located on the bearing spindle by means of a key is a pointer, together with a locking pin, by means of which the device may be locked, with the receivers in a fore and aft position.

The dial and illuminating lamps are attached to the underside of the supporting frame and spider.

Inside the valve body is a flapper valve which seats upon a rubber gasket set in the lower bearing spindle and so arranged as to close by gravity when the lower extension column is removed.

A cap having a rubber gasket is provided and screws on to the lower end of the bearing spindle thus making the sound receiver proper water-tight, when the apparatus is not in use and in case of emergency.

The extension or detachable unit consists of a pipe within which are two brass tubes. These tubes are securely held in place by means of a rubber plug at either end. The upper ends of these tubes are shamfered on the outer edge. The lower ends are provided with tips which fit into the rubber ends of the stethoscope tubes.

On the outside of this extension column near the top is a collar and an accurately located key, which are securely fastened to the column. At the lower end of the column is a collar or hub to which are fastened the two handles for rotating the device

Operation:- The following procedure covers the operation of this instrument:

1. Remove the water-tight cap and with short stick make sure that the flapper valve is free to close.

2. Insert the upper end of the detachable extension column into the hole in the bearing spindle, taking care to see that the keyway in the spindle and the key on the column are in line, and push up until the collar on the column sets against the lower end of the bearing spindle. Tighten hand nut.

3. Secure the column in place by means of the hand nut and pull down locking device.

4. Put the stethoscopes in place on the tips at the lower end of the column, taking care to see that the leads are of the same length and are pushed onto the tubes the same amount. If this is not done, incorrect readings will be obtained.

5. Stand facing the column with the pointer indicating 0 degrees on the dial directly above, place the stethoscopes to the ears such that right ear is connected to the right-hand sound tube and receiver and the left ear is connected to the left-hand tube and receiver.

6. Upon listening, if the sound appears to come from the right the set is rotated to the right until the sound seems to shift to the left ear; likewise, if the sound appears to come from the left, the set is rotated to the left until the sound seems to be in the right ear. These swings are repeated graduall decreasing their amount until the sound seems to be directly ahead. The pointer then indicates the direction of the source of sound. If the above instructions are not followed errors of 180 degrees may occur. As a check on the above reading after the direction of the source of sound is found rotate the set to the left 90 degrees. The sound will have moved to the right ear. Still facing the column, the sound will off to the right-hand.

Maintenance:- The apparatus is extremely simple and only requires examination from time to time of the following items:

1. The rubber receivers should be kept as far as possible onto their tubes and the clamp securely tightened, otherwise a leak will occur at this point, which in addition to admitting water is liable if the apparatus is in use at the time, will injure the operators ears.

2. The stuffing gland should be kept well supplied with grease in order to insure easy rotation at all times.

3. The ball bearings should be greased at regular intervals and inspection should be made to see that salt water is not allowed to leak into this bearing and cause erosion.

4. The length of the stethoscope tubes should be kept exactly the same. If there is any difference in length, it will cause an error in observations.

5. The extension column should be examined from time to time to see that it has not become bent, or that the tubes have not shifted their position, otherwise it will be difficult to insert it into the bearing spindle, because the tubes of the lower column will not be in line with the tubes of the upper column.

6. The entire assembly should be examined from time to time to see that there is no water in the pipes or tubes. If there is any water present the sense of direction will be lost.

Notes for dissassembly of permanently installed units:

1. Remove the water tight cap.
2. Remove pointer, complete with locking pin from bearing spindle.
3. Remove dial.
4. Remove bearing support or spider.
5. Remove valve housing complete with bearing spindle from upper vertical column.

6. Release plug packing.
7. Remove upper vertical column from "T".

Note:- During this operation great care should be taken to see that the column slips freely around the lower plug packing, otherwise all tubes will become badly twisted. It is well to insert two short pieces of the rod in the lower end of the vertical sound tubes, and by holding these keep them from rotating.

8. Remove plug packing together with packing washers from the tube end.
9. Unsolder vertical sound tubes at connection sleeve.
10. Cut off lower end of vertical sound tubes and vertical column to such a length so that the receivers are between 14 and 20 inches above superstructure.
11. Rethread lower end of vertical column taking care that new thread fits a standard Briggs guage.

Notes for disassembly of the extensions column:

1. Release plug packings by loosening screws approximately one-third of an inch.
2. Remove sound tubes from housing column.
3. Cut off bottom end of housing column to right length so that handles will be 4½ feet above deck when assembled for operation.
4. Cut off end of sound tubes to suit alteration to housing tube.

Notes for assembly of permanently installed units:

1. Clean and tin about 1 inch of lower end of vertical sound tubes.
2. Solder connection sleeve together with tube end.

Note:- Plug packings should all be coated with soap suds or talcum before proceeding further.

3. Replace upper vertical column and screw hard into "T".

Note:- During this operation care must be taken to see that vertical sound tubes do not turn with the pipe, or become bent or touch the inside of the column. They must remain parallel and in the same plane as horizontal sound tubes.

4. Compress plug packing at lower end by means of the tightening screws.

Note:- Before proceeding further with the reassembly, the upper housing (furnished by installing yard), the top flange, and main stuffing should be in place on the submarine.

5. Assemble unit completed in operations 1,2,3, and 4 into the stuffing body, housing, etc.
6. Assemble valve housing or body (complete with clapper, bearings, spindle, etc) on end of upper vertical column.

Note:- When the pipe thread makes up, the keyway in the bearing spindle must be in the same plane as the vertical sound tubes. If this cannot be done by means of the pipe thread alone it will be necessary to move the bearing spindle on the valve body by taking out the cap screws and moving it ahead or back one hole as necessary. An assembly fixture should be used for accurately checking the alignment.

7. Braze upper vertical column to valve body.
8. Assemble ball thrust bearing support or spider.
9. Assemble bearing support on the main stuffing body with cap screws.
10. Assemble dial complete with lamp brackets on bearing support.
11. Assemble pointer complete with locking pin.
12. Screw on water-tight cap.

Note:- After this assembly with the horizontal column and receivers in a fore and aft position, a check test should be made to see that the pointer indicates either 90° or 270° on dial

Notes on assembly of the extension column:

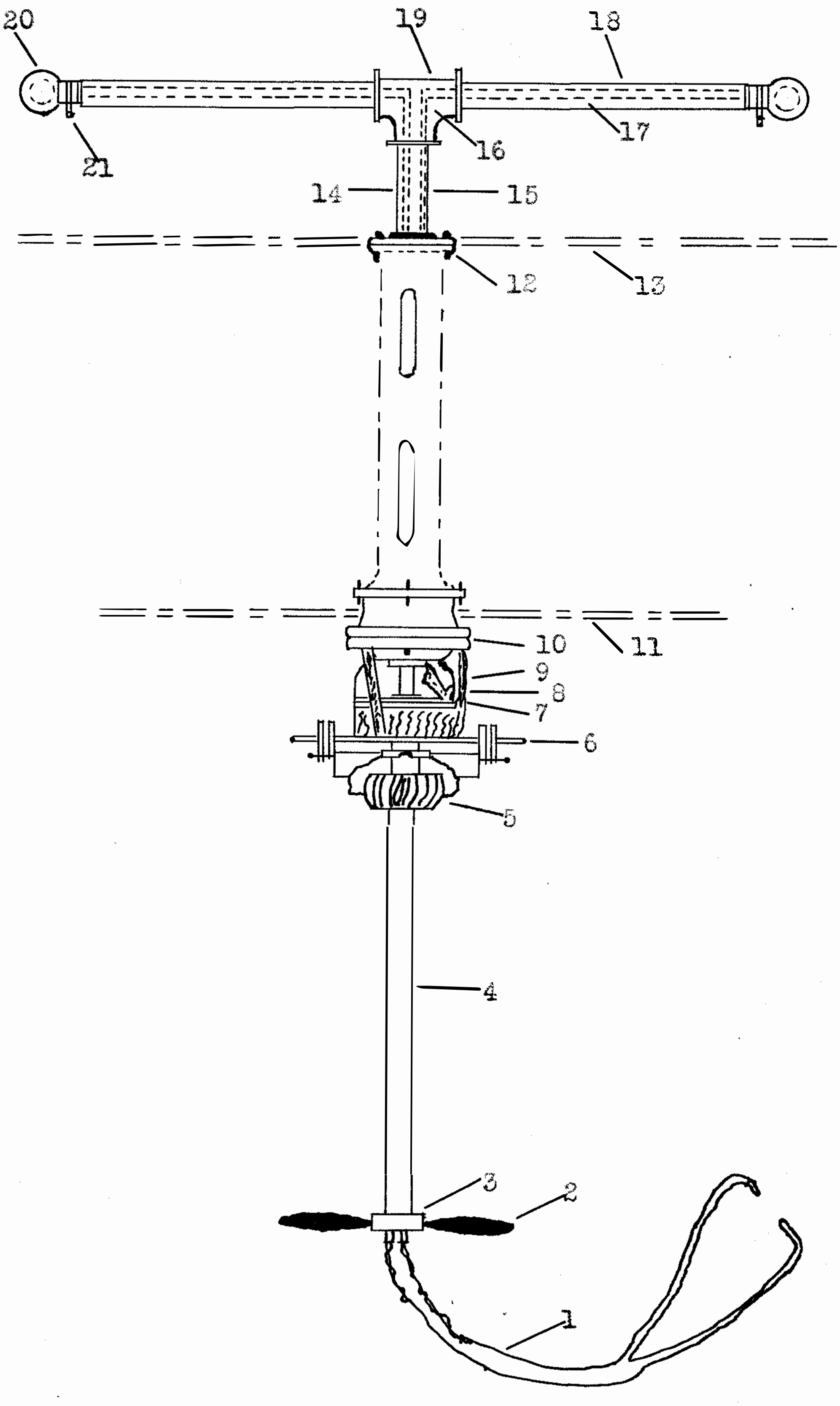
1. Slip hand nut in place on the lower extension column.
2. Weld handle hub to lower vertical column.
3. Put plug packing together with packing washers and tightening screws in places on lower sound tubes.
4. Put assembled sound tubes in place in lower extension column.

Note:- The lower sound tubes should be located straight, parallel and be in the same plane as the key on the outer surface, upper end of the extension column. This condition may be obtained by using "Assembling fixture" which should be left in place until the plug packings are compressed. These lower sound tubes should not touch the extension column pipe.

5. Tighten plug packings with screws.

NOMENCLATURE OF S. C. TUBE.

NO.	PIECE	METAL.
1.	Stethoscope	Rubber and metal earpiece
2.	Handle	Wood.
3.	Handle hub	Steel
4.	Lower vertical housing tube.	Steel or Brass
5.	Handle Nut.	Steel
6.	Azimuth circle, or dial.	Brass
7.	Flapper valve.	Steel
8.	Valve body	Steel
9.	Bearing support	Steel
10.	Stuffing body	Brass
11.	Pressure hull	Steel
12.	Top flange	Brass
13.	Superstructure of Sub.	Wood and steel
14.	Sound lead pipe	Steel
15.	Upper vertical housing tube	Steel
16.	Plug packing	Rubber
17.	Sound lead pipe from mike.	Steel
18.	Horizontal housing pipe	Steel
19.	Housing pipe tee.	Steel
20.	Receiver	Rubber
21.	Steam hose clamp.	Comb.



S. C. Tube, Acoustic Rotatable, two-unit receiver.
Type SE-4214.

The Model JE (MV) Sound Receiver.

Its description, principle of operation, use, care and calibration.

The Model JE (MV) sound receiver is an acoustic multiple unit underwater sound receiver. For purpose of description it is convenient to consider this device as made up of four separate parts, viz the receiver; the blister shaped chamber which encloses the receivers, the connection tubes, and the compensator.

The Receivers:- Each receiver consists of a cluster of eight flexible rubber nipples attached water-tight to the free ends of branching metal tubes. The installation carries 24 such receivers 12 being mounted on each side of the vessel. The 12 receivers of each group are equally spaced along a straight line. The spacing between adjacent receivers is 21 inches. The two lines of receivers occupy symmetrical positions on either side of the vessel. They are placed as far as possible below the water line, near the bow and as near parallel with the keel as the shape of the vessel will permit.

The Blisters:- Each line of receivers is housed beneath a streamed line protecting "Blister" attached to the outside of the ships skin. The blister is made of comparatively thin iron and is reinforced by ribs on the inner side. The blister plate is bolted to heavy iron tapping strips, which in turn are riveted to the hull of the vessel. (The junction between the blister plate and tapping strips carries a packing and thus the blister chamber is made practically water-tight.) The side of the blister chamber next to the hull is lined with heavy metal plates "Inertia Plates" and a sound screen interposes between these plates and the ship's skin. The "Inertia Plates" decrease the absorption of the outside sounds by the ship's hull, thereby increasing the sensitivity of the noises coming from within the vessel and along the skin. The 12 receivers and their connection tubes are held in position by attaching them to inertia plates.

The Connecting Tubes;- The sound responses from each receiver are led into the vessel through seamless steel tubing. The 12 tubes, one for each receiver, enter the vessel through a compound water-tight stuffing box opening through the ships skin from the center of the blister chamber. From here these tubes are carried to the sound room where they connect with the compensator.

Formula for finding the amount of Compensation Necessary.

To find the binaural base line, (B.B.L.) we multiply one half of the number of units times the distance between adjacent units.

B.B.L. x .23 x Cos θ = Retardation in air passage necessary to compensate for sound coming from any angle.

As in the following figure, the sound is coming from an angle of thirty degrees, then the following is an example for finding the different necessary compensation for each stage.

First Stage:- 42 x .23 x .5 = 8.36
B.B.L x .23 = Maximum compensation.
42 x .23 = 9.66
9.66 - 8.36 = 1.30
1.30 / 2 = .65
8.36 / .65 = 9.01 Air inches
needed to compensate on A side in the following figure, .65 Air inches is needed to compensate on other side.

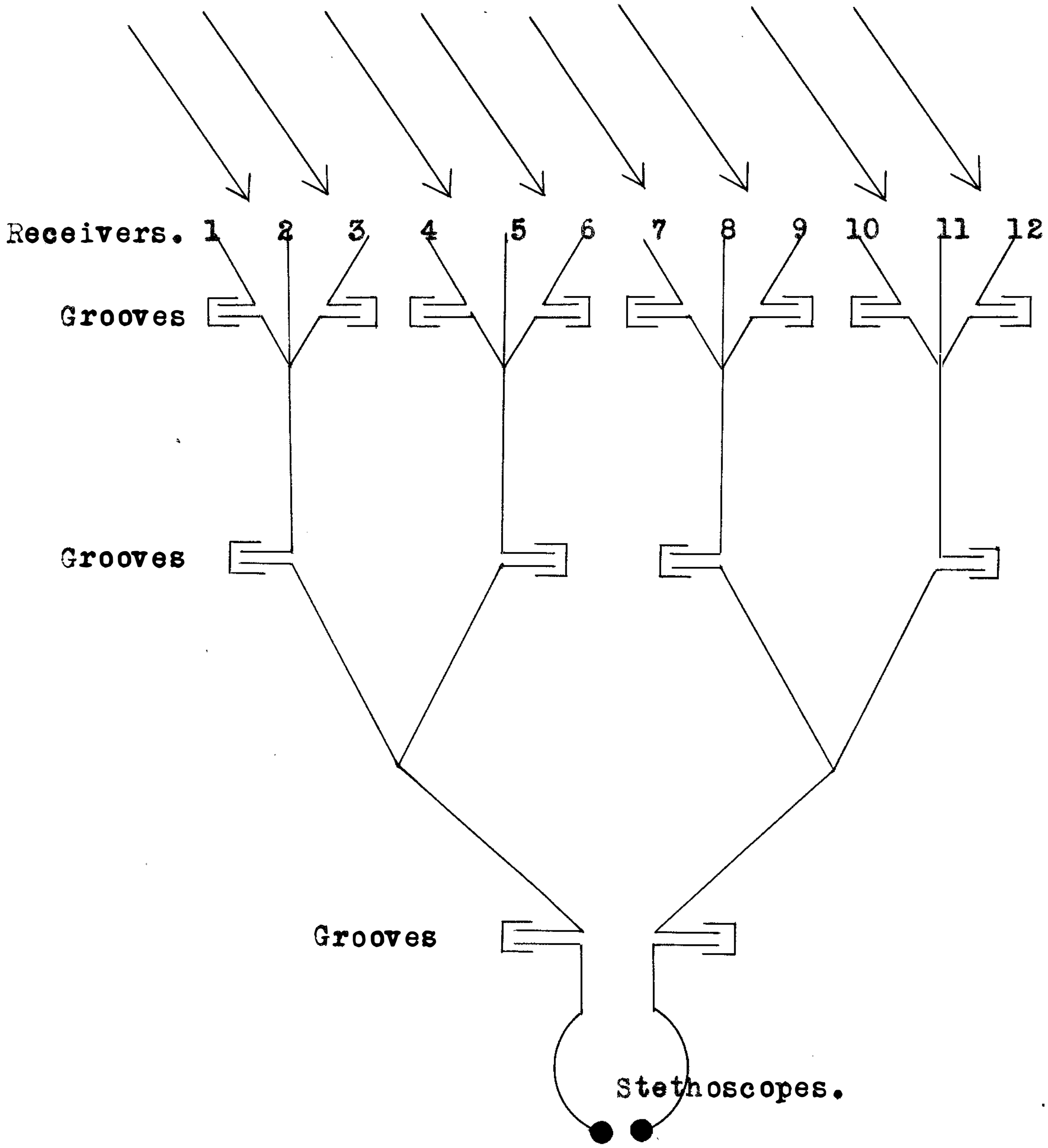
Second Stage:- 63 inches in the B.B.L.
63 x .23 = Maximum compensation
63 x .23 x .86693 = 12.54
14.49 - 12.54 = 1.95
1.95 / 2 = .975
12.54 / .975 = 13.51 Air inches.
needed on A side in the second stage. .975 Air inches needed on the other side.

Third Stage:- 126 inches is the B.B.L.
126 x .23 x .86603 = 25.09
28.98 - 25.09 = 3.89
3.89 / 2 = 1.954
25.09 / 1.945 = 27.035 Air inches.
needed on A side in the third stage. 1.945 Air inches needed on the other side.

This diagram shows theoretically how it is accomplished when a sound is coming from an angle of 30 degrees. Referring back to trigonometry.

C.R.V. means compensation retardation value.

B.B.L. is parallel to keel of ship.



Model JE (MV) receiver with sound approaching at an angle of 30 degrees.

Since the several tubes connecting to the various receivers serve the same purpose as speaking tubes, it is absolutely necessary that they be water-tight. To insure such tightness, all junctions which come in contact with the water are welded. A three-way cock is connected to each receiver tube between the stuffing box and the compensator to facilitate testing for leaks.

The Compensator:- The function of the compensator is to determine the direction of sounds picked up by the receivers. Either a type H or a type K compensator may be used, but the latter is to be preferred. The construction of the type K compensator is such that when the rotating plate carrying two projecting handles A and B (on each side) is turned to the right hand positions, sounds for the twelve starboard receivers is used for receiving. When this plate is rotated to the left hand position, the twelve port receivers are used for receiving. When this plate is rotated to the center position, the six receivers in the center of both the port and starboard lines are used. The three positions are spoken of as the "Starboard", and "Port", and "Forward" positions, respectively. The type H compensator is provided with only the starboard and port positions.

Various grooves, arranged as shown between the different plates of the compensator, constitute an enxtension of the tubes leading from the receivers. These grooves, for the most part are fixed in length; but the effective length of the grooves of the upper plate can be varied. These grooves are stopped by close fitting blocks so arranged that when the plate is rotated by means of the wooden hand rim, the position of the stops in the groove is varied and hence the length of grooves through which the sound travels is varied. The process of varying the tube lengths connecting the receivers and the operators ears is called compensation and any device that accomplishes this is called a compensator.

Principle of Operation:

How the Model JE sound receiver determines Direction:

The principle of operation of the compensator with the twelve receivers:

Distribution of receivers;- The design of both the type H and the type K compensators is such that the "binaural principle " is used for determining a direction. This is accomplished by arranging the connection through the compensator so that half the receivers connect to each ear. The division between the tow ears of the twelve receivers employed in each of the three listening positions is as follows;-

(a) Starboard Position:-
Starboard receivers 1 to 6 Inc. connect to left ear
Starboard receivers 7 to 12 Inc. connect to right.

(b) Port position:-
Port receivers 1 to 6 Inc. connect to left ear.
Port receivers 7 to 12 Inc. connect to right ear.

(c) Forward position:-
Starboard receivers 4 to 9 Inc. connected to left.
Port receivers 4 to 9 Inc. connected to right.

Note:- The receivers are numbered consecutively from the forward end of the lines. Thus, the receivers on the starboard side are referred to as starboard receivers 1 to 12, and those on the port side as port receivers 1 to 12.

How to center sound:- The six tubes connecting with the right ear are shortened and the six connecting with the left ear are lengthened when the compensator plate is rotated to the right and as a result, such a procedure will cause a sound to shift to the operators right because the sound impulses will progressively reaching the right ear earlier and the left later. If the plate is rotated to the left, the opposite effect takes place; the sound shifts towards the operators left. In other words, the sound shifts in the direction that the compensator is moved. If, then, the listener hears a sound at his left, he must turn the compensator to the right to CENTER the sound; if the sound appears to his right, he must turn the compensator to his left. To center any sound, the operator must run the compensator in the direction that he wants the sound to move.

Model JE Sound Receiver:- This receiver not only enables the operator to determine the direction of a sound, but its design is such that the sound is much more intense and clear cut when it is centered than when it is off center. This "FOCUS" effect greatly reduces the intensity of all sounds except those on which the operator is centering and thereby enables him to pick up and follow the propeller sounds of a vessel through a mass of disturbing sounds produced by his own propeller and nearby vessels more successfully than he can with a sound receiver that does not weaken or eliminate the undesirable sounds. The success of this receiver is largely dependent upon the FOCUSING ability, or, what is often called its selectivity.

The focusing ability is due to the fact that it employs several receivers distributed over considerable distance and not bunched together. Under such conditions the time which elapses between the reception of a sound by the various receivers changes and as a result, when the compensator is adjusted so that the sound responses from all the receivers reached the ears simultaneously for some definite directions, the responses from the receivers to the sound from other directions will not reach the ears at the same time but will follow one another by a short interval. The length of this interval depends upon the length of the line of receivers and the spacing of the receivers. Those sounds which come from a direction such that they reach the ears simultaneously will reinforce one another and result in a loud clear-cut response, but sounds from any other direction not only will not perfectly reinforce one another, but will in part destroy another, thereby resulting in a response which is weak or muffled.

Compensation effected by two stages:- The compensators therefore, serves two distinct purposes, namely, to bring a sound into focus and to center the sound in the receivers head. These two results are accomplished in two separate stages of compensation which are termed the focusing and the Binaural stages, respectively. Both stages are affected at the same time by turning the top plate of the compensator except when the compensator is set at the forward position. In this case the focusing stage is affected by turning this plate and the Binaural stage by turning the top plate of the small compensator located between the two stethoscopes leads.

The arrangement inside the compensator is as follows:- Of the twelve paths that pass through the compensating part of the compensator, six are finally united into a single path which eventually terminate in one stethoscope lead, and the other six units finally terminate in the other stethoscope lead. The focusing part of a compensation is effected in the twelve separate paths before they unite into two paths. The binaural part of the compensation is effected in the two paths before they leave the compensator plates.

When the compensator is set at the starboard or port receiving positions, the sound passes directly from the large compensator to the stethoscope leads without passing through the smaller auxiliary compensator on the type K compensator only. This small compensator is then shunted. The grooves beneath the top plate of the main compensator are so ingeniously arranged that both stages of compensation are accomplished when the compensator is set at either of the above named positions.

When the compensator is set at the Forward receiving positions, the compensating paths, which lead from each junction of 6 to the stethoscope leads are shunted out and the sound passes directly from each of these junctions through fixed paths to the small auxiliary compensator where the Binaural stage of the compensation is effected and from thence through the stethoscope leads. It will be shown that this arrangement does not require the operator to operate both compensators when receiving with the compensator set at the Forward position.

Inherent weakness and overcome:- The Model JE (MV) sound receiver determines directions nearly normal to the line of receivers with greatest accuracy and those nearly parallel with the line of receivers with the least accuracy and since the line of receivers is nearly parallel with the ship's keel, it ofllows that this type of receiver cannot determine the direction of sounds nearly dead ahead or astern with a high degree of accuracy. The type K compensator was developed for the purpose of overcoming this weakness. When the compensator is set at the forward receiving position, 6 receivers on either side of the vessel are employed and the line joining the two groups is then perpendicular to the ship's keel. Under such conditions directions nearly dead ahead or astern are determined with the greatest accuracy.

Another apparent weakness of the JE (MV) sound receiver or any other receiver that determines direction by means of compensations, is that every adjustment of the compensator plates will center a sound from either of two different directions. If the line of receivers is placed parallel with the keel, then the same compensator setting that will center a sound off the starboard side will also center a sound from a symmetrical direction off the port side. Every compensator setting, therefore, corresponds to two different direction and the sound maybe approaching from either of these directions and th sound maybe approaching from either of these directions. The two lines of receivers, one on either side of the vessel, are used in order to avoid this ambiguity. If a sound is heard and CENTERED when the compensator is set at either the starboard or port position, the listener then sets the compensator at the other position and, since the hull of the vessel serves as a sound screen, he can tell whether the sound is off starboard or port by comparing the intensity of the sound as received on the two sets of receivers. The sound will of course, be off the side carrying the receivers that respond with the greatest intensity. Thus, the ambiguity of direction is readily removed when the compensator is set at either the starboard or port listening position. When the compensator is set at the Forward receiving position, every adjustment of the small auxiliary compensator plate will center the sound for each of two directions, but in case, since, the line of receivers is across the ship and not parallel with the keel, one of these directions will be within 90° of the bow and the other within 90° of the stern, and the two directions will be symmetrical with respect to a direction across ship and perpendicular to the ship's keel.

Thus, if one direction were 25° off the starboard stern or a bearing of 155°. To tell which of the two directions is the correct one, it is only necessary to know whether the sound is approaching from fore or aft of the direction across the ship. This can be readily be determined by centering the sound when the compensator is set at the STARBOARD or PORT position. The reading given in either of these positions is never ambiguous as regards fore and aft but only as regards starboard or port. Similarly, the readings, when the compensator is set at the FORWARD position, are never ambiguous as regards starboard and port but only as regards fore and aft.

Since the ambiguity in direction, when the compensator is set at either the STARBOARD or PORT position, is only as regards starboard and port and when set at the FORWARD position is only ambiguous as regards fore and aft, the ambiguity in either the STARBOARD or PORT position can be removed by setting the compensator at the FORWARD position. This position will determine whether the sound is off port or starboard. It is, however, usually more convenient to decide this point by judging the intensity of the sound as reporduced by the port or starboard receiver; but, if the sound is coming from nearby, dead ahead or astern, the shielding effect of the ship's hull is not marked, and the question of whether the sound is off port or starboard can best be decided by setting of the compensator gives the most accurate determination for sounds which are nearly parallel with the ship's keel.

Briefly, then, the Model JE (MV) sound receiver normally is weak in two respects -- first, it does not accurately determine the direction of sounds which approach in a direction nearly parallel to the line of receivers. and second, it only determines direction with an ambiguity as to port or starboard of the line of receivers. Both of these weaknesses are readily removed if two lines of receiver are placed in symmetrical positions on opposite sides of the vessel and the compensator so arranged that three different combinations of receivers, distributed as for the STARBOARD, PORT, and FORWARD positions, can be used.

USE.

Two uses:- The Model JE (MV) sound receiver serves two purposes.

(a) To detect and determine the direction of submarine sounds, such as are emitted by moving propellers, submarine bells, and submarine oscillators.

(b) To determine the depth of water beneath the vessel

How to detect and determine the direction of submarine sounds:-It is a focusing device. This means that it responds very sensitively to sounds from the particular direction in which it is focused and weakly, or not at all, to sounds from other directions. As already shown, the particular direction in which it is focused depends upon the setting of the large rotating compensator plate. Therefore, to detect the presence of all vessel about the horizon with the hydrophone it is as necessary for the listener to rotate the compensator plate as it is for the loookout to turn his field glasses about the horizon. To make a sound survey about a vessel the operator should proceed as follows:-

(a) Adjust the ear pieces of the stethoscopes so that they fit the ears snugly.

(b) Set the compensator at either the STARBOARD or PORT positions. For definiteness say the compensator is to be set at the STARBOARD position.

(c) Turn the top plate of the compensator slowly back and forth over the whole length of the scale and listen intently for any sounds that are brought into focus.

Note:- This operation results in changing the directio in which the hydrophone is focused progressively through all points off the starboard side of the vessel and, unless the compensators turned slowly, a faint sound may come into focus and out again without being heard by the operator, just as the lookout may fail to observe a dimly outlined vessel on the horizon if he turns his glasses too rapidly.

(d) If, during this operation, any foreign sound is heard, it should be CENTERED by properly adjusting the compensator plates.

Note 1:- The direction of the sound can not yet be announced since it is not yet known whether the sound comes from off starboard or port.

Note 2:- By Foreign Sound is meant a sound not originating on the receiving vessel. Every moving power-driven vessel generates numerous sounds and they vary considerably with the speed of the vessel and the depth of the water. The operator must familiarize himself with these various local sounds before he can successfully detect and determine the direction of foreign sounds.

(e) Leaving the compensator plate set at the position which causes the sound to be CENTERED shift over from starboard to the Port receiving position and judge carefully which position gives the louder response.

(f) Announce the direction as indicated by the scale corresponding to the position that gives the louder sound response.

Note:- If the direction of the sound is nearly dead ahead or astern, say within 15° off the bow or stern, the shielding e effect of the vessels hull is nearly the same for both starboard and port lines of receiving and, as a result, the intensity of the sound will be nearly the same for both STARBOARD and PORT receiving positions. Under such conditions there is considerable difficulty and uncertainty in deciding which side of the vessel the sound is on. This doubt is readily removed by shifting the compensator to the Forward receiving position, as is shown under the heading, USE OF THE FORWARD RECEIVING POSITION.

(g) Repeat operations (d), (e) and (f) for any other foreign sounds that are detected during the operation (c).

(h) Set the compensator at the other receiving position in this case the PORT position and execute operation (c)

Note:- It is evident that by so doing the compensator is progressively focused on all points off the port side.

(i) If, during the operation (h) one or more foreign sounds are heard, operations (d), (e) and (f) must be executed for each sound in turn.

Use of the Forward listening position:- An inspection of the spacing of the compensator scales corresponding to the STARBOARD and PORT receiving positions shows that direction within 10 to 15 degrees off bow or stern can not be determined with much accuracy. Moreover, it is evident that sounds approaching within these limits strike both lines of receivers about alike and, as a result, the operator will have difficulty in deciding whether the sound is off starboard or port by judging which side responds with the greater intensity. An inspection of the two scales on the small auxiliary compensator shows that it determines directions ahead or astern with greatest accuracy. This, as has been stated, is due to the fact that the line connecting the two groups of receivers is perpendicularly across the ship when the compensator is set at the FORWARD position

If, on centering the sound (operation (d)), the operator finds the direction is within 15° of the end of the scale, then, instead of executing operation (e) to determine whether the sound is off starboard or port, he should shift to the FORWARD receiving position and center the sound by means of the small compensator. The direction will then be accurately given on one of the small compensator scales. There is never any doubt as to which scale to use. The direction has already been roughly determined with the compensator set at either the STARBOARD or PORT position and can be read off on the scale attached to the large compensator plate.

It is important to remember that the FORWARD position of the compensator is never used until the sound has been centered with the compensator set at either the STARBOARD or PORT position. The reason for this is the compensation consists of two parts:- The focusing part, which brings the response of the 6 receivers of each group into phase and the Binaural part, which brings the combined response of each group (2) of 6 receivers into phase. When the compensator is set at the STARBOARD or PORT position, both parts of the compensation are accomplished by turning the large compensator plate, When this plate is so adjusted that the sound is CENTERED then the 12 sound paths connecting with the receivers are also properly adjusted to bring the responses of the receivers into phase. If, now the compensator is shifted to the FORWARD position, the focusing part of the compensation is not disturbed but Binaural part is shifted from large to small compensator. And, since it is through the Binaural part of the compensation that the operator CENTERS the sound, he will usually need to RE-CENTER itafter the compensator has been shifted to the FORWARD listening position.

From the above it should be understood that the operator nevers uses both compensator plates at the same time. If the direction is determined by using only the STARBOARD and PORT positions, both stages of compensation are accomplished at the same time by CENTERING the sound through proper adjustment as the large compensator plate. If the direction proves to be near dead ahead or astern that is becomes necessary to shift to the FORWARD position, then only the Binaural part of the compensation needs to be readjusted and this only requires the use of the small compensator. The large compensator must not be turned, as it is already adjusted properly for the focusing part of the compensation.

SUMMARY:- The above directions for detecting and determining the direction of a sound will now be briefly summed up:-

To determine the direction of a sound, set the compensator at either the STARBOARD or PORT receiving position. Center the sound by properly adjusting the large compensator plate. Leaving this plate in the position that causes the sound to be CENTERED shift the compensator back and forth from STARBOARD to PORT position and vice versa, and decide which position gives the louder response. Read the directions of the sound from the scale corresponding to the receiving position that gives the louder response.

If, in centering the sound, it proves to be nearer the bow or stern, leave the compensator plate in the position that causes to be CENTERED and shift to the FORWARD receiving position. Again CENTER the sound by means of the small compensator and read off the directions of the proper scale of this compensation. The proper scale will be evident from the rough determination of direction given by the scale on the large compensator plate.

How the Model JE (MV) sound receiver determines depth:- It determines the angle between the direction of a sound and a direction of the line of receivers. And, since the line of receivers underneath each blister is nearly parallel with the keel, it is evident that the hydrophone must give the angle between the sound and the ship's keep when the compensator is set at either the starboard or port listeneing position, This statement holds true whether or not the sound is traveling in a horizontal plane.

Then the submarine sound waves meet a surface of different density such as the sea bottom to the surface; they are reflected away at the same angle that they meet the surface. The reflected sound is usually called an echo. The receiver determines the direction of the reflected sounds or echoes. As readily as it does direct sounds, or sounds that have not been deflected.

The shielding effect of a hull of a vessel prevents sounds originating near the stern from reaching the receivers directly. Only the echo of such sounds is heard. This echo is the sound reflected from the sea bottom and its direction with respect to the keel depends on the depth of the water. If the depth is great the echo will be nearly perpendicular to the keel. For intervening depths it will make some angle intermediate between these limits. (If the water is very shallow, the echo will be nearly parallel to the keel). For every depth the echo will make a definite angle with the keel and this angle can be determined with this receiver when the compensator is set at either the STARBOARD or PORT receiving position.

The relation between the depth of water and the direction of the echo can be determined from the relative location of the sound source and sound receivers and expressed in a curve having depth as one set of coordinates and the angle that the echo makes with the keel as the other set of coordinates. The depth calibration curve should always be checked up and corrected experimentally. From the corrected curve it is possible to provide the compensator with a sounding scale such that the depth can be read off directly without referring to the calibration curve.

Procedure for taking soundings:- The procedure for taking a sounding is as follows:-

(a) Set the compensator at either the STARBOARD or PORT receiving position.

(b) Determine the direction of the echo of whatever sound sourve is provided for taking soundings by centering the sound.

Note:- Most vessels will be provided with a submarine oscillator located well astern having control panel and key located in the sound room convenient for the operators use. Under such conditions, the listerner will sound short dashes on the oscillator and the same time adjust the compensators that the oscillator signals are heard on the sound receiver or CENTERED. Do not hold the key down and attempt to CENTER the steady oscillator sound. Besides the oscillator may overheat if the current is maintained at a long period. If the vessel is not provided with an oscillator located aft, then the echo of the propeller is used instead for taking soundings. It is to be remembered, however, that the sounding scale, or sounding calibration curve refers to one, and only one, sound source. It will not give correct sounding when the propellers are used as sound source, and vice versa.

(c) Read off the depth directly from the sounding scale on the compensator or note the angle given on the compensator scale and ascertain the corresponding depth from the sounding calibration curve.

The maximum Binaural switch:- If the two stethoscope outlets from the compensator are brought together in a single tube and then separated again into two different outlets for the stethoscope leads, the sound impulses which reach the two ears will be the same and reach the two ears at the same time, and as a result the operator will experience no shifting of the sound from one side to the other as the compensator is rotated. The sound remains CENTERED at all times. The so-called double Y-ing of the outlet leads destroys the Binaural stage of the compensation but not the maximum stage, and as a result the operator will notice that the intensity and sharpness of the various sounds will not change as the compensator is rotated, or , in other words, as they are brought into and pass out of focus. It will be found that two sounds which have nearly the same bearing can be separated and identified somewhat better when the receiver is used as a maximum instrument than when used Binaurally.

Some compensators are provided with a switch which connects in between the compensator outlets and the stethoscope leads by means of which it is possible to quickly adjust the leads for either maximum or Binaural receiving. Full value of this switch was not at first realized, and, as a result, it is not incorporated in the earlier compensators. Its chief value is not that it enables the operator to use the compensator as a maximum or Binaural receiving device, but rather because it enables him to determine where a sound should seem to be when it is properly CENTERED.

If the compensator is provided with a maximum Binaural switch, the operator can best CENTER a sound by adjusting the compensator so that the sound does not seem to change its position when the switch is turned back and forth between the Binaural and maximum settings. The accuracy of settings made in this way is independent of the adjustment of the stethoscopes in the operators ears and of the quality in length of the two stethoscopes leads, and also to a large extent of any inequalities in the operators ears. These advantages are doubtless all compensators will eventually be provided with the maximum Binaural switch.

The above explanation of the principle of operation and use of the Model JE (MV) sound receiver is purposely made brief and as a result is somewhat incomplete. A more complete description of the underlying principles upon which it operates will be found in two small pamphlets. DETECTION OF SUBMARINES and THE US NAVY MC TYPE of hydrophone as a side and safeguard. The operator should read both of these pamphlets carefully.

Care:- The Model KE (MV) sound receiver is a rugged device and not easily damaged. If properly cared for it should last almost indefinitely. Permanent injury is most liable to be caused by water leaks or by improper lubrication of the compensator.

Water leaks:- Since the connecting tubes which come in contact with the water are made of heavy walls seamless steel tubing, wlded at all junctions, the chances of their developing water leaks are slight but the life of the rubber nipples is limited and these should be renewed at least every two years and possibly every year, in order to eliminate the development of water leaks through the receivers.

The damage caused by water leaks is not serious if the leaky tube can be disconnected or closed before the compensator becomes flooded. The development of leaks usually is a slow process and, if they can be detected within a week after starting, the leaky tube can be closed off before the water reaches the compensator. Such leaks are readily detected by attaching the stethoscope leads directly to each of the twenty four connecting tubes in turn. If any tube of the receiver connecting with any tube, has sprung a leak, the response of the tube to outside sounds will be NIL or at best very weak compared to the intensity of the response from a perfect tube. This is due to the fact that the water that has entered blocks off the air path.

A specially designed three-way cock is inserted into each of the twentyfour connecting tubes directly underneath the compensator plates to facilitate the operator in making such test. Each tube should be tested for water leaks once a week by attaching the single lead of the testing stethoscope to the small extension tube projecting from the top of the elbow and turning the three way cock to the position marked TEST. This position closes off the compensator. If a leak exists in the connecting tube or receivers, the listener will not be able to hear outside sounds clearly.

Under such conditions, close off this connecting tube by turning the cock to the position marked CLOSED. If no leak is discovered by the test, connect the tube to the compensator by turning the cock back to position OPEN.

Lubrication of Compensator:- The usefulness of the Model JE (MV) sound receiver is dependent to a large extent upon the condition and adjustment of the compensator. Unless the sliding surfaces and bearings are properly lubricated and adjusted, scraping of the metallic surfaces whenever the plates are rotated produces disturbing sounds which not only serious interfere with the CENTERING of weak sounds, but may prevent the operator from detecting foreign sounds that would otherwise be readily heard. Moreover, disturbing sound developed within the compensator due to improper adjustment and lubrication always grows worse instead of better, due to the formation and accumulation of metallic dust between the moving metallic curfaces. For this reason is is extremely important that the compensator should be looked over and put into proper shape whenever such sound starts to develop.

All sliding surfaces are scraped to fit with a high degree of precision. The high cost of the compensator is due to the care and skill required to fit these surfaces and if they are allowed to become corroded or scored because of improper lubrication ro adjustment the injury can be only repaired by anexpert. When the compensator is correctly adjusted and lubricated there is not metallic contact between the fixed and movable plates. And yet all the air passages are perfectly sealed so that no sound can leak across the between the passages. Under such conditions the compensator makes no sound to disturb the operator when he turns the various plates as is required to CENTER a sound.

The type K compensator has three bearings that must be cared for, namely, between the top plate and the main body of the large compensator, between the bottom plate and the main body of the compensator and between the top and bottom plates of the small auxiliary compensator.

In order to insure perfect lubrication between two surfaces that are not continually sliding across one another, it is necessary that the pressure between the surfaces should not be great otherwise, while the surfaces are at rest, the lubricating fluid will be squeezed out and thus allow the surfaces to come into metallic contact. The pressure between the top plate and the main body of the compensator can be relieved by means of the large knurled set screw in the center of the plate. A draft of from one tenth to one twelfth turn of this screw gives the proper amount of pressure release. The pressure between the bottom plate and the main body of the compensator is relieved by a heavy coil spring extending down into the supporting column. The tension on this spring can be adjusted by means of the knurled nut at its lower end. The tension of this spring is carefully adjusted when the compensator is assembled and will seldom need readjustment. The weight of the top plate of the small compensator is not sufficient to cause undue pressure between the bearing surfaces and no pressure adjustment is required.

Both bearings of the large compensator receive lubrication through the four small oil cups on the top plate. The waste oil that has passed through the bearing finally drains out through a small tube underneath the lower plate to a small cup underneath the small compensator. The small compensator seldom needs lubrication and is not provided with an oil cup. It should be lubricated about once a month by lifting off the top plate and placing oil directly on the lower plate and in the creases of the upper plate. The excess oil passes down through the openings of the lower plate and finally drains out into the oil well underneath. For lubricating the compensator, never use anything but a high grade of castor oil.

In case the compensator develops troublesome noises and this defect is not remedied by excess lubrication, the plate should be carefully removed and the bearing surfaces washed clean with alcohol or gasoline. These surfaces should be well coated with castor oil before reassembling. Extreme care must be taken to prevent dust or lint from getting on the bearing surfaces during the cleaning operation. Make sure that the plate has been so replaced that the scales occupy their normal position before attempting to rotate the plate, otherwise the stop plugs will not engage and the plate may be seriously damaged by being rotated too far. This work should only be undertaken by the Navy Yard forces.

Development of disturbing noises outside of the compensator:- The 24 receiver tubes which connect to the compensator must necessarily be bunched where they pass through the stuffing boxes and where they join the compensator. Care must be taken to prevent metallic contact between the tubes themselves or between the tubes and the skin of the vessel or blister, otherwise the clicking or rubbing of such contacts will produce disturbing noises that seriously interfere with the successful operation of the receiver. Such contacts are avoided by inserting felt or rubber packing when the installation is made, but, occasionally , due to the improper mounting or due to continued wear, the above mentioned defects develop and it will then be necessary to locate the trouble and renew the packing.

Calibration of the Model JE (MV) Sound Receiver:- As stated, the Model JE (MV) sound receiver serves two purposes. Namely, to determine relative bearings or submarine sounds, or signal and to take depth soundings, but before any great reliance can be placed upon the device it must be calibrated for both of these purposes. The procedure which has been found simple and successful for calibration is described below.

Calibration for Bearings:- The compensator is provided with three scales for taking bearings. These scales are duplicates of scales that have been determined experimentally for a similar installation and, if centered properly on the compensator plate, should give fairly accurate results, but the small variations in each installation are such that the sound receiver will not give the high degree of accuracy that it is capable of giving unless the scales are checked over and corrected.

The best procedure for correcting the starboard and port scales is to let the listening vessel lie to in from 15 to 20 fathoms of water in an area where the sea bottom is smooth and of uniform depth and have another vessel serve as sound source by circling the operators vessel at a range of from 1½ to 2 miles. The bearing of the sound source is taken every minute simultaneously on the sound receiver and the pelorus until sufficient data has been collected for determining these two scales. During this procedure only the starboard and port positions are used.

As will be seen later, the more data that is collected the more accurate will be the calibration since thecalibration curve which results from this data is a curve of mean error. It should also be remembered that the sound receiver determines the direction of the propellers of the sound source and the pelorus bearing should therefore be taken from the flagstaff.

To calibrate the forward scale, let the receiving vessel follow the sound source at a distance of from 1½ miles to 1 mile, meanwhile so manipulating her course as to bring the course of sound back and forth through all bearings, within twenty degrees off the bow to starboard and port. During this process simultaneous bearings of the sound sources are taken every minute with the pelorus and the sound receiver until the data of sufficient nature has been collected for calibration purposes. During this process, the compensator is set at the forward receiving position and the large compensator is left set at the 0° or 360° setting.

Plotting the Data:- The calibration data should be plotted on two separate sheets, one containing the data relative to the STARBOARD and PORT receiving positions, and the other data relating to the FORWARD listening position. In plotting this data, use compensator readings for abscissa and corresponding pelorus bearings for ordinates. If the compensator scales are correct and the operator makes no errors in CENTERING sounds then the points will fall along a 45° straight line. But due to slight errors in compensator setting and to irregularities of the sea bottom, the points will not fall on a straight line, even though the compensator scales are correct. The errors will tend to cause some of the points to fall on each side of the line, but if a sufficient number of readings are plotted the average error on each side of the line will be the same. It is therefore evident that the calibration curve can be located by drawing a medium line through the plotted points, even though the nature of the curve is not known.

Each of the curves will be approximately a straight line making an angle of 45° with the axis of coordinates. The PORT and STARBOARD scales will probably deviate somewhat from this line for direction near 0°, 180° and 360°. If the calibration for the PORT scale falls on one side of the 45° line and that for the STARBOARD scale on the other side of this line, the chances are that the scale is not properly CENTERED on the compensator plates. A proper shifting of the scale may cause the calibration curve to fit the 45° line. However, it is not necessary to shift the scale, Any sort of scale on the compensator will serve, provided that the calibration curve is carefully worked out in terms of this scale.

Use of the calibration curve:- By means of the calibration curves it is possible to construct accurate scales for the compensator. If this is not done then the listener determines bearings on the incorrect scale and then refers to the curve to get the correct bearing from it before announced the bearing to the bridge.

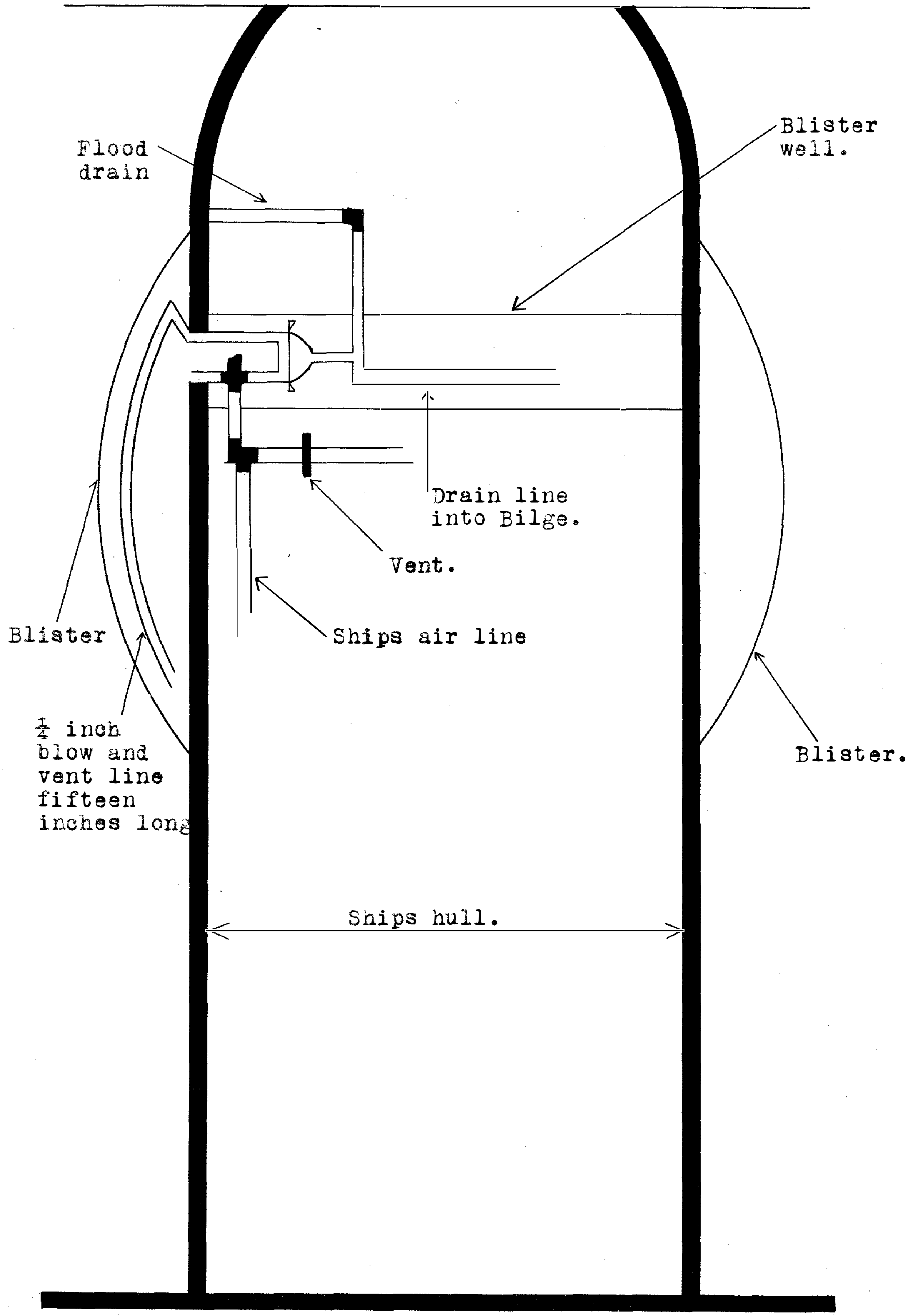
Calibration for Depth Soundings:- To calibrate the sound receiver for depth finding, it is necessary to operate the vessel in water of various depths where the sea bottom is fairly smooth and the change of depth not rapid. Simultaneous soundings are taken with the sound receiver and the hand lead or sounding machine. The sound receiver sounding simply consists of a determination of the direction of the echo or whatever sound is used for the purpose of taking depth soundings.

Usually this will be the oscillator signals, but, if there is no oscillator it will be the propeller sounds. In plotting the data use the compensator readings for the abscissa and the corresponding depths for ordinates. The calibration curve will be a medium line through these points. The character of this curve is shown on the attached sheet. Here the ships propellers served as a sound source.

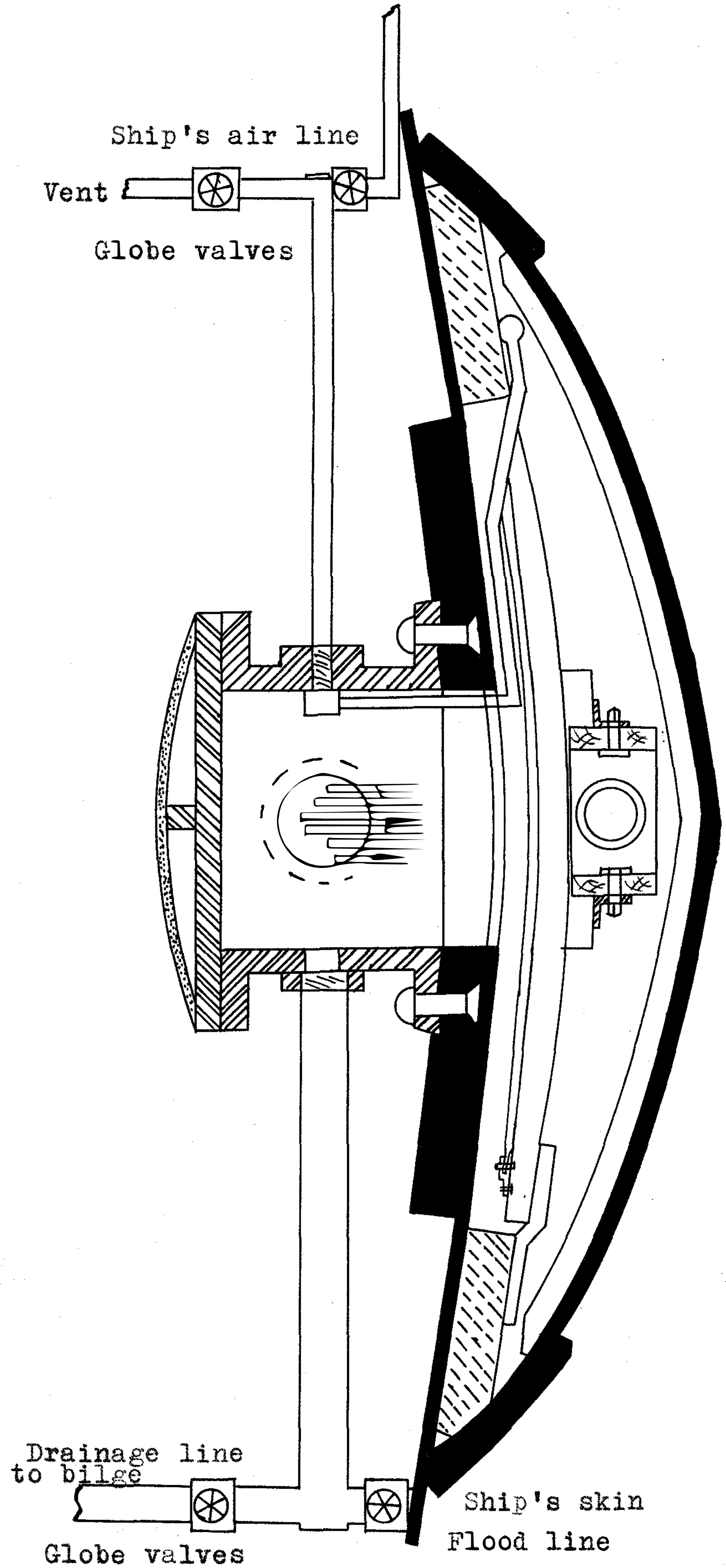
As a further check on this curve it is well to run the vessel out and back over a straight course where the depth is well charted and varies somewhat gradually from a minimum to 100 fathoms. The operator will, in the meanwhile, take soundings on the hydrophone every three minutes thoughout the course. These readings and the corresponding charted depths should also be plotted on calibration curve and, if the medium line through these points differs materially from the curve determined from the actual sounding data, the work should be gone over and checked up.

Probably the checking up process will disclose that the charted values are in error, but it may show that the soundings machine was not functioning properly. If the calibration curve is carefully done, it will be found that soundings given by the sound receiver are thoroughly reliable and the instrument will serve as a valuable aid to navigation.

Blister--Flood, Drain, Blow and Vent System.



Blister - Flood, Drain, Blow and Vent System.

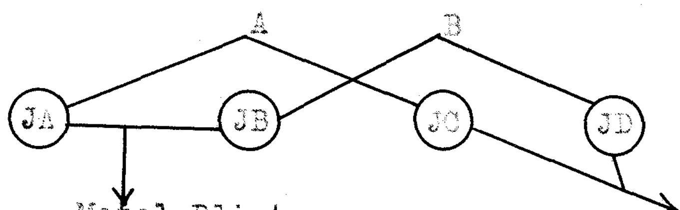


COMPENSATOR CHART.

Types.		Number of Steps	Steps Used.	Center Step.	Effective Step.	Retardstion Value.	Binaural Base Line.	Number of Units.	Distance Between Units
4215	Side	36	36	18	18	4W"	72"	12	12"
	Cross	64	64	32	32	2W"	Var.	24	12"
4216	Side	98	90	49	45	3W"	135"	18	15"
	Cross	64	64	32	32	2W"	Var.	18	15"
4217	Side	72	72	36	36	2W"	72"	12	12"
	Cross	72	72	36	36	2W"	72"	12	12"
Nav. 6 Spot	Side	64	60	32	30	2W"	60"	6	20"
	Cross	64	60	32	30	2W"	Var.	6	20"
CBM 4125	Side	36	36	18	36	2W"	72"	12	12"
	Cross	36	36	18	36	2W"	Var.	12	12"

A. BBL 72" 12-Spot 12" apart. SE 4215 or Comp.

B. BBL 135" 11-spot 15" apart. SE 4216 Comp.

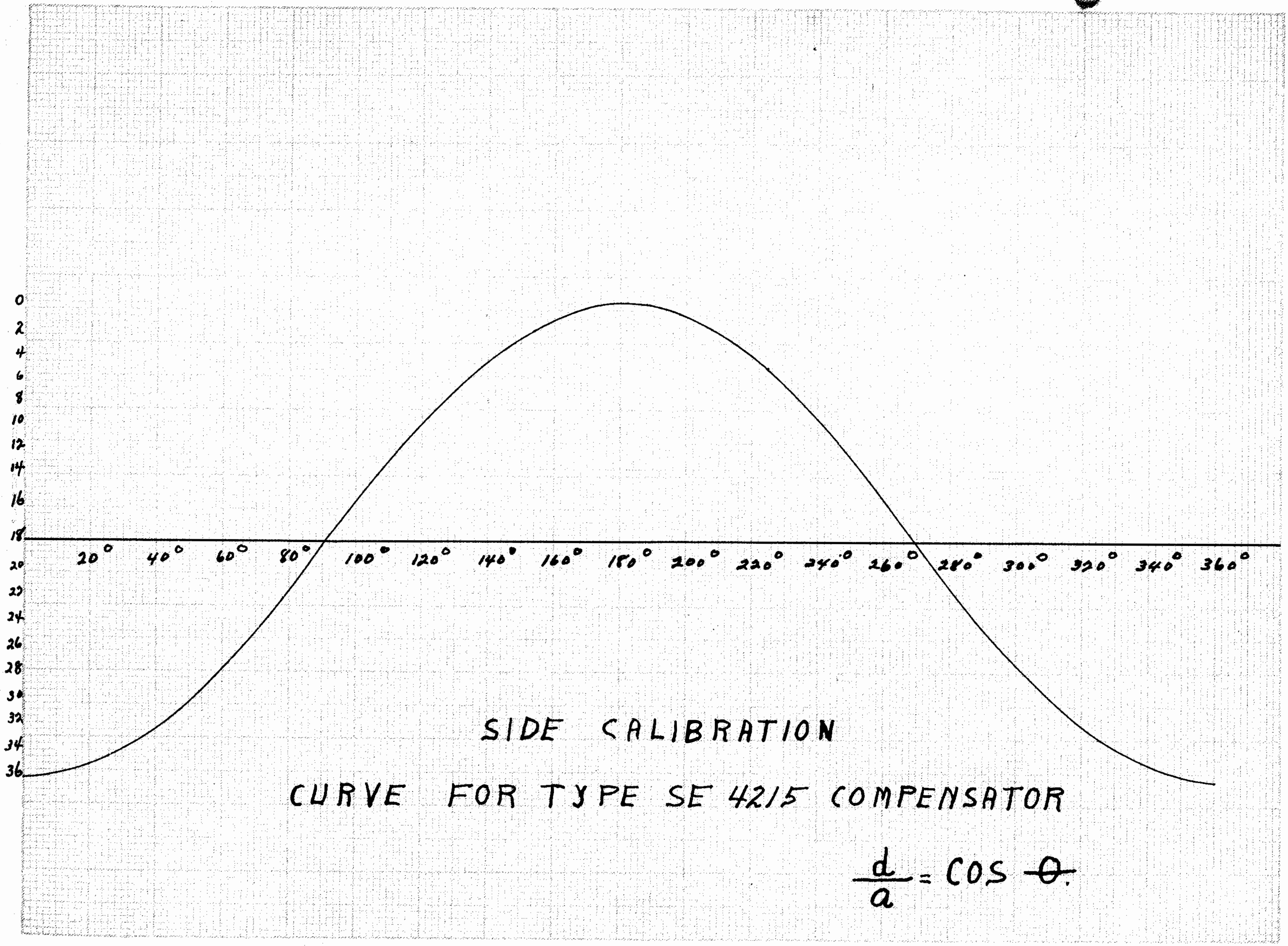


Metal Blisters with Sound Screens and Inertia Plates.

Wooden Blisters with Inertia Plates.

(JE) 12 - Spot BBL 126" Type K or H

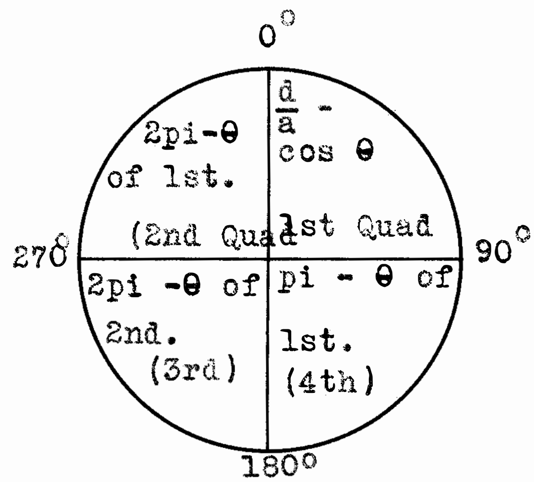
(Nav. 6 Spot.) 6-Spot 20" Apart. CAC-1845 Nav. 6 Spot Comp. Blisters optional.

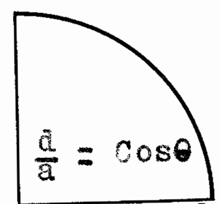

0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
20° 40° 60° 80° 100° 120° 140° 160° 180° 200° 220° 240° 260° 280° 300° 320° 340° 360°
SIDE CALIBRATION
CURVE FOR TYPE SE 4215 COMPENSATOR
d/a = COS θ

Compensator Calibration Data of SE 4215 Compensator.

(Side Calibration).

Port	Stern Step	Star'b.
180-	0	180-
199-12'	1	160-48
207-17'	2	152-43
213-34'	3	146-26
218-57'	4	141-03
223-14'	5	136-14
228-12'	6	131-48
232-20'	7	127-40
236-15'	8	123-45
240-	9	120-
243-37'	10	116-23
247-07'	11	112-53
250-32'	12	109-28
253-53'	13	106-07
257-10'	14	102-50
260-25'	15	99-35
263-37'	16	96-23
266-49'	17	93-11
270-	18	90-
273-11'	19	86-49
276-23'	20	83-37
279-35'	21	80-25
282-50'	22	77-10
286-07'	23	73-53
289-28'	24	70-32
292-53'	25	67-07
296-23'	26	63-37
300-	27	60-
303-45'	28	56-15
307-40'	29	52-20
311-48'	30	48-12
316-14'	31	43-46
321-03'	32	38-57
326-26'	33	33-34
332-43'	34	27-17
340-48'	35	19-12
360-	36	0-
Port	Bow.	Star'b.



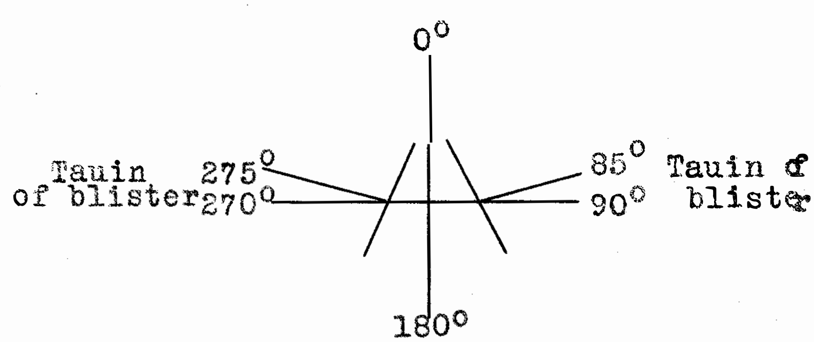


cross calib.

Note: Inside calibration the tauin of the blister must be known.

For the starboard side, the tauin of the blister is subtracted.

For the port side, the tauin of the blister is added.



The Electrical MV Sound Receiver.

Its Description, Principle of Operation, Use, Care and Calibration.

The Electrical MV sound receiver is a so-called multiple receiver, underwater sound detector. For the purpose of description it is convenient to consider the device as made up of four separate parts, viz., the receivers, the blisters, the connecting cables and the compensator.

The two different types of electrical MV sound receiver used in the Navy, Viz., a so-called "12 spot" (Models JA and JC) which employ two lines of 12 receivers. The receivers of each line being spaced 12 inches apart and the so-called "18 spot" (Models JB and JD), which employ two lines of 18 receivers, the receivers of each line being spaced 15 inches apart. The description principle of operation, use, care, etc., which follows, applies in general to both types. There are, however certain differences in the principle of the two types of compensators which will be explained.later.

The Receiving Line:- Each unit of the receiving line consists of a water-tight cylindrical chamber closed at one end by a rubber diaphragm to the inside center of which is attached a carbon granule microphone of the inertia type. The other end of the chamber carries a stuffing box through which passes a two-conductor concentric wound cable. The two leads from the microphone are soldered to the two cable conductors, respectively. Proper spacing between the several microphones employed in a line is maintained by attaching them to two messenger cables. As will be explained later, an extension of the messenger cables serves to draw the line of receivers into or out of the blister through a hand-hole and to anchor them in position within the blister.

The Blisters:- Each line of microphone receivers, known as the "Receiving Line" is housed beneath a protecting "Blister" attached to the outside of the ship's skin. The Blister is made up of heavy wood planking bolted to a ¾ inch iron plate. This heavy plate not only furnishes a means for attaching the blister to the ship,but its inertia tends to prevent the absorption by the vessels hull of the sound energy meeting the microphones and thereby increases their sensitivity.

The Shape of the Blister is determined in accordance with the principle of streamlining for the purpose of reducing the friction that such a projection might offer and also for the purpose of reducing the disturbance that is always caused by turbulent water and also eddies formed about a non-streamlined body when it is moved rapidly through the water. The outside of the wood is covered with thin sheet metal to protect it from marine insects. The Blister as a whole is mounted in position by riveting or welding the ¾ inch plate to the outside of the vessel skin.

A slot 5½ inches square in cross section extends nearly the whole length of the blister. The iron plate forming the inside surface of this slot. The purpose of the slot is to house the microphone receivers.

Communication between the inside of the vessel and the slot is accomplished by means of a hand-hole carrying a water-tight cover plate and a multiple cable stuffing box. A small metal tube imbedded in the wood except for its end extends from the hand-hole opening to the end of the receiving line slot within the blister. A cable passed through this tube forms the hand-hole end and returning through the slot, from its outer end, attaches to the two messenger cables at the end of the receiver line and serves to draw it into place within the slot. The receiving line is held in place within the blister by anchoring this return cable to a fixed point within the neck of the hand-hole and also anchoring the other end of the messenger wires to a hool carried by the end of the blister slot and located directly beneath the hand-hole.

A 1 inch pipe, which serves for filling and emptying the blister, attaches to the lower part of the hand-hole neck and a ½ inch pipe, which serves as an air vent, attaches to the upper part of the neck. The filling pipe carries a valve and a T-outlet also provided with a valve. The outer end of the pipe line connects with sea pressure through the vessels skin. The shut-off valve is located between the T-outlet and the end terminating in the ships skin.

The two blisters required by the electrical MV sound receivers are located in symmetrical positions, one on either side of the ship, and they should be placed as far forward as far below the water line, and as near parallel with the vessel's keel as possible.

Model numbers:- For various types of multi-unit electrical and acoustical sound receivers have been assigned by the Bureau of Engineering as follows:

Model JA: °Twelve microphones in each line, housed in metal blisters and connected to a type SE 4215 compensator.

Model JB: °Same as JA except that there are 18 housed instead of 12 microphones in each line which are connected to a type SE 4216 compensator. Blisters are of metal.

Model JC: °Twelve microphones in each line, housed in blisters of wooden construction and connected to a type SE 4215 compensator.

Model JD: °Eighteen microphones in each line, housed by blisters of wooden construction and connected to a SE 4216 compensator.

Note:- Wooden blisters of Models JC and JC are covered with 1/16 inch galvanized iron.

Model JE: °Twelve acoustical receiving units in each line housed by metal blisters and connected to a type K or H compensator by means of tubing.

Special Model MV: ° An electrical sound receiver having 24 microphones.

The connecting cables:- The receiving station for an electrical MV sound receiver is usually located in the radio room or the chart room, either of which position is a considerable distance from the blisters. The method employed for carrying the electrical leads from the several receivers to the compensators in the listening station is as follows:

(a) All the two conductors concentric cables that lead from the several microphones are carried from the blister to the inside hull through a pepper box type stuffing box located in the side of the hand-hole neck. From this point the several cables are bunched and passed through a short water-tight conduit tube into a standard 40 wire junction box where the 24 conductors in case of a 12 spot (Model JA or JC), or 36 conductors in case of an 18 spot (model JB or JD) terminates.

(b) Electrical connection between the several terminals of the two junction boxes (one near the outlet from each blister) to the two corresponding terminals on the terminal board of the compensator is accomplished by means of standard Navy lead and armour 26-conductor interior-communication cable.

In practice, all of the microphones of both receiving lines are connected in parallel across the terminals of a 6 volt storage battery and, as a result, one lead is common to all receivers The receivers are not joined to the common lead within the blister because of the difficulties encountered in securing perfect insulation at the junction, but the outside conductor of all cables of a receiving line are joined to a common lead in the junction box where they terminate.

The number of conductors required between each of these junction boxes and the compensator is one more than the number of receivers carried by the blister. Thus an interior-communication cable of thriteen conductors would serve for a 12 spot and one of 19 conductors would serve for an 18 spot installation one conductor in each case being common to all the units of a receiving line. However it has been found best to use a cable of carrying several extra conductors as a factor of safety in case some of the leads prove to be too short circuited or grounded and therefore a 26 lead conductor cable has been adopted.

The two common leads, one for each receiving line, are joined to a single conductor within the compensator and the battery switch are connected into this part of the circuit. The individual lead from each micrphone includes the primary coil of a transformer within the compensator and finally joins an extension of the common lead beyond the battery.

Note:- Type B Microphone receivers require from 30 to 36 volts instead of 6 volts as required by types SE 1802 microphone receivers.

The Compensator:- The function of the compensator is to determine the direction of sounds picked up by the receiving lines. Two types of electrical compensators are in use in the Navy, namely, Type SE 4215 used with 12 spot and Type 4216 used with 18 spot sound receivers. The design of both of these types is such that the microphone receivers of either the port or starboard receiving line can be used for receiving, or under certain conditions which will be explained later, a part or all of the microphones of both lines can be used simultaneously for receiving. But type 4216 permits only the simultaneous use of the forward nine microphones or the after nine microphones of both lines.

It has been explained that each of the microphones is connected in series with the primary coil of a transformer within the compensator, and that all the microphone circuits are parallel across the terminals of a common battery, similarly the secondary circuits within the compensator are all connected in parallel. Each circuit contains in series the secondary coil of a transformer a telephone receiver, and certain inductances and capacities, the value of which can be varied at will by means of a rotary switching device. The purpose of the inductances and capacities is to retard the passage of the electrical impulses traversing the various circuit and originating in the several corresponding microphones.

By turning the rotating switch to different positions the amount of retardation imposed upon the current impulses of the secondary circuits can be relatively varied and, as a result, the relative time of arrival at the telephones of corresponding current impulses from the several microphones can be varied.

The process of varying the relative time of arrival at the receiving device (telephone in this case) or current impulses of two or more parallel circuits is called "COMPENSATION" and any device that accomplishes this is called a "COMPENSATOR."

Principles of Operation.

Definition of Terms:- The MV Sound Receiver determines the direction of a sound by means of the so-called BINAURAL sense. It succeeds in bringing that sense into play by use of the so-called PRINCIPLE OF COMPENSATION. It has the ability to intensify the sound from any desired direction and at the same time weaken the intensity of all sounds from other directions. This latter ability is usually spoken of as its SELECTIVITY OR FOCUSING ABILITY. These four terms BINAURAL SENSE, BINAURAL PRINCIPLE, COMPENSATION, and SELECTIVITY, which have become associated with the art of detecting and determining the direction of sounds, will now be explained in detail, since they must be used freely indescribing the principle of operation of the electrical MV Sound Receiver.

The Binaural Sense:- Experiment proves that the direction of a sound can not be judged with any degree of accuracy by using one ear alone, i.e. monaurally, unless the pitch of sound is very high, but that the direction of any audible sound can be judged with considerable accuracy by using both ears, i.e., binaurally.

The determination of direction when both ears are used (by means of the BINAURAL SENSE) depends largely on the difference in time between the reception at the two ears of corresponding impulses of the sound. Since this time difference does not depend upon the intensity of sound at either ear, it follows that persons partially deaf in one ear or both ears can determine the direction of a sound nearly, if not quite so accurately as one with normal ears.

When a sound reaches the two ears at the same time, the listener judges it to come from a direction perpendicular to the line joining his two ears. If the sound source is to the listeners right the sound strikes his right ear first and he judges it to come from his right, the apparent direction depending upon how much earlier the sound strikes his right ear. The operation of the binaural sense is always such that a sound is judged as coming from the listeners right or left, depending upon whether it reaches his right or left ear respectively.

 either to the right or to the left) and where direction is determined with greatest accuracy.

Neglecting the possible effect on the listeners features one can conceive of ways other than by turning his head whereby he could binaurally center a sound and thereby determine it-s direction. If we remember that a sound is binaurally centered when the impression of the sound entering the two ears registers simultaneously on the listeners brain, then, instead of turning his head (ears) until this condition is reached, one can conceive of an individual having the ability to binaurally center sound by varying the length of air-passage between the ear drum and the outer drum. Suppose such an individual heard a sound somehwere to his right. If his binaural sense were normal, this would imply that the sound reached his right ear first, or more particularly, that the sound entering his right ear registered first on his brain. Now, without turning his head, he could cause the sound impression at both ears to register simultaneously by delaying the time of transit of the sound from the outer ear to the brain in case of the right ear, or by decreasing the time of transit in case of the left ear, or by causing such vibrations to operate by a definite and proper amount in both ears simultaneously.

This effect could be brought about by lengthening the air passage in the right ear and shortening it in the left ear, or by causing such proper amount from their normal lengths or by leaving these passages alike in both ears and imposing a proper amount of time lag and acceleration upon the nerve transmitting mechanism of the right and left ear respectively. In either case the process of binaurally centering the sound without moving the receivers would be called COMPENSATION.

Compensation, then is the process of mechanically producing at will a variation in the relative time of arrival of sound impulses at the two ears in such a manner and by such an amount that impulses register simultaneously, thereby giving the operator the impression that the sound is neither to his right nor to his left.

The design of the MV sound receiver is such that the process of compensation can be employed to binaurally center sound from any direction thereby enabling the operator to determine its direction. As has been stated, the particular part of the device use for varying the relative time of arrival at the two head telephones of electrical impulses generated by the sound is termed a COMPENSATOR.

Selectivity or focusing ability:- As a sound detecting device the ear has at times certain disadvantages, the chief one of which is that it is non-focusing or non-selective. It receives sound from all directions with equal intensity. Oft times it would be necessary, if the ears could be focused to receive sound from a definite direction and at the same time made insensitive to sounds from other directions with equal intensity. Under such conditions it would be possible to follow the conversion of any one individual in a gathering of people all of whom are conversing.

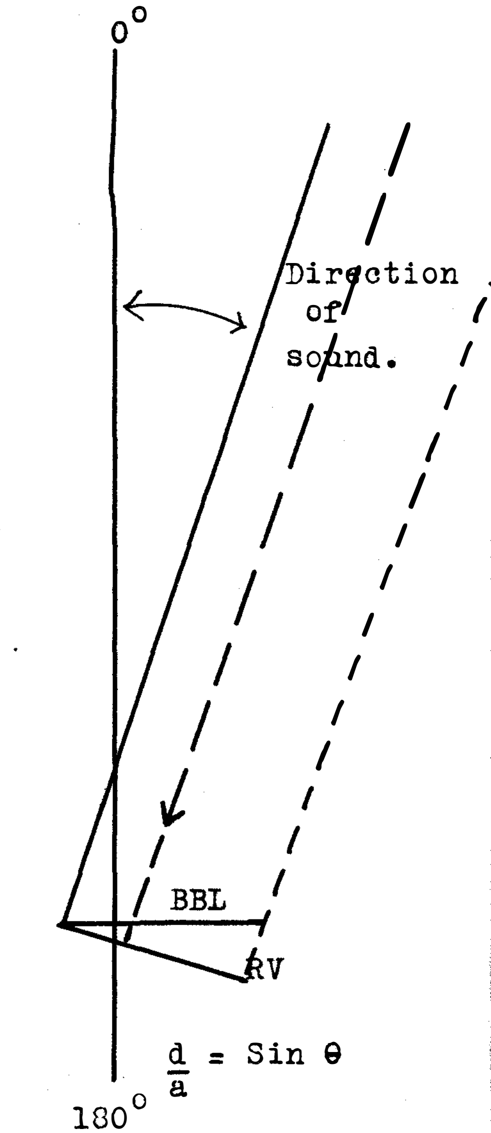
One can readily conceive of an individual endowed with such hearing powers. If, instead of one ear on each side of his head, he could have several extending outward on each side along a line passing through the two ears, and if the time of transit of the sound from each ear were compensated so that the impressions from all the ears would reach the brain simultaneously for sound approaching the line of receivers (ears) from some definite direction, then he could hear sensitively any sounds approaching from this direction, since the impressions from all ears would arrive in phase and therefore add, while sounds from any other direction would not be distinctly heard due to the fact that responses from the different ears would arrive out of phase and would then tend to cancel one another through the process of wave interference. Such a compount ear would be said to have SELECTIVITY, or FOCUSING ABILITY.

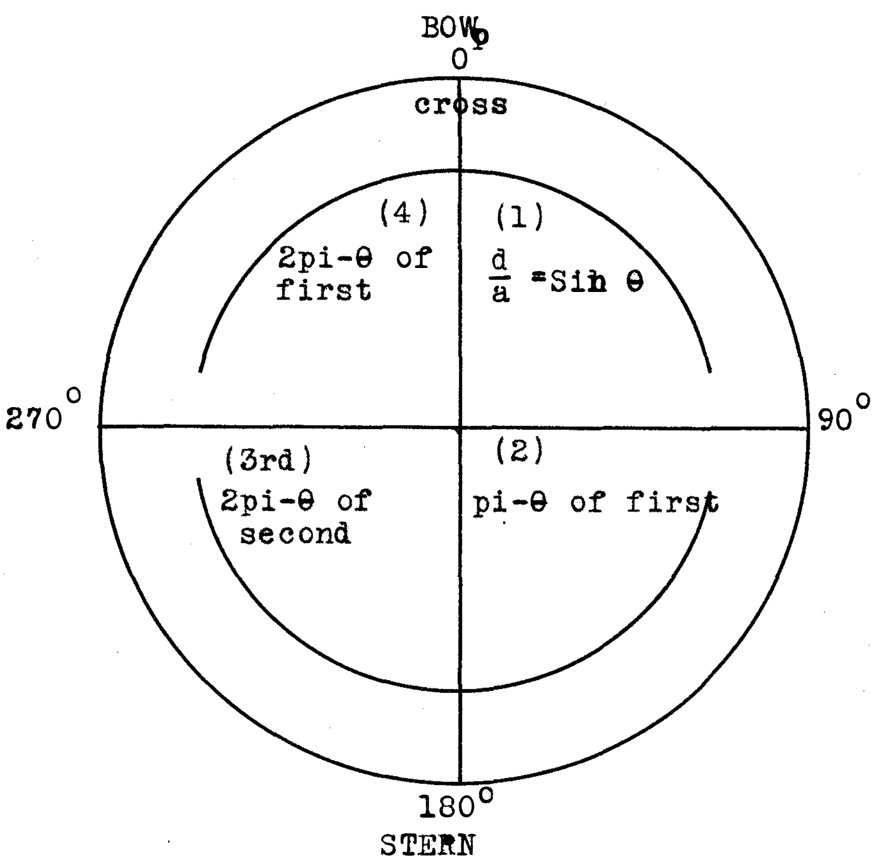
Theoretical Calibration of the SE 4215 Compensator.

Cross Calibration.

Step	RV	Sine.	θ
32	0	.0000	0°-
33	2	.0500	2°-52'
34	4	.1000	5°-44'
35	6	.1500	8°-38'
36	8	.2000	11°-32'
37	10	.2500	14°-29'
38	12	.3000	17°-27'
39	14	.3500	20°-29'
40	16	.4000	23°-35'
41	18	.4500	26°-45'
42	20	.5000	30°-
43	22	.5500	33°-22'
44	24	.6000	36°-52'
45	26	.6500	40°-33'
46	28	.7000	44°-25'
47	30	.7500	48°-35'
48	32	.8000	53°-52'
49	34	.8500	58°-47'
50	36	.9000	64°-51'
51	38	.9500	71°-12'
52	40	1.0000	90°-

1st Quadrant.





Theoretical Cross Calibration
For
SE 4215 Compensator.

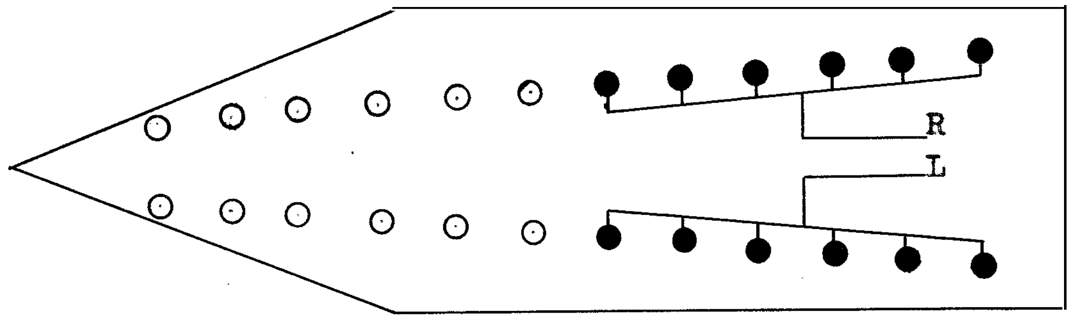
(B.B.L. - 40 Inches)

Stern	Step	Bow
	64	
	63	
	62	
	61	
	60	
	59	
	58	
	57	
	56	
	55	
	54	
	53	
90°-	52	90°-
108°-48'	51	71°-12'
115°-09'	50	64°-51'
121°-13'	49	58°-47'
126°-08'	48	53°-52'
131°-25'	47	48°-35'
135°-35'	46	44°-25'
139°-27'	45	40°-35'
143°-08'	44	36°-52'
146°-38'	43	33°-22'
150°-	42	30°-
153°-15'	41	26°-45'
156°-25'	40	23°-35'
159°-31'	39	20°-29'
163°33'	38	17°-27'
165°-31'	37	14°-29'
168*-28'	36	11°-32'
171°-22'	35	8°-38'
174°-16'	34	5°-44'
177°-08'	33	2°-52'
180°-	32	0°-
182°-52'	31	357°08'
185°-44'	30	354°-16'
188°-38'	29	351°-22'
191°-32'	28	348°-28'
194°-29'	27	345°-31'
197°-27'	26	342°-33'
200°-29'	25	339°-31'
203°-35'	24	336°-25'
206°-45'	23	333°-15'
210°-	22	330°-
213°-22'	21	326°-38'
216°-52'	20	323°-08'
220°-33'	19	319°-27'
224°-25'	18	315°-35'
228°-35'	17	311°-25'
233°-52'	16	306°-08'
238°-47'	15	301°-13'
244°-51'	14	295°-09'
251°-12'	13	288°-48'
270°-	12	270°-
	11	
	10	
	9	
	8	

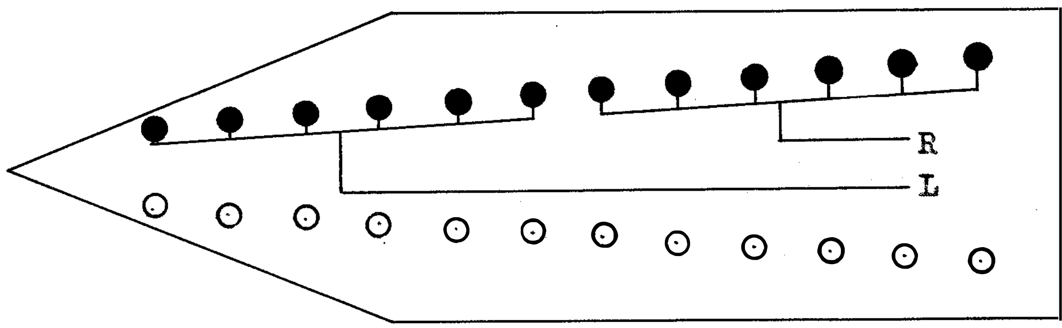
7
6
5
4
3
2
1

Stern Port Bow

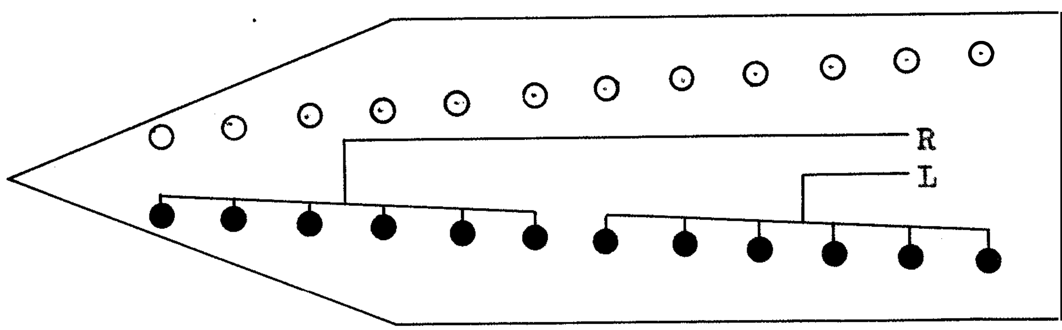
ARRANGEMENTS OF MICROPHONES USED WHEN RECEIVING ON THE FOUR POSITIONS OF THE "CBM" "4125" COMPENSATOR.



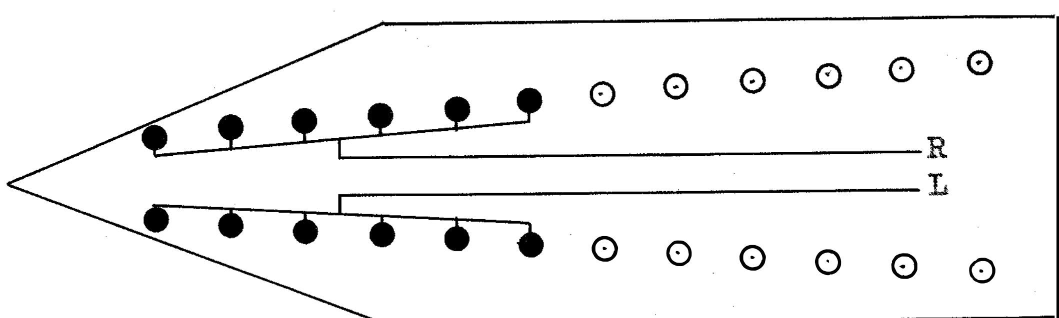
CROSS TAIL.



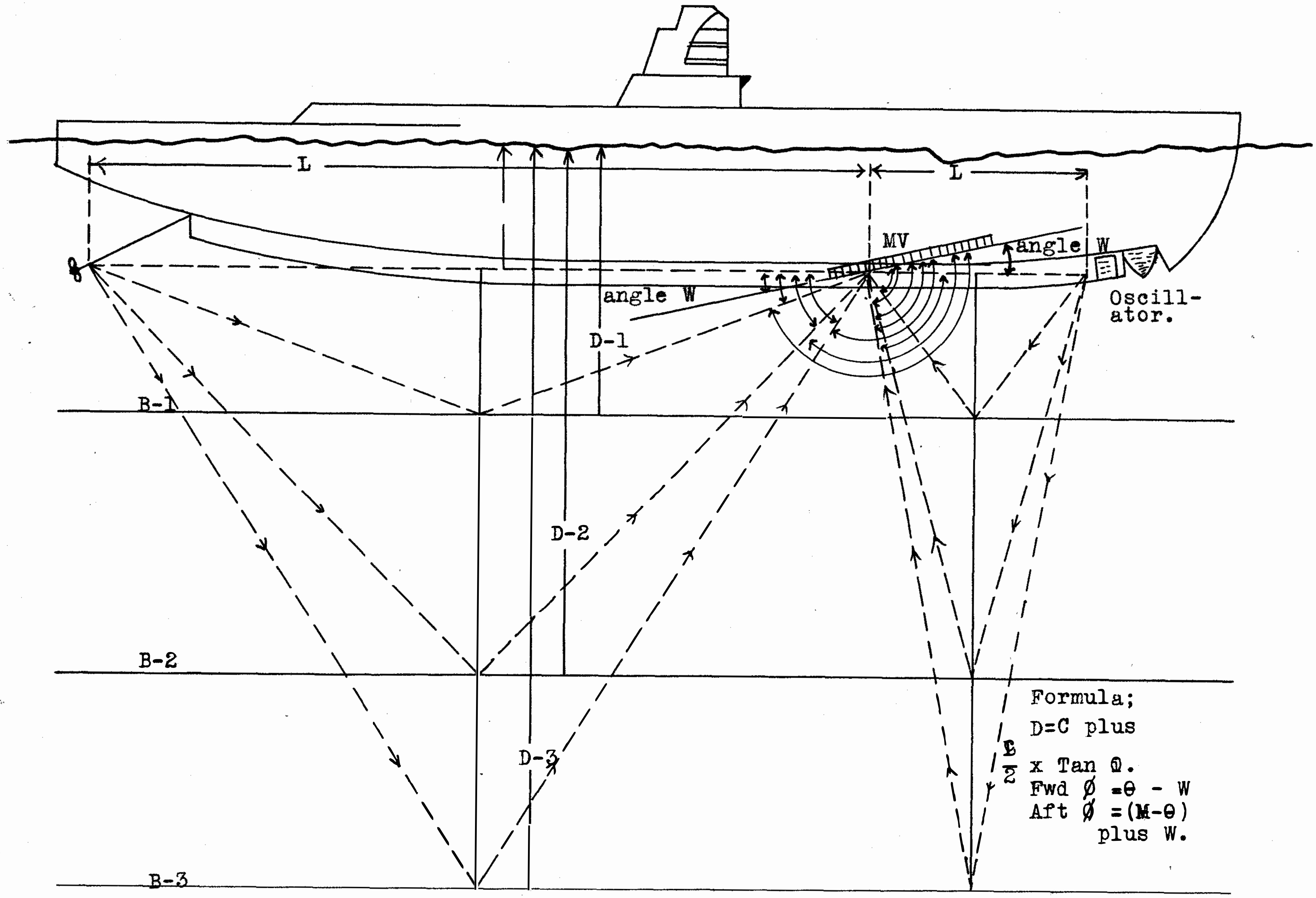
STARBOARD.



PORT



CROSS HEAD.


L
L
MV
angle W
angle W
Oscill-
ator.
D-1
D-2
D-3
B-1
B-2
B-3
Formula;
D=C plus
L/2 x Tan θ.
Fwd Ø =θ - W
Aft Ø =(M-θ)
plus W.

Sound Transmitters.

Four types of instruments have been developed for the transmission of subaqueous sound within the audible range. These are the Submarine Bell, the Fessenden Low Frequency Oscillator, the Type KA High Frequency Oscillator, and the KE High Frequency Oscillator.

Fessenden Low Frequency Oscillator.

The Fessenden Low Frequency Oscillator is an electrical sound apparatus, used, primarily, for thepurpose of transmitting subaqueous sound signals. It is also used for the reception of sound, and, in some cases, for determining the direction from which the sound is coming. This oscillator surpasses the submarine frequency around 540 cycles. As a receiver, it is not nearly as efficient as other types, being, in many instances, unable to detect the same sound that other receivers are capable of receiving. It is, however, quite sensitive to sounds of other oscillators of like frequencies. From this it can be assumed that the Fessenden Oscillator is a resonant instrument, in that, as a receiver, it only responds readily to frequencies of its own natural period.

The purpose sought in designing this oscillator was to provide an apparatus of superior qualities over the Submarine Bell. This is accomplished by use of a larger diaphragm, which is caused to vibrate in a plane perpendicular to the surface. This produces sound energy in a wave like form, consisting of regions of condensations and rarefactions.

There are three types of installations, viz., tank, keel and skin. The tank installation is so termed because the oscillator is submerged in water in some suitable tank contained within the vessel. The sound energy travels from the oscillator through the water, and, thence through the ship's hull. In the keel installation, the oscillator is installed within, or near the keel of the ship. In some installations, provisions have been made for lowering the oscillator until the diaphragm is somewhat below the bottom of the vessel. Recent experience has shown that this is not necessary, as the oscillator can be used advantageiously with the diaphragm flush with the ship's bottom. In the skin installation, the oscillator diaphragm forms a part of the ship's skin. A hole is cut in the side of the vessel below the water line, and the oscillators are secured in such a manner that the diaphragms are as nearly flush with the hull as construction will permit. To eliminate local disturbances, when the ship is in motion. It is very important that the water should pass freely over the diaphragm.

The standard installation consists of two oscillators. The present practice is to either install these oscillators one on each side of the ship diametrically opposite and well forward or in the keel, one forward and one aft.

The working parts of an oscillator:- The field magnet consists of two thick recessed steel rings clamped together by bolts. A coil of wire inserted in the spaced formed by the recess. Direct current supplies the coil of wire with field excitation.

The oscillator system consists of a copper tube supported one at each end, by two steel discs, a shaft, and the diaphragm of the oscillator. The discs, which are used to hold the copper tube, are clamped to the shaft. The shaft is secured and extends perpendicularly from the center of the inner surface of the diaphragm. The shaft passes through the center of each disc, which of course necessitates its passage through the center of the tube. The tube is in such a position that it fits in the air gap space between the inner surface of the magnetic field piece and the outer surface of the core

The core is a steel shaped cylinder upon which is wound two coils of wire of opposite polarity, one over each half of the core. It is contained within the copper tube, the shafting passing through its center. It is so secured by two brass castings that free movement is allowed the tube and shaft. The magnetic field and the core are stationary while the oscillating system is free to move back and forth in a perpendicular plane. The two coils of wire are in series with each other and are contained in an AC circuit.

The cable head is an iron casting which fits over the back steel ring of the magnetic field piece. The cover plate of the oscillator fits over the cable head. A large stuffing box is contained within the circular part of the cable head and serves to permit a four conductor armored cable to enter the oscillator. The stuffing box is rubber packed and as all points are provided with rubber gaskets, the oscillator is thus made airtight.

The diaphragm is about thirty inches in diameter which gives a surface area of more than two hundred times greater than the ordinary telephone diaphragm. The diaphragm is about five eighths of an inch thick. It is apparent that great energy is required to vibrate this diaphragm especially when it is opposite the water pressure on its outer surface.

Principle of Fessenden Low and High Frequency Oscillator when a conductor is placed in a magnetic field and cut by lines of force it will tend to move at right angles to accomodate the greatest number of lines of force. In accordance with the magnetic law of attraction and repulsion an electric condenser with a current flowing through it if given the necessary freedom will move when brought under the influence of a foreign magnetic field in such a way that it will be in a position to accomodate the greatest number of lines of force. The south polarity of the conductor will seek the north polarity of the magnetic field and the north polarity of the conductor will be attracted by the south polarity of the magnetic field. If the current in the conductor be reversed in direction the conductor will tend to reverse its movement diametrically opposite to the original motion. This action as utilized in the oscillator is accomplished essentially by the use of a powerful electromagnetic conductor in the form of a tube and an induction coil. The induction coil serves the purpose of inducing current in the tube of an AC character and as the tube is contained within the field of the electromagnet, it moves back and forth in synchronism with the changing polarities induced in it. The direction of the induced current is changed with great rapidity and by mechanical means the energy causing the tube to move is transmitted to the oscillator diaphragm which causes it to vibrate in the desires manner.

Use of the oscillator as a receiver:- When the Oscillator is used as a receiver, the electromagnet is energized by direct current in the same manner as in sending and the core windings are connected to telephone receivers. When incoming sound energy actuates the diaphragm of the oscillator, motion is imparted to the copper tube. The tube being at the right angle position to the magnetic field alternately varies the intensity of the flux threading through the core windings, with the result that a current of varying values flows in the core windings, which causes the diaphragm in the telephone receivers to vibrate in unison.

The essential parts necessary for the oscillator equipment other than the oscillators themselves are: the switchboard; motor-generator; motor starter junction box; connecting cables and head-phones.

The switchboard is generally located in the radioroom. The following devices are found to be mounted and wired to the switc board:-

(a) The oscillator field switches, No 1 and 2.
(b) One motor line switch.
(c) One motor starter control switch.
(d) One switch for connecting the oscillator for sending and receiving positions. This switho is called SEND and RECEIVE switch.
(e) One AC voltmeter.
(f) One telegraph key with inclosed contacts.
(g) Two resistances units shunted across oscillator field switches for the purpose of consuming the full discharge with open key.
(h) Two field pilot ammeters.
(i) Two core switches.
(j) Two motor line fuses.
(k) Four Oscillator field fuses.
(l) Four Oscillator core fuses.
(m) Twenty terminals for external wiring.
(n) Two binding posts for connecting telephone receiver cords.
(o) One pair of head phones with cords.

The motor generator consists of a direct current motor and an alternating current generator. It is for the purpose of supplying single phase AC of 540 cycles at 180V to core windings of the oscillators when the oscillators are used as transmitters. The rotors of the AC end are mounted on the same shaft with the armature of the DC motor end. The running speed is 2025 RPM. The stators are excited from the DC supply. The DC supply is taken from the ships main.

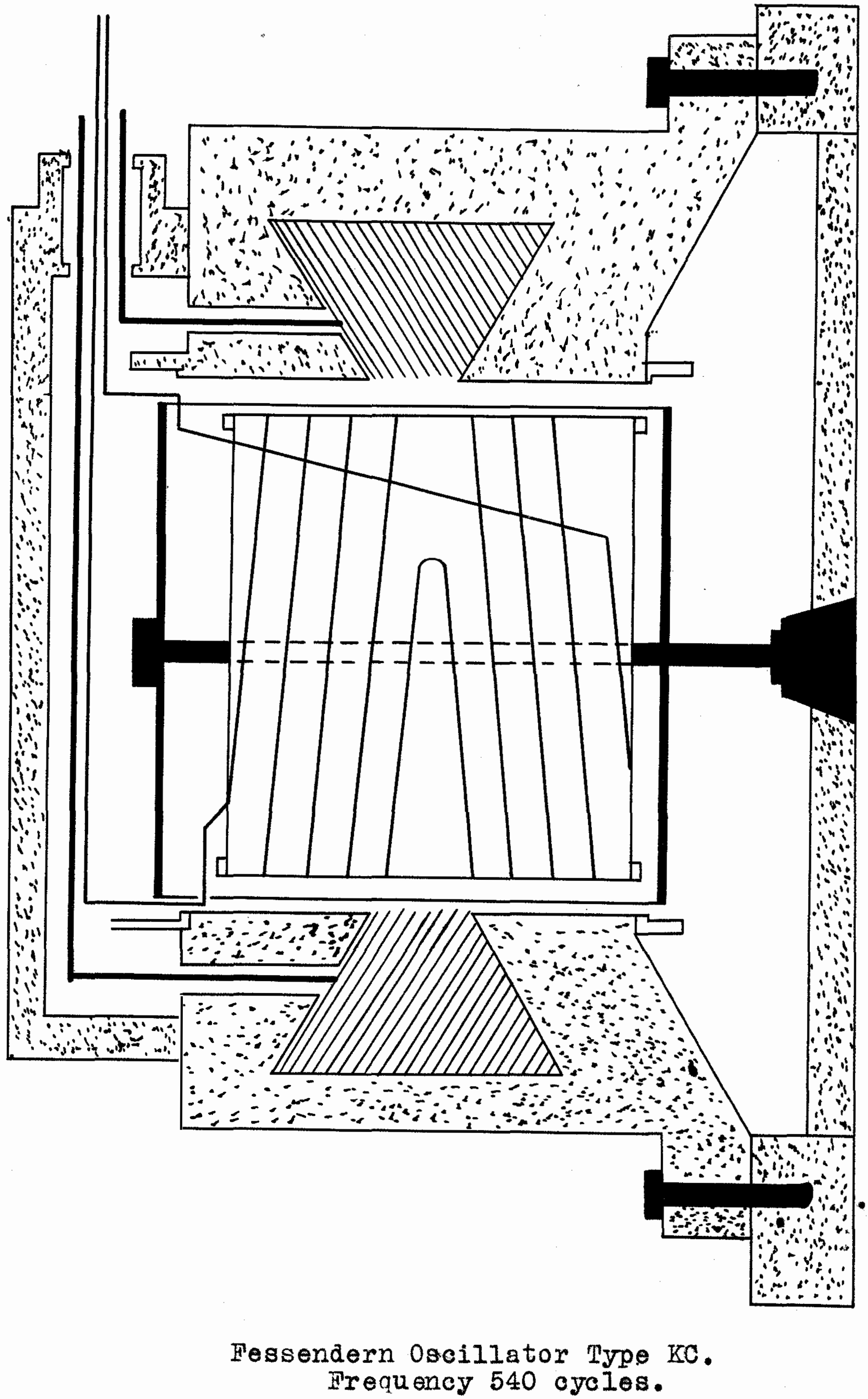
Readings of Meters Before Sending:

	One oscillator	Two oscillator
Frequency	558	578
Voltage	210	230
Amperage	none	none

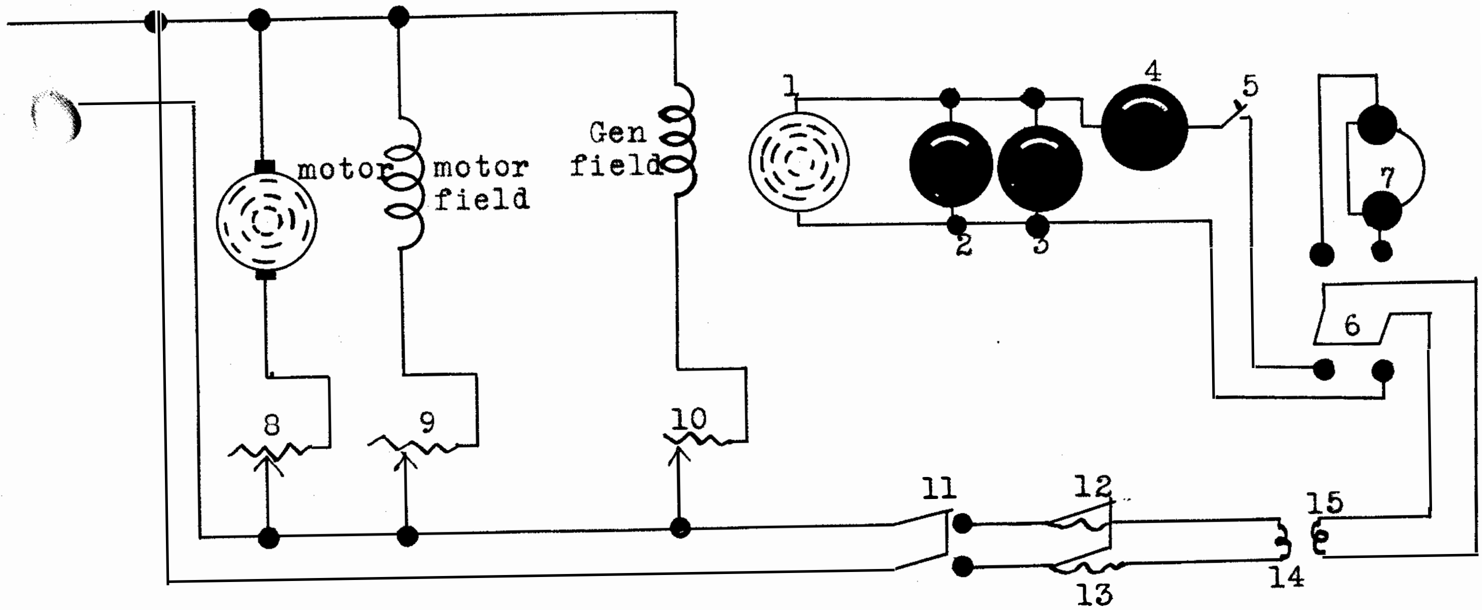
Readings of Meters while sending:

Frequency	540	540
Voltage	180	180
Amperage	11 to 14	20 to 25

To determine direction:- To determine direction of an incoming sound with an installation consisting of two oscillators one on each side of the ship the observer should receive first on one oscillator and then on the other noting on which oscillator the sound is of the greatest intensity. By swinging the ship toward the direction in which the loudest sound is heard, the sound source will lie dead ahead when the sounds at the two oscillators are of equal intensity. Any ambiguity that might exist can always be eliminated by swinging the ship and noting the difference in intensities.



Fessendern Oscillator Type KC.
Frequency 540 cycles.



Wiring Diagram of the KC Oscillator.

Nomenclature.

1. Collector Rings.
2. Voltmeter.
3. Frequency Meter.
4. Ammeter.
5. Key.
6. Double-Pole Double Throw switch
7. Phones.
8. Starter Resistance.
9. Motor field resistance.
10. Generator.
11. Number 2 line switch.
12. Number 1 line switch.
13. Line resistance.
14. DC Field.
15. AC Field.

The Type KA High Frequency Oscillator.

The Type KA High Frequency Oscillator is a sound signalling transmitter having a working frequency slightly above the normal range of subaqueous sound. It is superior to the low frequency oscillator due to the fact that it takes up less space; is more rugged; and has a greater range.

The type KA oscillator operates on the principle that motion can be produced by the application of alternately attracting bodies together by electromagnetism and separating them by the elasticity contained in the metal used for holding the bodies apart. By this application vibrations result consisting of moments of electromagnetic attractions and moments of elastical separation. By suitably securing the bodies to the back of a diaphragm the reaction produced when the bodies alternately come together and separate causes the diaphragm to oscillate.

The essential parts of the equipment are the oscillator the main control panel, the auxiliary control panel, the motor generators, the automatic starter, control button and the auxiliary operating key.

The motor generator is a 2 KW machine supplied by direct current of 125 volts, and capable of generating alternating current of 1100 cycles at 190 volts.

Echo Sounding.

Stop Watch Method:- The average speed of sound in water is considered to be 4800 feet (800 fathoms) per second. A sound in going to the bottom and returning to the surface travels twice the distance from the ship to the bottom. If a sound is emitted by the transmitter and heard with the sound receiver one second later the depth is 400 fathoms (½ second 200 fathoms; ¼ second 100 fathoms, etc) It is entirely practicable to determine the depth roughly by the stop watch method in depths from 160 fathoms to the extreme depths at which the echoes of the transmitter can be heard. Hold the stop watch in left and push in on the starting button at the same time depressing the transmitting key. Listen for the echo with the head-phones of the compensator. Note the number of seconds and fifths of a second that have elapsed at the instant the echo is heard. Compute the depth by multiplying the total number of fifths of a second by 80 fathoms. Some practice will be required in obtaining simultaneously in starting the watch and sounding the transmitter.

Echo sounding, depth finder method:- Methods of echo sounding by the use of Sonic depth finders are described in the instruction books furnished with the various types of depth finders. It may be well to mention here, however, that when sending in shallow water, the AC potential should be reduced in order to avoid the prolonged sound impulses which are contained in the sound impulses which are contained in the sound impulse when full power is used and which would overlap the returning echo interfering with accuracy of device.

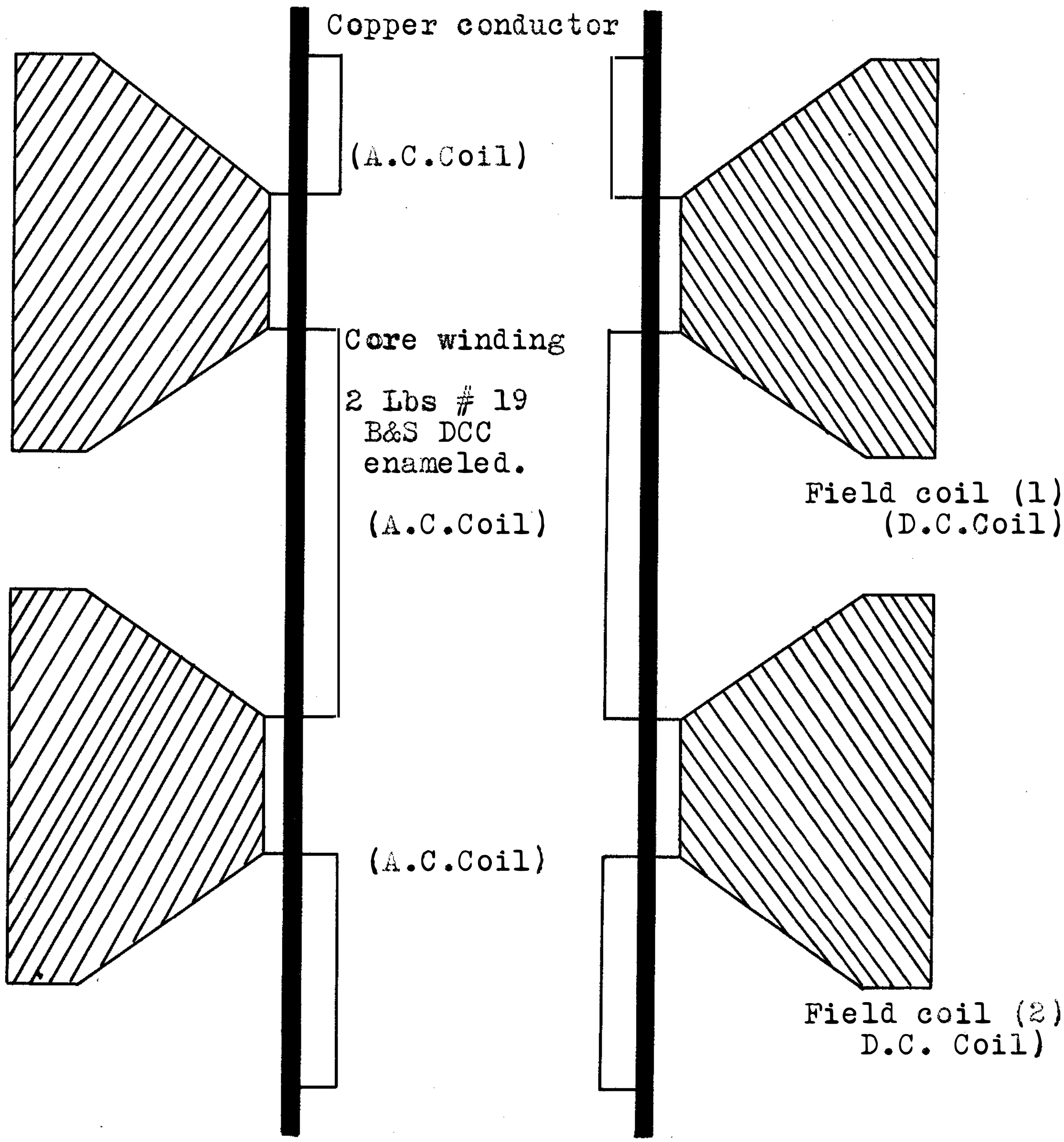
Maintenance.

Motor Generator:- If properly installed in a dry clean location little trouble will be encountered in maintaining the motor-generator in proper operating condition. The usual attention to cleanliness of the machine, lubrication of bearings and adjustments of brush tension on commutator and slip rings is required. This machine should be inspected frequently and troubles arising from improper wear of the commutator, poor connections at the terminals, improper lubrication, etc., corrected. Spare brushes and brush holding springs and spare bearings will be found in sound transmitting spare parts box

Automatic Starter:- The automatic starter is of the magnetic lock-out type. Failures in this device are usually due to burned out magnet coils. Trouble with the starter can generally be avoided by frequently inspecting it while the operator stops and starts the motor-generator with a remote control panel. If a faulty performance of circuit breaker or clapper switch is noted proper adjustment should be made before continuing the use of the apparatus. A limited number of spare coils and contactors are carried on board in the sound transmitter spare parts box.

Troubles likely to occur with oscillators:- An understanding of the principles set forth above is necessary in order that the sound transmitter may be properly assembled and connected after repairs have been made. The failures which may be looked for in sound transmitter units are grounds, burned out windings, broken connection and cracked tuned discs. In some cases the expansion rod nuts may work loose, but this is not likely to occur except in the case of a unit which has been disassembled and lock washer omitted when reassembling.

Grounds in the DC field circuits will show up on the ground detector lights in the ships main switchboard, and also will affect the field ammeter on the sound transmitter control panel. If enough current is shunted to the ground, the field and likewise the signals emitted will be weak. Grounds in the core circuit will result in an increase of current as shown by the AC ammeter. Signals will also be weak or the sound transmitter may fail to function entirely. Opens in with core or field circuits may be detected at once by failure of the field or AC ammeters to register when the respective circuits. Are closed. First test fuses then check the connections to the junction box near the unit with a magnet before proceeding to open up the unit itself. When winding the transmitter unit first release the compressed air by inserting a small nail in the top of the case cover and pushing down on the ball in the check valve. Next, remove the case cover and ring out the circuits from the control board to the transmitter terminal. The two terminals which are diametrically opposite each other are for the armature core. the other two are field terminals. To test out the two filds separately, it will be necessary to remove the jumper between the main terminals and the upper field piece about one inch outward from the main terminal to which the smaller wires of the imput cable are connected. If the trouble is detected in the upper field, this coil may be removed by disassembling the transmitter unit



COIL ARRANGEMENT OF "KE" OSCILLATOR.

Sonic Depth Finder.

Due to the fact that all depth finders primarily measure the time elapsed between the transmission of a signal and the reception of its reflection from the bottom of the sea, some method of speed control must be used to take care of the rise and fall of the line voltage and changeable load due to fiction.

Constant speed is imperative and in types 1370 and 1987 this is accomplished by means of a tuning fork, developed and controlled by the LEEDS and NORTHRUP COMPANY OF PHILADELPHIA.

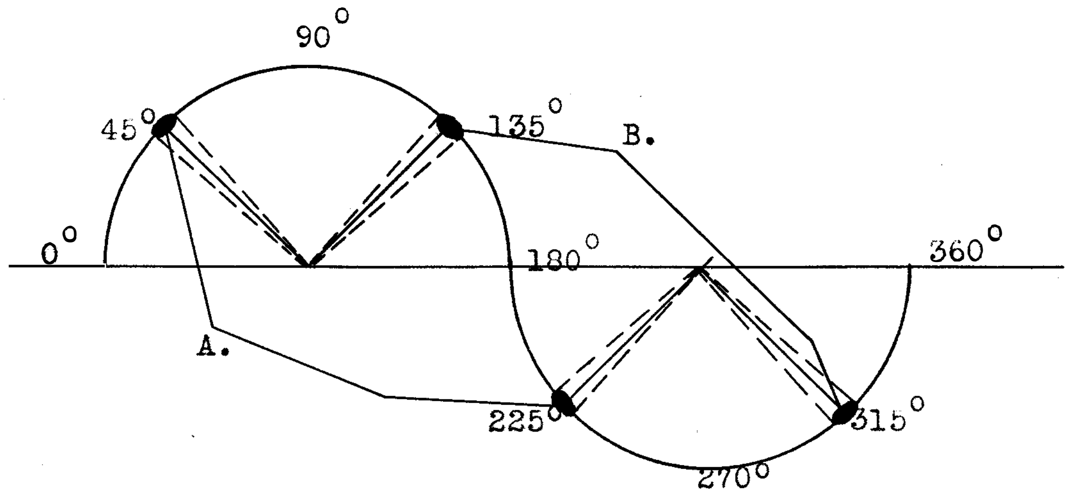
The fork is made to vibrate by means of a solenoid between the prongs. The solenoid is energized on the outward swing. The natural period of the tuning fork is 60 cycles but by means of sliding weights on the ends of the prongs and a thumb screw in the vase, its frequency can be varied between fifty and seventy-five cycles. The output of the rotor converter is about 70 volts and a transformer is placed in the circuit to enable commercial lamps to be used for its synchronization. Also with a great potential, a greater change of speed control is obtained.

The tuning fork circuit consists of transformer secondary, a one ohm coil, the synchronizing lamp (100 watts) and two contacts on the fork arms, the fork should be adjusted so that the circuit is closed twice for each cycle of the output of the rotor converter. Upon starting the Sonic Depth Finder the rheostat is used to synchronize the fork, with the output of the rotor converter. Thereafter, constant speed is maintained by the fork.

If the motor speeds up, the contacts of the fork will close at a point on a cycle where the potential is the highest, and as the resistance is non-conductive, the current is proportional to the potential. This increased load has a tendency to slow the motor down, as a shunt motor has a constant speed with a constant load. If the motor slows down due to a drop in the line voltage or change in mechanical load, the fork is again out of synchronization, while the output and contact is made at a lower potential, consequently the current is less and the motor speeds up. The synchronization lamp and the one ohm coil act as a constant load for the shunt motor. Condensers are shunted around the AC and DC fork contacts to take up the arc.

Depths from 20 fathoms up to the limit can be measured with the Sonic Depth Finder. All types work on the same principle.

SONIC DEPTH FINDER.



A and B Contact Arcs.

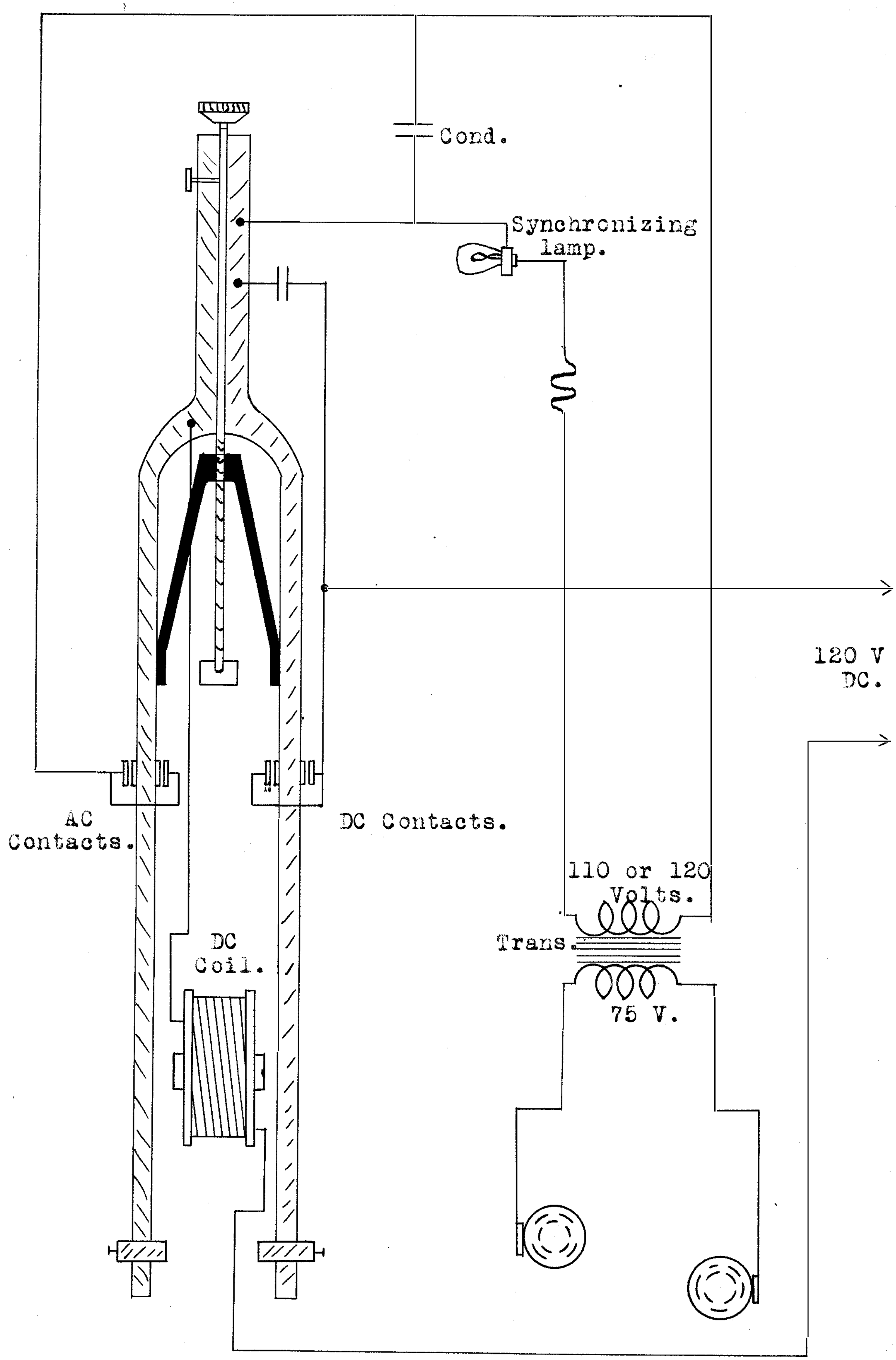
When properly adjusted, the tuning fork should make contact at 45 degrees and 225 degrees, or at 135 degrees and 315 degrees.

Formula:- Time x 400 (fathoms) = Depth.

Note:- Since sound travels 4800 feet per second, or 800 fathoms per second, 400 fathoms is used which will give the depth one way only.

175 fathoms is the limit for most compensators, while the Sonic Depth Finder has a much greater limit.

WIRING DIAGRAM OF TUNING FORK.



The Sonic Range and Depth Finder
Type SE 1378 and SE 1987.
SUMMARY.

The Sonic Rangefinder is a device used for determining the distance between two stations be means of sound waves. It operates in accordance with the law that the distance a sound travels in a uniform medium in a given time is equal to the product of the time interval and the velocity of the sound wave. In principle it is the connecting link between an MV or some other sensitive type of sound receiver and a sound transmitter of the oscillator type which serves to measure the time required for sound signals to travel from the transmitter to the receiver. It is a simple rugged piece of apparatus that only requires ordinary care and which can be quickly and easily calibrated or checked for accuracy by means of a stop watch.

Description:- Mechanical. The mechanical construction of the Sonic Rangefinder can be understood in principle by referring to Drawings (RX 55A)-143A) and (RX 55A)-144A) wherein each member is designated by the same numeral. A disk (1), carrying a vertical axis (2), is driven at uniform speed by means of a rotary converter (3), whose armature shaft carries a worm that engages in a gear (4), which is keyed to axis (2), at its lower end. The top of the disc (1) is covered with canvas or other material to form a friction surface for driving the relatively small friction wheel (5), which engages with shaft (6) by means of a slot and slide arrangement such that member (5) is free to slide along number (6) but causes these two members to rotate together. The alignment of shaft (6) is such that its axis is parallel with the surface of disc (1) and intersects the axis of pinion (2) extended upward. Shaft (6) is set in a groove such that this bearing can move slightly up and down so as to allow the pressure between members (1) and (5) to be adjusted by varying the tension on spring (9). Shaft (6) carries two cam-shaped discs on the end supported by bearings (8) one of which (10) has a single saw tooth shaped depression and the other of which (11) carries ten such depressions equally spaced about its perimeter.

Two spring members (12) and (13) bear against the two cam discs, respectively, and by dropping into depressions as the cams rotate serve to operate contact points (14 & (15) in such a way as to temporarily close an electrical signalling circuit. An arrangement is provided whereby either spring member can be made to operate against its respective cam, but which prvents both members from operating at the same time, number (16) which carries a special spiral thread engaging in a nut member (17) serves to move friction wheel (5) along a radius of disc (1) and measured the radius of the circle it scribes on the surface of the disc by means of a micrometer scale on cylinder (18) which is integral with (16).

Electrical Drawing (RX 55A-145A):- Is a schematic diagram of the electrical circuits employed in the Sonic Range Finder. By means of a double-pole, double-throw switch (left hand corner) either the hand sending key provided for the submarine sound oscillator or a radio sounding key can be shunted through the fixed coil of a variocoupler (V) and one or the other of the pairs of contact points (14a) or (15) thus allowing the contacts which are operated by their respective cams to serve as an automatic transmitting key for either the radio or sound installation. The current for operatin the sound oscillator enters the Rangefinder through switch (AC).

The three terminals marked (L) (C) & (R) have to do with the telephone circuits and each connects directly with the corresponding terminal of the MV compensator. The two leads from each phone of a double receiver head set connect to the two sets of telephone terminals respectively. The three way switch interposed in the telephone circuits, permits of connecting in the two receivers in the following ways:

(a) When set at position (MV) the receivers are both connected through the compensator in the usual way and can be used for the determining of the direction of any sound signal or echo.

(b) When set at position (E) one phone connects to the compensator and the other connects across the secondary coil of the vario-coupler; thus allowing the operator to hear the sound signal or its echo in one ear and the transmitted signal in the other phone By means of the vario-coupler the intensity of the transmitted signal can be adjusted approximately to equality with the sound heard in the other phone.

(c) When set at position (S) one phone shunts the one ohm coil in the AC output circuit from the rotary converter. This setting enables the operator to synchronize the motor generator with the fork by adjusting the regulating rheostat such that no beats are heard. It also serves to quickly check whether or not the speed of the motor generator is correct.

Adjustment and regulation of the speed of the rotary converter used to drive the Rangefinder is accomplished by means of a tuning fork arrangement developed and controlled by the LEEDS NORTHRUP AND COMPANY OF PHILADELPHIA, the principle of the operation of which depends upon making the (AC) power supplied by the motor generator such a function of the phase relation between this current and the tuning fork that the load on the motor increases when the current gains in phase and decreases when it looses in phase with respect to the fork. By varying the load on the motor in this way it speed can be kept constant when the variation of load or applied voltage is as great as about ten percent.

The speed of the motor is determined by the frequency of the tuning fork and this can be adjusted to any value between 50 and 75 complete vibrations per second by placing sliding weights on the prongs and by means of heavy springs which press between the prongs and which can be moved forward or backward by means of a thumb screw arrangement attached to the base upon which the fork is mounted. The fork is kept vibrating by the well known method of placing an electromagnet between the prongs, the DC thru which, is made and broken by means of a pair of contact points which are so operated by one of the prongs that the circuit is made when the prongs swing outward and broken when the prongs swing inward beyond their normal rest position. Both the prongs of the fork and the motor operate on 125 volts DC and this current enters the rangefinder thru the double pole single throw switch so marked.

The single phase AC output from the rotary converter is taken from the motor armature windings by means of collector rings The voltage is boosted to 110 or 220 by means of the transformer, the secondard of which is included in a circuit containing a 1 ohm coil (1), a 100 watt lamp, one prong of the fork and either of two pairs of contact points, one pair of which is closed when the prong swings inward and the other pair of which is closed when the prong swings outward. Thus the current is made and broken twice during each complete vibration of the fork. The power drawn from the circuit during the intervals when the circuit is closed depends upon the phase relation between the voltage and the fork so as to increase the load and any decrease in speed will cause a lessening of the load for this is the only condition of stable equilibrium.

Conclusion:- The device described may be regarded as an automatic signalling key designed to send out equally spaced signals of the character of short dashes and provided with means for continuously varying the period between signals through all the values included between infinity and a certain minimum value that is determined by the apportionment and dimension of the various parts.

MATHEMATICAL EQUATIONS OF THE SONIC DEPTH FINDER.
Type SE 1378.

1st equation $D = VT$

2nd " $T = Np$

3rd " $p = \frac{Pr}{CS}$

4th " $\text{Distance} = \frac{VNPr}{CS}$

5th " $\text{Depth} = \frac{VNPr}{2CS}$

The Speed of the disc which is coupled to the motor by reduction gears, makes one complete revolution every ten seconds.

P = RPM of disc. (1 in every 10 seconds.
p = Period of revolution of small friction wheel.
Circumference = 2 x pi x r
r = Radius of friction wheel or 1 inch.
S = Radius scribed by friction wheel.
(Taken from micrometer scale reading on handle).
2 x pi x S = Circumference scribed by friction wheel.
N = Number of signals in water.
C = Number of teeth in cam used.

From this equation, we find that the period of revolution of the friction wheel which determines the speed at which the signals are sent out is computed from the following formula:

$$p = \frac{2\text{pi}rP}{2\text{pi}S} \text{ or } \frac{Pr}{S}$$

TIME LAGS.

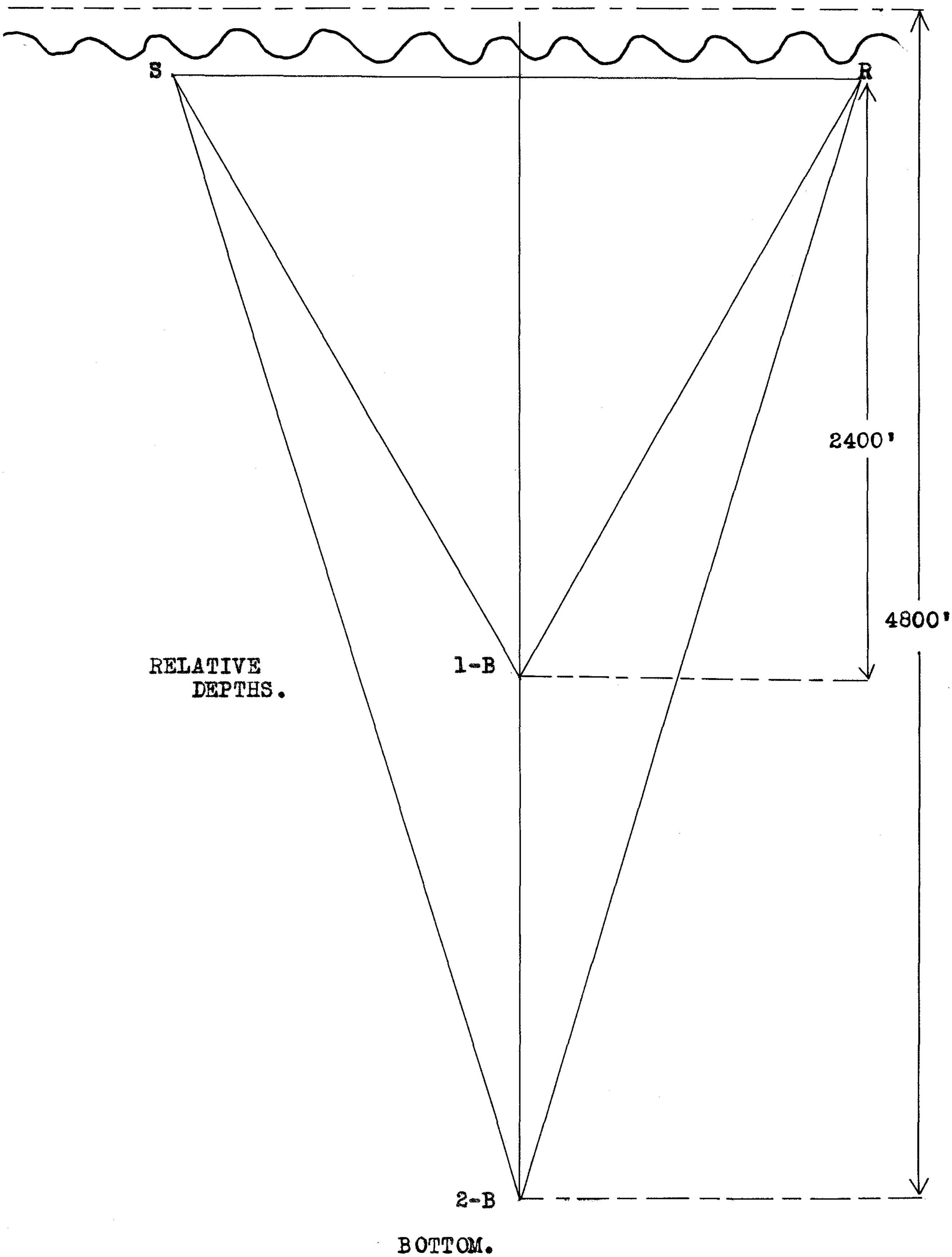
The following formulae are used in computing the time lags in seconds or fraction of seconds:

$$\text{Tan } A = \frac{R}{2H}$$

$$\text{Distance sound travelled (total)} = \frac{R}{\text{Sin } A}$$

$$\text{Time lag in seconds} = \frac{D-R}{4800}$$

R = Range.
H = Depth.


S
R
2400'
4800'
1-B
RELATIVE
DEPTHS.
2-B
BOTTOM.

The Fathometer.

PRINCIPLES OF OPERATION.

The fathometer was designed and is completely controlled by the Submarine Signal Company. The system 1, was designed primarily for the purpose of determining depths of water by measuring the time elapsing between the creation of a submarine sound on a vessel and the return of the sound to the vessel after reflection from the bottom of the ocean. The velocity of sound in water is known, consequently, if the above time interval is carefully measured, it is a simple matter to calculate the depth of the water. The Fathometer is so designed that no calculations are necessary as the device, which indicates the time interval, is calibrated to show upon its face, not time, but fathoms of depth.

Fathometer System 1 consists of:

(1) The time measuring device known as the Fathometer unit.

(2) The device used on the vessel to create the submarine signal whose time interval to the bottom of the ocean and return is to be measured is known as the oscillator.

(3) The device by means of which the arrival of the reflected sound waves at the vessel can be detected. This submarine sound receiver is known as a valve Hydrophone or Type G microphone.

(4) The device used to reduce the disturbing noises created by the movement of the vessel through the water and to amplify the intensity of the reflected sound waves is a Filter.

(5) The generator required for the operation of the oscillator.

(6) The wiring, switches, and circuits required to connect the above apparatus in a manner to insure successful operation.

The Fathometer Unit:- All of the time measuring apparatus together with the switches and other associated apparatus are contained in a metal box the outside dimensions of which are each about thirteen inches. The front face or cover of the box a brass casting in which a circular hole is fitted with a glass dial through which the scales and indicators can be seen. The box is thus practically hermetically sealed and never requires to be opened except for the purpose of maintenance.

The purpose of the Fathometer Unit is to measure the time elapsing between the creation of a signal and the return of an echo. This is accomplished in the present instrument by revolving an opaque disc at a uniform and known speed. This disc carries a pointer in reality a narrow slot in the disc through which a light shows, and this pointer passes near a fixed scale calibrated in fathoms.

At the instant the slot in the disc passes the zero of the scale a circuit is closed, by means of a cam, which energizes the oscillator for an instant and causes it to emit a very short train of submarine sound waves of a frequency of 1050 cycles per second. These sound waves are reflected from the bottom of the sea and when they reach the vessel, actuate the hydrophone and indicates to the observer their arrival. The position of the slot relative to the fixed scale can then be read and that reading indicates the depth of the water at that particular point.

Submarine sounds travel at the rate of about 4800 feet a second, so that, to make soundings in the shallow water, a very short interval of time must be measured. Thus, if a depth of 10 fathoms is to be measured, the Fathometer must be capable of indicating accurately an interval of one fortieth of a second. This means that the arc traversed by the slot in that short time must be long enough to be readily apparent to the observer. This is accomplished in the Fathometer Unit by using a disc of fairly large radius and by revolving the disc with its slot pointer at a fairly high speed. The Fathometer is designed in such a way that the disc, when used for measuring shallow depths, makes four complete revolutions a second. For measuring the depths of shallow water the illuminat used, back of the slot, is a Goissler tube which is connected with the hydrophone in such a way that the tube is lighted when the hydrophone is agitated by the echo of the submarine signal created by the oscillator. By means of a cam, a submarine signal is created by the oscillator for every revolution of the disc so that there are four possibilities per second of the illuminated pointer indicating the depth. This rapid succession of signals makes it extremely for the observer to read the depth on the scale at a point where the light flashes. This light is reddish in color so that the scale for shallow deptchs, that is, from 10 to 100 fathoms, is frequently spoken of as the RED LIGHT METHOD.

The disc in the red light method makes one revolution in one quarter of a second which corresponds with the time which it takes a submarine sound to travel to and from a reflecting surface 100 fathoms distance. If greater depths are to be measured it is necessary to revolve the disc less rapidly. Provisions are made in the Fathometer Unit whereby the trains of gears employed can be quickly changed so that the disc, instead of revolving four times each second, makes a single complete revolution in one and one half seconds. This change of speed necessitates a new scale on which depths can be read directly up to six hundred fathoms. When the disc is revolving at this slower speed and measurements are to be made in deep water, a second slot on the disc is employed which is diametrically opposite that used for shallow water. Therefore when the gears are shifted to cause the disc to revolve more slowly a small incandescent lamp back of the second slot is lighted permanently and, shining through the slot. makes the finger of light which moves out over the outer scale of the fathometer once in every 1½ seconds. This light is that of the incandescent light, hence this method of reading depths is frequently called the WHITE LIGHT METHOD.

Attention should be called to the fact that in the RED LIGHT method the zero of the scale, that is, the instant when the submarine signal is created, is at the top of the inner scale, where as the corresponding point in the WHITE LIGHT method is at the bottom of the outer scale.This prevents any confusion between the two scales.

In using the WHITE LIGHT method, the observer uses one or two telephone receivers which are connected in the plate circuit of the detector tube. The observer, when he hears the echo, notes the position of the illuminated slot pointer on the outer scale. Thus for depths less than six hundred fathoms a depth measurement can be made in this way once in every second and one half.

It must be clearly understood that the two methods are not rigidly confined to the depths above described, that is, RED LIGHT from one to one hundred fathoms and WHITE LIGHT from one hundred to six hundred fathoms. On the contrary, if properly operated, the two may be made to overlap to a very considerable extent. Thus with the WHITE LIGHT method readings have been made at depths less than fifty fathoms and with the RED LIGHT method, when proper precautions are taken, depths far greater than 100 fathoms are read.

The necessity for taking proper precautions arises from the fact that in a RED LIGHT method a second signal is given at the end of each quarter of a second. If the depth of water is greater than one hundred fathoms there would be an uncertainty in the reading. To avoid this ambiguity, a push button is provided, which, when depressed, holds the oscillator circuit open after a signal until the echo has registered. The observer notes the number of revolutions of the disc between the signal and the reception of a signal. He then knows that the depth is the reading of the fathometer plus 100 times the number of complete revolutions.

This same push button is used in a similar way with the WHITE LIGHT method to record depths greater than 600 fathoms. In this case the depth is the reading of the fathometer plus 600 times the number of complete revolutions between the emission of a submarine signal and hearing the echo.

The fathometer unit is essentially a time measuring device and consequently the speed of the revolutions of the disc must be accurate. The small motor, which is housed inside of the fathometer and produces the rotation of the disc maintains a constant speed as long as the ships voltage line remains constant. Changes in speed of the motor can be made by means of the rheostat, in the lower left hand corner. A special vibratory tachometer is provided to indicate the speed of the motor. This frequency motor can be seen at the upper right hand corner of the face of the fathometer unit.

An adjustment is provided on the inside surface of the rotating dial graduated in fathoms in order that the depth reading may be made to indicate either depth from the surface or depth below the ship. This adjustment is graduated in fathoms so that if for instance the ship is drawing 3 fathoms of water, the marker should be set on that figure on the dial. To make the instrument read correctly this adjustment should be made whenever the draft is changed due to loading, although in many large ships the draft remains practically constant.

OTHER TYPES.

The modified types, SE 1987 is about one third in size and weight as the SE 1378. The rotary disc is covered with horned beam fibre instead of canvas. A tuning fork starter is also supplied and commutators are used to energize the keying circuit instead of cams.

The synchronizing light is behind a ground glass screen and it is not necessary to open the panel for operating purposes. All connections are external. Also the readings are given in revolutions per second.

THE END