CHAPTER 4

ANTISUBMARINE WARFARE

The detection of enemy submarines is one of the Navy's major problems today. There are many types of equipment in use that aid in the detection and tracking of submarines. As an aviation electronics technician, you will need to understand the principles used in these equipments. Once again, every effort is made to discuss as many different platforms and equipments as possible.

SONAR PRINCIPLES

Learning Objective: *Identify factors that affect the behavior of a sound beam in water.*

The word *sonar is* derived from the initial letters of SOund, NAvigation, and Ranging. The word *sonar* is used to describe equipment that transmits and receives sound energy propagated through water. Airborne sonar equipment is commonly called "dipping sonar," and is used aboard various helicopters. Sonobuoys, also a form of sonar, will be discussed later in this chapter.

The operating principles of sonar are similar to that of radar, except sound waves are used instead of radio frequency waves. When the sound wave strikes an object, some of the energy reflects back to the source from which it came. Since the speed of the sound wave and the time it takes to travel out and back are known, range can be determined. By knowing the direction from which the sound echo is reflected, the operator can determine the bearing information.

The type of sonar equipment that depends primarily on a transmitted sound wave and the reception of an echo to determine range and bearing of a target is known as echo-ranging or active sonar equipment. Another type of sonar equipment is referred to as listening or passive sonar. This type of sonar uses the target as the sound source. Although most sonar equipment can be used in either mode of operation, surface ships and aircraft generally use the active mode, and submarines use the passive mode.

In echo-ranging sonar equipment, the source of the sound wave is a transducer. The sonar transducer is a watertight unit that is used to convert electrical energy into acoustical energy and acoustical energy back into electrical energy. The transducer acts like a loudspeaker in an office intercom system, alternately converting electrical energy into mechanical energy and mechanical energy into electrical energy. The transducer acts like an underwater loudspeaker during transmission and an underwater microphone during reception. The sound waves produced by a sonar transducer are represented by the circular lines shown in figure 4-1. Refer to this figure as you read the following text.

When the diaphragm of the transducer moves outward, it moves the water next to the diaphragm. This produces a high-pressure area or compression in the water. When the diaphragm of the transducer moves inward, the water next to the diaphragm moves inward. Thus, a low-pressure or rarefaction is produced in the water. As long as the diaphragm is vibrating, alternate compressions and rarefactions travel outward from the transducer in the water. The distance between two successive rarefactions or two successive compressions is the wavelength of the

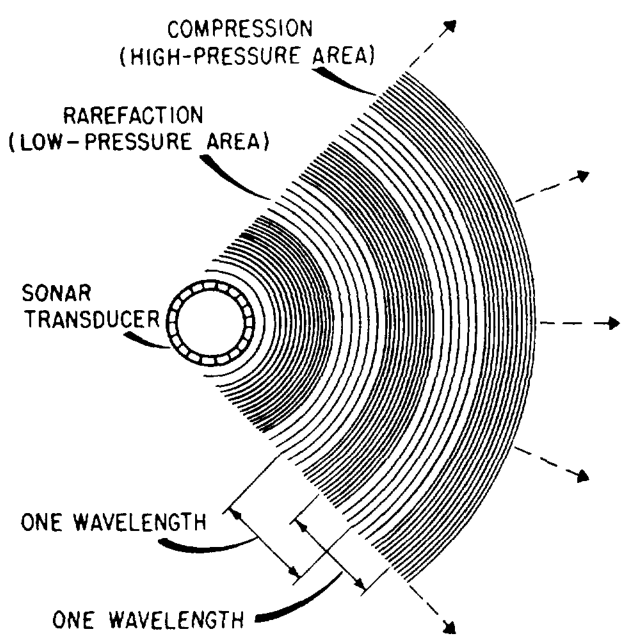

Figure 4-1.-Sound waves produced in water by a transducer.

sound wave. The frequency (in hertz) of the sound wave is the number of wavelengths that occur every second.

FACTORS AFFECTING THE SOUND BEAM

The particular sound waves of interest to the sonar operator are the waves that leave the sonar transducer in the form of a beam and go out into the water in search of a submarine. If the sound beam finds a target, it will return in the form of an echo.

The use of sonar equipment depends on the presence and the recognition of an echo from a target. Detection of the echo depends on the quality and relative strength (loudness) of the echo compared to the strength and character of other sounds, since they tend to mask or cover it.

The sonar operator should know what factors can weaken the sound beam as it travels through water, what factors in the seawater determine the path and speed of the sound beam, and what factors affect the strength and character of the echo. Any signal strength lost during the beam's travel through the water is known as "transmission loss." Some of the factors determining transmission loss are discussed in the following paragraphs.

Absorption and Scattering

Some of the sound energy emitted by the source will be absorbed while passing through the water. The amount absorbed this way depends on the sea state. Absorption is high when winds are great enough to produce whitecaps and cause a concentration of bubbles in the surface layer of the water. In areas of wakes and strong currents, such as riptides, the loss of sound energy is greater. Therefore, echo ranging through wakes and riptides is difficult because of the combined effect of false echoes, high reverberations, and increased absorption. Absorption is greater at higher frequencies than at lower frequencies.

Sound waves are weakened when they reach a region of seawater that contains foreign matter, such as seaweed, silt, animal life, or air bubbles. This foreign matter scatters the sound beam and causes loss of sound energy. The practical result of scattering is to reduce echo strength, especially at long range.

Reflection

Echoes occur when the sound beam hits an object or a boundary region between transmission mediums in such a manner as to reflect the sound or to throw it back to its origin. Reflection of sound waves sometimes happens when a wave strikes a medium of different density from that through which it has been traveling. This will occur in cases where the two mediums are of sufficiently different densities, and the wave strikes at a large angle. This happens because the sound wave travels at different speeds through the two different densities. For example, a sound wave traveling through seawater is almost entirely reflected at the boundary of the water and air. The speed of sound in seawater is about four times greater than the speed of sound in air, and the density of water is more than 800 times greater than that of air. Therefore, practically all of the sound beam will be reflected downward from the sea surface.

Similarly, when a sound wave traveling through the seawater strikes a solid object like a submarine, the difference in the density and the sound velocity in the two mediums is such that all but a small amount of the sound beam will be reflected. That portion of the beam that strikes surfaces of the submarine perpendicular to the beam will be reflected directly back to the origin as an echo.

In calm seas, most of the sound energy that strikes the water surface from below will be reflected back down into the sea. A scattering effect occurs as the sea gets progressively rougher. In these circumstances, part of any sound striking the surface is lost in the air, and part is reflected in scattering directions in the sea. In water less than 600 feet deep, the sound may also be reflected off the bottom. Other factors being equal, the transmission loss will be least over a smooth, sandy bottom and greatest over soft mud. Over rough and rocky bottoms, the sound is scattered, resulting in strong bottom reverberations.

Reverberation

When sound waves echo and re-echo in a large hall, the sound reverberates. Reverberations are multiple reflections. Lightning is an example of this from nature. When lightning discharges, it causes a quick, sharp sound; but by the time the sound of the thunder is heard, it is usually drawn out into a prolonged roar by reverberations.

A similar case often arises in connection with sonar. Sound waves often strike small objects in the sea, such as fish or air bubbles. These small objects cause the waves to scatter. Each object produces a small echo, which may return to the transducer. The reflections of sound waves from the sea surface and the sea bottom also create echoes. The combined echoes from all these disturbances are called "reverberations." Since they are reflected from various ranges, the y seem to be a continuous sound. Reverberations from nearby points may be so loud that they interfere with the returning echo from a target.

There are three main types of reverberation, or backward scattering of the sound wave. They are as follows:

1. There is reverberation from the mass of water. Causes of this type of reverberation are not completely known, although fish and other objects contribute to it.

2. There is reverberation from the surface. This is most intense immediately after the sonar transmission; it then decreases rapidly. The intensity of the reverberation increases markedly with increased roughness of the sea surface.

3. There is reverberation from the bottom. In shallow water, this type of reverberation is the most intense of the three, especially over rocky and rough bottoms.

Divergence

Just as the beam from a searchlight spreads out and becomes weaker with distance, so does sound. The farther the target is from the sonar transducer, the weaker the sound waves will be when they reach it. This is known as spreading or divergence.

Refraction

If there were no temperature differences in the water, the sound beam would travel in a straight line. This happens because the speed of sound would be roughly the same at all depths. The sound beam would spread and become weaker at a relatively constant rate.

Unfortunately, the speed of sound is not constant at all depths. The speed of sound in seawater increases from 4,700 feet per second to 5,300 feet per second as the temperature increases from 30°F to 85°F. Salinity and pressure effects on sound speed are not as extreme as the large effects produced by temperature changes in the sea. Because of the varying temperature differences in the sea, the sound beam does not travel in a straight line, but follows curved paths. This results in bending, splitting, and distorting of the sound beam.

When the sound beam is bent, it is said to be refracted. A sound beam is refracted when it passes from a medium of a given temperature into a medium with a different temperature. An example of this is a sound beam traveling from an area of warm water into an layer of cold water. The sound beam will bend away from the area of higher temperature (higher sound velocity) toward the lower temperature (lower sound velocity).

As a result of refraction, the range at which a submarine can be detected by sound may be reduced to less than 1,000 yards, and this range may change sharply with changing submarine depth.

Speed of the Sound Beam

As mentioned previously, sound travels much faster in seawater than in the atmosphere. Near sea level, sound travels through the atmosphere at approximately 1,080 feet per second. In seawater, that same sound beam will travel at approximately 4,700 to 5,300 feet per second.

There are three main characteristics of seawater that affect the speed of the sound wave traveling through it. These characteristics are as follows:

1. Salinity (the amount of salt in the water)

2. Pressure (caused by increased depth)

3. Temperature (the effect of which is calculated in terms of slopes, or gradients)

There is a high mineral content in seawater. The density of seawater is approximately 64 pounds per cubic foot, while fresh water has a density of about 62.4 pounds per cubic foot. This difference is caused by the salt in the seawater. Salt content in seawater is called the salinity of water.

The overall effect of increasing the salinity is an increase in the speed of the sound beam in the water. This means that as the sound travels through water of varying salinity, it travels faster through the water with more salt content. Such a change in salinity is considerable at the mouth of a river emptying into the sea. Elsewhere, the difference in salinity is too small to affect the rate of travel of the sound beam significantly, and may be ignored.

Since sound travels faster in water under pressure, the speed of sound in the sea increases proportionally with depth. This difference in speed is also very small and has little effect for the operator.

Temperature is the most important of the factors affecting the speed of the sound beam in water. The speed will increase with increasing temperature at the rate of 4 to 8 feet per second per degree of change, depending on the temperature.

The temperature of the sea varies from freezing in the polar seas to more than 85°F in the tropics. The temperature can also decrease by more than 30°F from the surface to a depth of 450 feet. Thus, the temperature is the most important factor because of the extreme differences and variations. Remember, the speed of sound in water increases as the temperature increases.

Depth and Temperature

Except at the mouths of great rivers where salinity may be a factor, the path of the sound beam will be determined by the pressure effects of depth and by temperature. The pressure effect is always present and always acts in the same manner; it tends to bend the beam upwards. Figure 4-2 illustrates the situation when the temperature does not change with depth. Even though the temperature does not change, the speed of the sound increases with depth. The speed increase is due entirely to the effect of pressure. Notice in figure 4-2 that the sound beam bends upward.

Figure 4-3 shows what happens when temperature increases steadily with depth. When the surface of the sea is cooler than the layers beneath it, the temperature increases with depth, and the water has a positive thermal gradient. This is an unusual condition, but when it does happen, it causes the sound beam to be refracted sharply upwards.

When the sea gets colder as the depth increases, the water has a negative thermal gradient. In this situation, the effect of temperature far outweighs the effect of depth, and the sound beam is refracted downward.

If the temperature remains the same throughout the water, the temperature gradient is isothermal

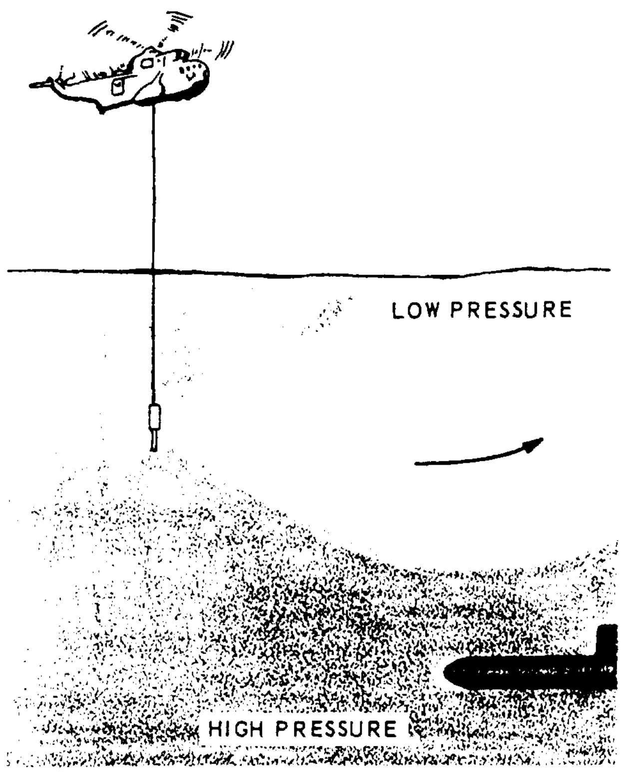

Figure 4-2.-Bending of a sound beam away from a high-pressure area.

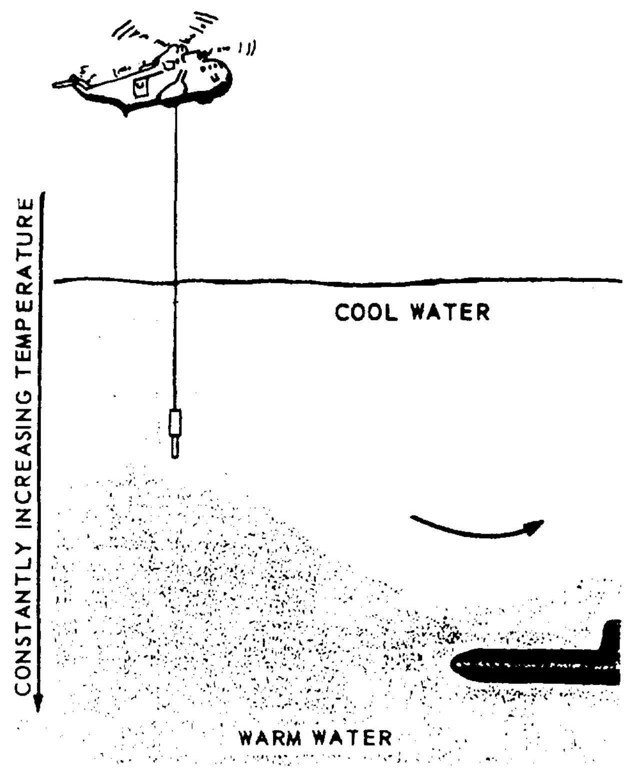

Figure 4-3.-The effect of a positive thermal gradient.

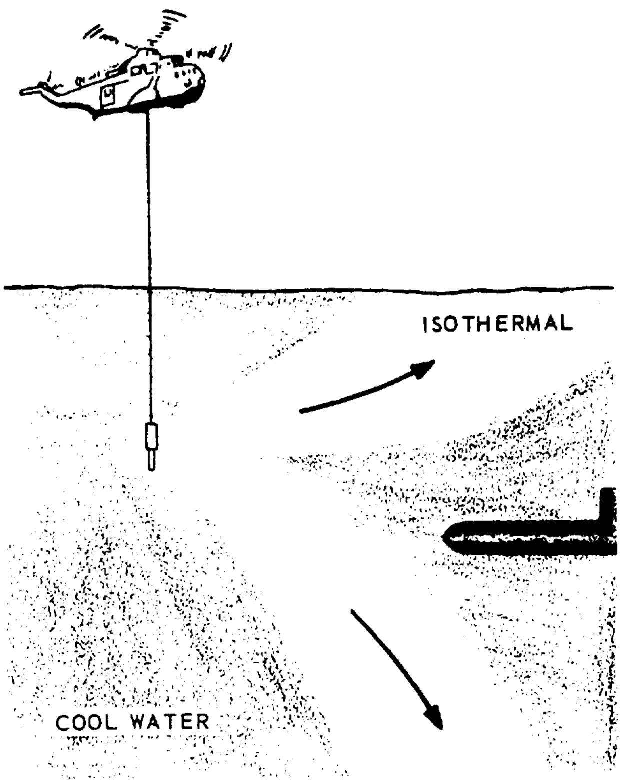

Figure 4-4.-Isothermal conditions.

(constant temperature). Refer to figure 4-4 as you read the following text. The surface layer of water in the figure is isothermal, but beneath this layer the temperature decreases with depth. This causes the sound beam to split and bend upward in the isothermal layer and downward below it.

Remember, when no temperature difference exists, the sound beam refracts upward due to pressure. When the temperature changes with depth, the sound beam bends away from the warmer water.

Under normal conditions the sea's temperature structure is similar to that shown in figure 4-5. This structure consists of three layers as follows:

1. A surface layer of varying thickness with uniform temperature (isothermal) or a relatively slight temperature gradient.

2. The thermocline, which is a region of relatively rapid decrease in temperature.

3. The rest of the ocean, with slowly decreasing temperature down to the sea floor.

If this arrangement changes, the path of the sound beam through the water will change.

Layer depth is the depth from the surface to the top of a sharp negative gradient. Under positive thermal gradient condition, the layer depth is the depth of maximum temperature. Above layer depth, the temperature may be uniform, or a weak positive or negative gradient may be present.

Layer effect is the partial protection from echo ranging and listening detection, which a submarine gains when it submerges below layer depth. Reports from surface vessels indicate that effective ranges on submarines are greatly reduced when the submarine dives below a thermocline, and that the echoes received are often weak and sound "mushy."

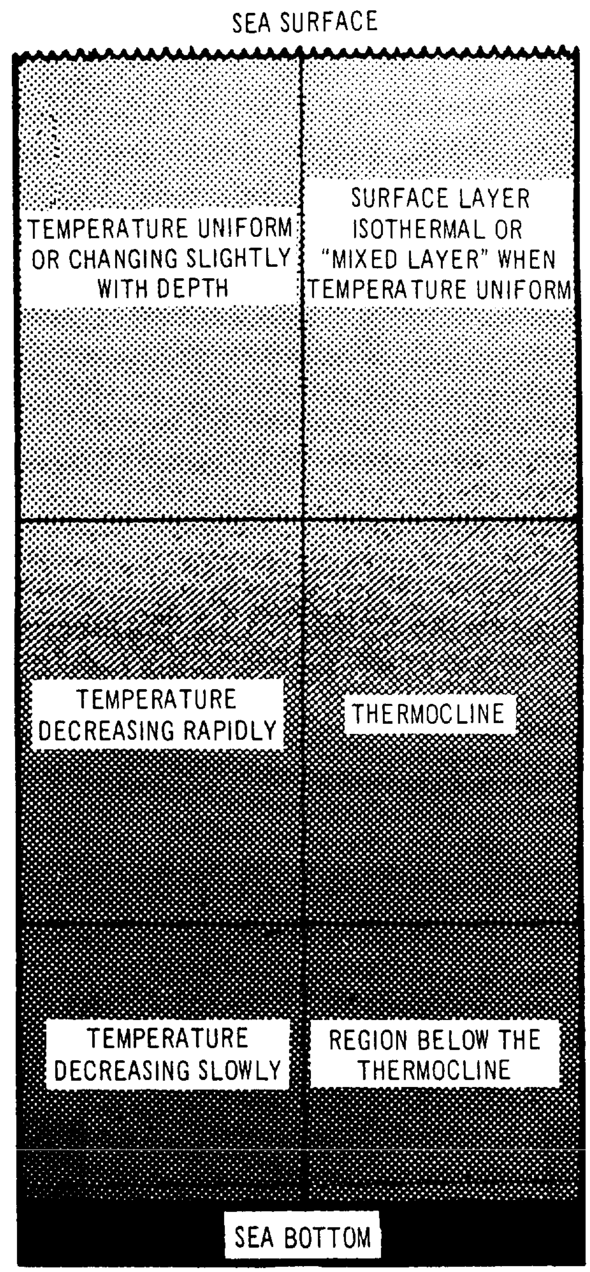

Figure 4-5.-Normal sea temperature structure.

DOPPLER EFFECT

When there is relative motion between the source of a wave of energy and its receiver, the received frequency differs from the transmitted frequency. When the source of wave motion is moving towards the receiver, more waves per second are received than when the source remains stationary. The effect at the receiver is an apparent decrease in wavelength and, therefore, an increase in frequency. On the other hand, when the source of wave motion is moving away from the receiver, fewer waves per second are encountered, which gives the effect of a longer wavelength and an apparent decrease in frequency. This change in wavelength is called the "Doppler effect." The amount of change in wavelength depends on the relative velocity between the receiver and the source. Relative velocity is the resultant speed between two objects when one or both are moving.

You have heard the term *Doppler effect* many times, but may not have known what the phenomenon was. An example of this is what you hear at a railroad crossing. As a train approaches, the pitch of the whistle is high. As the train passes you, the pitch seems to drop. Then, as the train goes off in the distance, the pitch of the whistle is low. The Doppler effect causes the changes in the pitch.

Sound waves generated by the whistle were compressed ahead of the train. As they came toward you, they were heard as a high-pitched sound because of the shorter distance between waves. When the train went by, the sound waves were drawn out, resulting in the lower pitch. Refer to figure 4-6 as you read the following explanation of Doppler effect.

If you examine 1 second of the audio signal radiated by the train whistle, you will see that the signal is composed of many cycles of acoustical energy. Each cycle occupies a definite period of time and has a definite physical wavelength. (Because of space limitations, only every 10th wave is illustrated in view A of figure 4-6.) When the energy is transmitted from a stationary source, the leading edge will move out in space the distance of one wavelength by the time the trailing edge leaves the source. The cycle will then occupy its exact wavelength in space. If that cycle is emitted while the source is moving, the source will move a small distance while the complete cycle is being radiated. The trailing edge of the cycle radiated will be closer to the leading edge.

Figure 4-6, view B, shows the effect of relative motion on a radiated audio signal. Notice the wavelength of the sound from the stationary emitter, as illustrated in condition (1) of view B.

In condition (2) of view B, the emitter is moving towards the listener (closing). When the cycle is compressed, it occupies less distance in space. Thus, the wavelength of the audio signal has been decreased, and the frequency has been proportionately increased (shifted). This apparent increase in frequency is known as UP Doppler.

The opposite is true in condition (3) of view B. The emitter is moving away from the listener (opening). The wavelength occupies more distance in space, and the frequency has been proportionately decreased. This apparent decrease in frequency is known as DOWN Doppler. The factors that determine the amount of Doppler shift are the velocity of the sound emitter, the velocity of the receiver, and the angle between the direction of motion of the receiver and the direction of motion of the sound emitter. This angle, known as angle 8, is used in a formula to determine the velocity of the emitted signal at the receiver and the frequency of the Doppler shift.

The Doppler shift works both ways. If you were on the train and had listened to a car horn at the crossing, the pitch of the horn would have changed. The effect is the same because the relative motion is the same.

The sonar equipment deals with three basic sounds. One of these sounds is the sound actually sent out by the equipment. The second sound is the reverberations that return from all the particles in the water—seaweed, fish, etc. The third sound is the most important one, the echo from the submarine.

The sound sent into the water (the actual ping) is seldom heard by the operator. Most of the equipment is designed to blank out this signal so that it doesn't distract the operator. This means there are only two sounds to deal within the discussion of Doppler effect in sonar.

Reverberations are echoes from all the small particles in the water. Consider just one of these particles for a moment. A sound wave from the transducer hits the particle and bounces back, just as a ball would if thrown against a wall. If the particle is stationary, it will not change the pitch of the sound. The sound will return from the particle with the same pitch that it had when it went out.

If the sonar transducer is stationary in the water and sends out a ping of 10 kHz, the particles all send back a sound that has the same pitch. Now suppose that the transducer acquires forward motion and a ping is sent out dead ahead. It is just as if the transducer were the oncoming train, and the particles were occupants of the car. Remember, that as the train came forward, the pitch of the whistle sounded higher to the occupants of the car. In the same way, the particles "hear" a higher note and reflect this higher note. Therefore, the sonar equipment will detect a higher note than the one sent out. If the transducer in this example is pointed dead astern, a lower note than the one sent out will be heard.

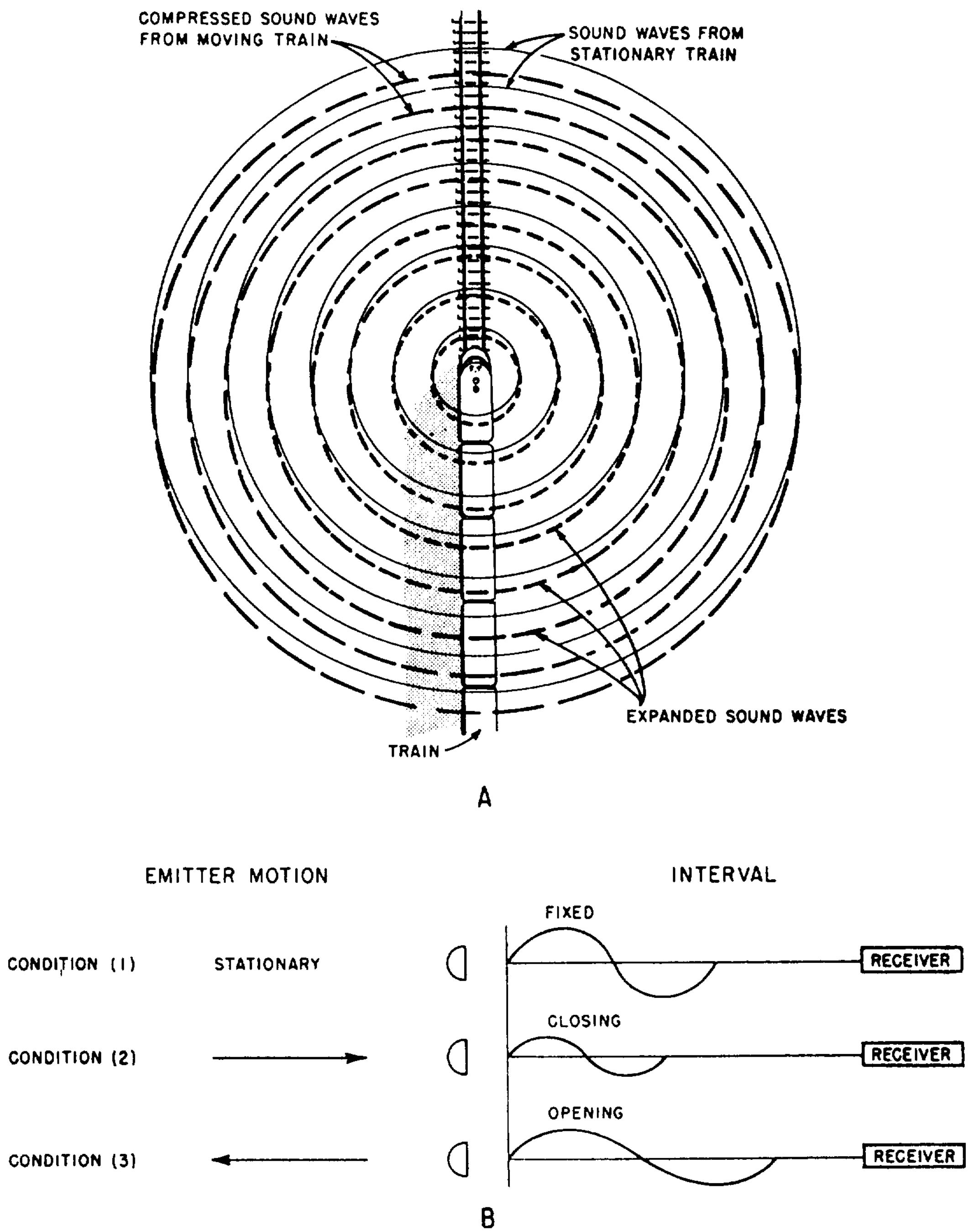

Figure 46-Doppler effect. A. One-second audio signal. B. One sine wave of the audio signal.

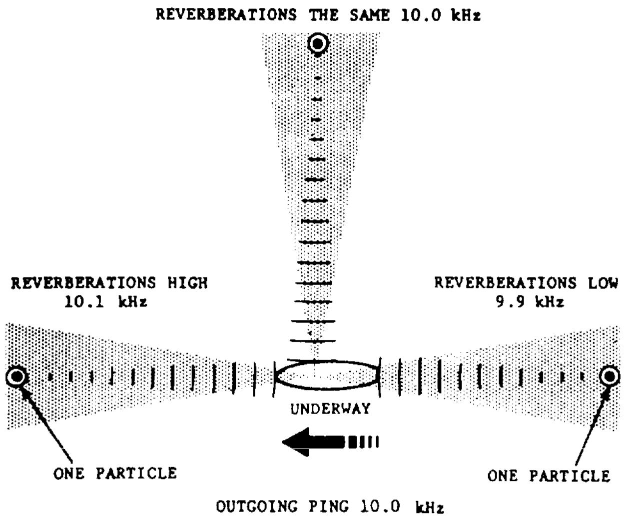

Figure 4-7.-Transducer installed on a moving ship.

If the transducer is aimed perpendicular to the direction of motion, the particles in the water will echo the same note sent out because the transducer is neither going toward the particles nor away from them. (See figure 4-7.)

Now consider the echo from the submarine, shown in figure 4-8. Again, the transducer is shown stationary. When the submarine is neither going toward nor away from the transducer, it must be either stopped or crossing the sound beam at a right angle. If it is in either condition, it reflects the same sound as the particles in the water. Consequently, the submarine echo has exactly the same pitch as the reverberations from the particles.

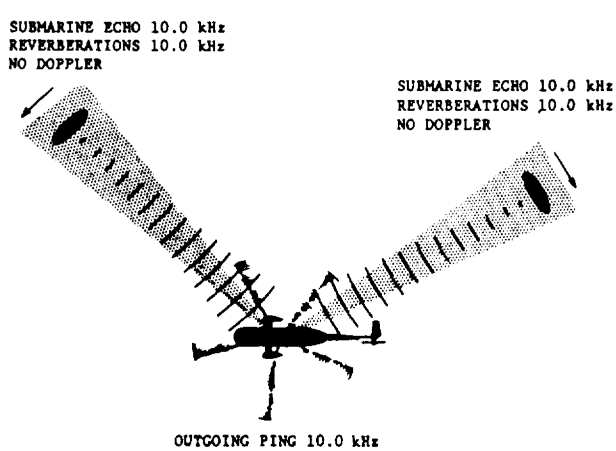

Figure 4-8.-Transducer supported by helicopter. Doppler effect is absent when submarine is stationary or moves at right angles to sound beam.

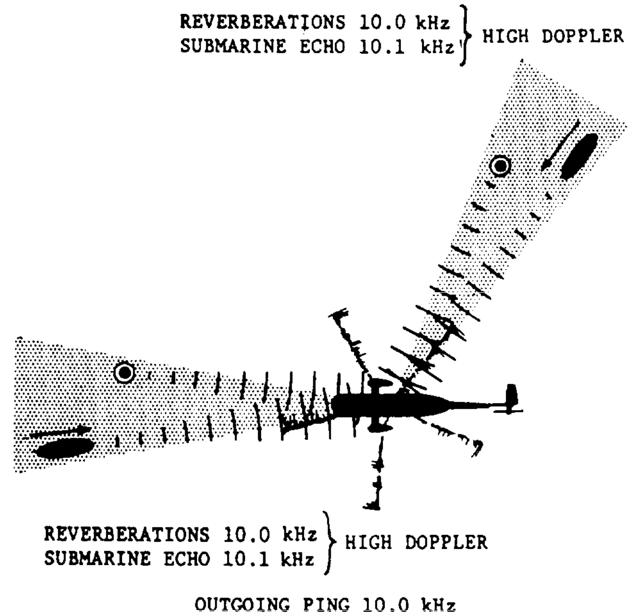

Figure 4-9.-Comparison of echo frequency and reverberation frequency when submarine moves toward transducer.

Suppose that the submarine is going toward the transducer, as shown in figure 4-9. It is as though the submarine is the train heading toward the car that is blowing its horn at the crossing. The horn sounds higher as the train approaches the car. In the same manner, the sound beam sounds higher to the submarine as it approaches the transducer.

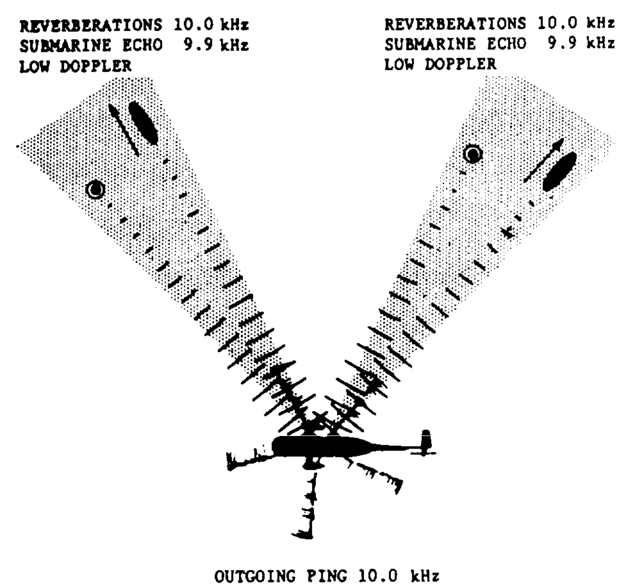

Figure 4-10.-Comparison of echo frequency and reverberation frequency when submarine moves away from transducer.

The submarine reflects an echo of higher pitch than that caused by the particles in the water, which are not moving. When the echo from the oncoming submarine is higher in frequency than the echoes from the reverberations, the Doppler is high. The opposite form of Doppler shift will occur when the submarine is heading away from the transducer. In this case, the pitch of the echo is lower than the pitch of the reverberations. (See figure 4-10.)

The degree of Doppler indicates how rapidly the submarine is moving relative to the transducer. For example, a submarine moving directly toward the transducer at 6 knots returns an echo of higher frequency than one moving at only 2 knots. Also, a submarine moving at 6 knots directly at the transducer returns an echo of higher frequency than one moving only slightly at the transducer. Refer to figure 4-11. This figure shows 12 submarines traveling at various speeds and courses with respect to a stationary transducer supported by the helicopter. Notice how the Doppler of each submarine is influenced by its speed and direction.

Doppler also makes it possible to distinguish the difference between a wake echo and a submarine echo. Relatively speaking, the submarine's wake is stationary. Therefore, its wake returns an echo with a frequency different from that of the Doppler shifted submarine echo.

AIRBORNE SONAR SYSTEM

Learning Objective: *Recognize components and operating principles of an airborne sonar system.*

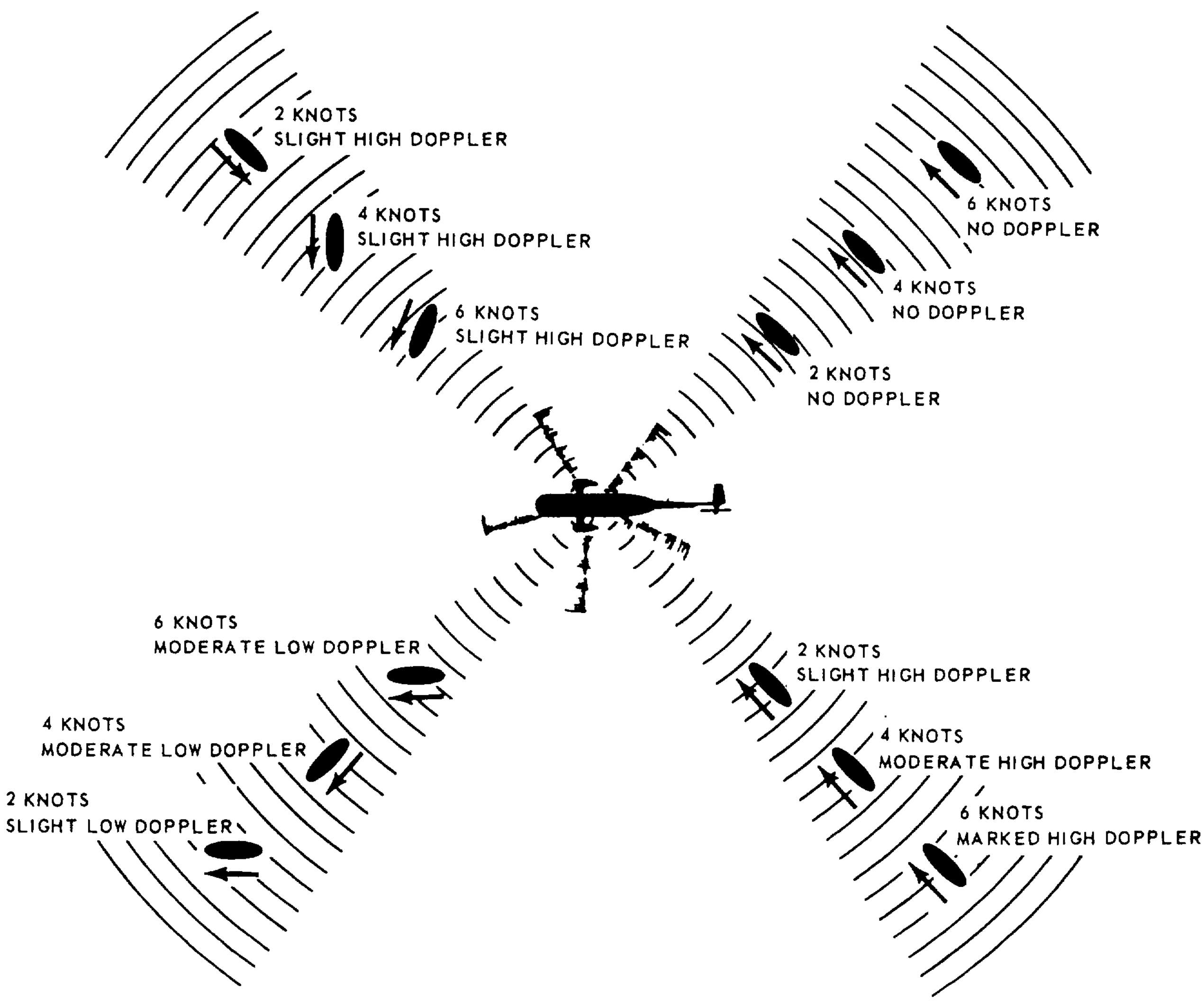

Figure 4-11-Varying degrees of Doppler effect due to differences in course and speed of submarines.

The Sonar Detecting-Range Set AN/AQS-13E is a lightweight, echo-ranging, dipping sonar set. It is capable of detecting, tracking, and classifying moving and stationary underwater objects. Also, this sonar set provides capabilities for underwater voice communication and generation of echo-ranging, aspect, and bathythermographic recordings.

MAJOR COMPONENTS

The following text will discuss the various components that makeup the AN/AQS-13E sonar detecting-range set.

Azimuth and Range Indicator

The azimuth and range indicator (fig. 4-12) is positioned at the sensor station. It provides the means for the operator to track targets. There are four controls on the left hand side of the indicator for operator comfort. The CURSOR INTENSITY switch controls the brightness of the cursor. The CRT INTENSITY controls the brightness of the overall CRT. The VIDEO GAIN controls the level of the video signal applied to the CRT. The AUDIO GAIN switch controls the level of the audio signal.

The right side of the indicator face contains a meter called the RANGE RATE-KNOTS meter. This meter displays the opening or closing speed of the selected target. The MTI THRESHOLD switch selects the range rate threshold of targets to be displayed on the CRT. The DISPLAY switch selects either sonobuoy signals or sonar signals to be shown on the CRT. To activate the sonar set, press the POWER switch. This activates the entire system with the exception of the dome control. The TEST switch initiates the built-in test functions and analyzes the results.

Bearing and Range Indicator

The bearing and range indicator (fig. 4-13) is mounted on the instrument panel, and presents the pilot with target bearing and range information. This information is supplied when the sonar operator sets the receiver TARGET switch to VERIFY.

The bearing is displayed on a three-digit display that shows degrees magnetic. The range is displayed on a five-digit display that shows yards to target. There is also a dimmer switch that controls the intensity of the display illumination.

Cable Assembly and Reel

The special purpose cable is 500±5 feet long, and is pretensioned on the reel. The cable contains 30 shielded conductors in a braided steel strength member, and is protected by a waterproof outer covering of polyurethane. There are colored bands spaced along the length of the cable to aid in checking the amount of cable payed out.

Dome Control

This control box (fig. 4-14) allows the operator to raise and lower the transducer (dome). There are three switches and two indicators on the face of this control box. The DEPTH-FEET indicator advises the operator on how far the transducer is lowered in feet.

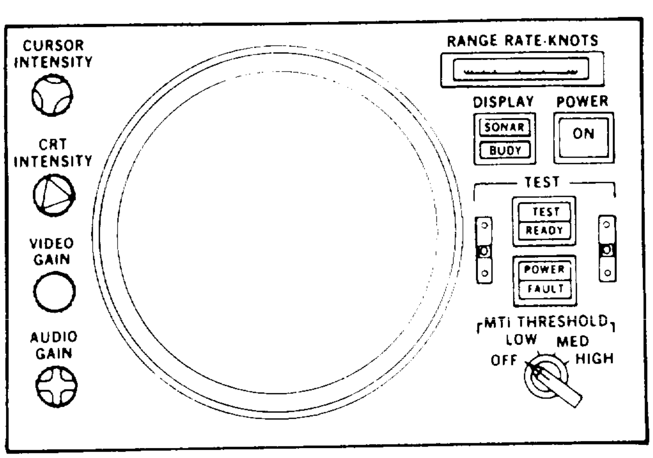

Figure 4-12.-Azimuth and range indicator.

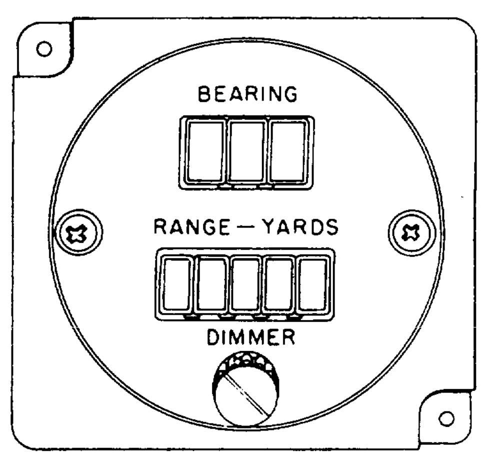

Figure 4-13.-Bearing and range indicator.

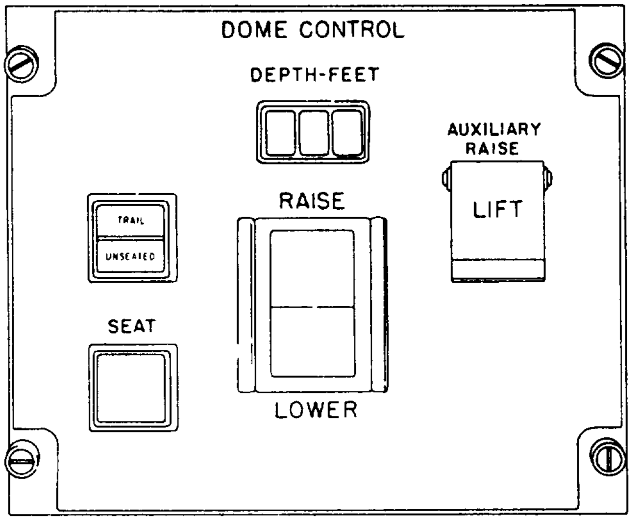

Figure 4-14.-Dome control.

The TRAIL/UNSEATED indicator advises the operator of the transducer's position.

The RAISE/LOWER switch activates the reeling machine to either raise or lower the dome. The SEAT s witch/indicator is used to raise the transducer from the trail position to the seat position, and then indicates that the transducer is in the seat position. When the operator selects the AUXILIARY RAISE switch, the transducer will be electrically raised in the event of a hydraulic malfunction.

Hydraulic Cable Reeling Machine

The hydraulic cable reeling machine (fig. 4-15) uses a hydraulic motor to raise and lower the dome. The sequence of raising or lowering is accomplished by energizing solenoids on the hydraulic control package, which programs hydraulic pressure to release or retrieve the dome.

The reel rotates to pay out or retrieve the cable. As the cable goes out or comes in, a level wind assembly, mounted on the frame, moves laterally to wind or unwind the cable evenly. The level wind is chain-driven from the gearbox assembly.

A standard one-half inch, square-drive speed wrench, which comes with the reeling machine, can be used to manually release or retrieve the cable. When the handcrank is used, the electrical circuits are disabled.

Recorder

The RO-358/ASQ-13A recorder (fig. 4-16) is located at the sensor operator's station and displays information on chart paper. This recorder is used for both the sonar system and the magnetic anomaly detection (MAD) system. MAD will be discussed later in this chapter.

The recorder contains the following switches and indicators on its faceplate: The CHART MOVE switch provides for rapid chart movement. The MODE switch selects the mode in which the recorder will operate. The RANGE RATE switch compensates for target range rate when in the aspect mode. A PULSE switch enables the operator to select transmit pulse duration while in the aspect mode. The CONTRAST control allows the operator to control the intensity of the recorded trace, while the PATTERN SHIFT knob shifts the information to the left. The SAD indicator/switch indicates when a SAD signal is being processed, and it resets the SAD indication. The REFERENCE switch enables the operator to select a new stylus during MAD operations.

Sonar Hydrophone and Sonar Projector

The underwater transmitting and receiving element consists of a projector (transmitting array) and a hydrophone (receiving array). The combination of these two components, which are electrically and

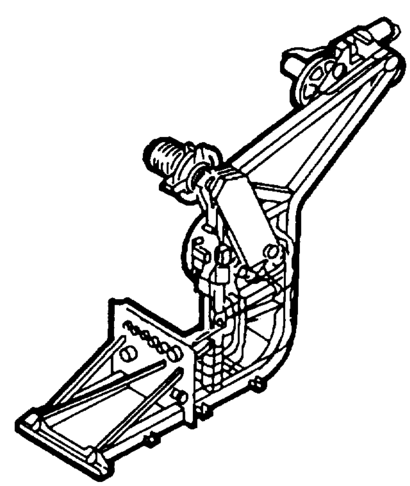

Figure 4-15.-Hydraulic cable reeling machine.

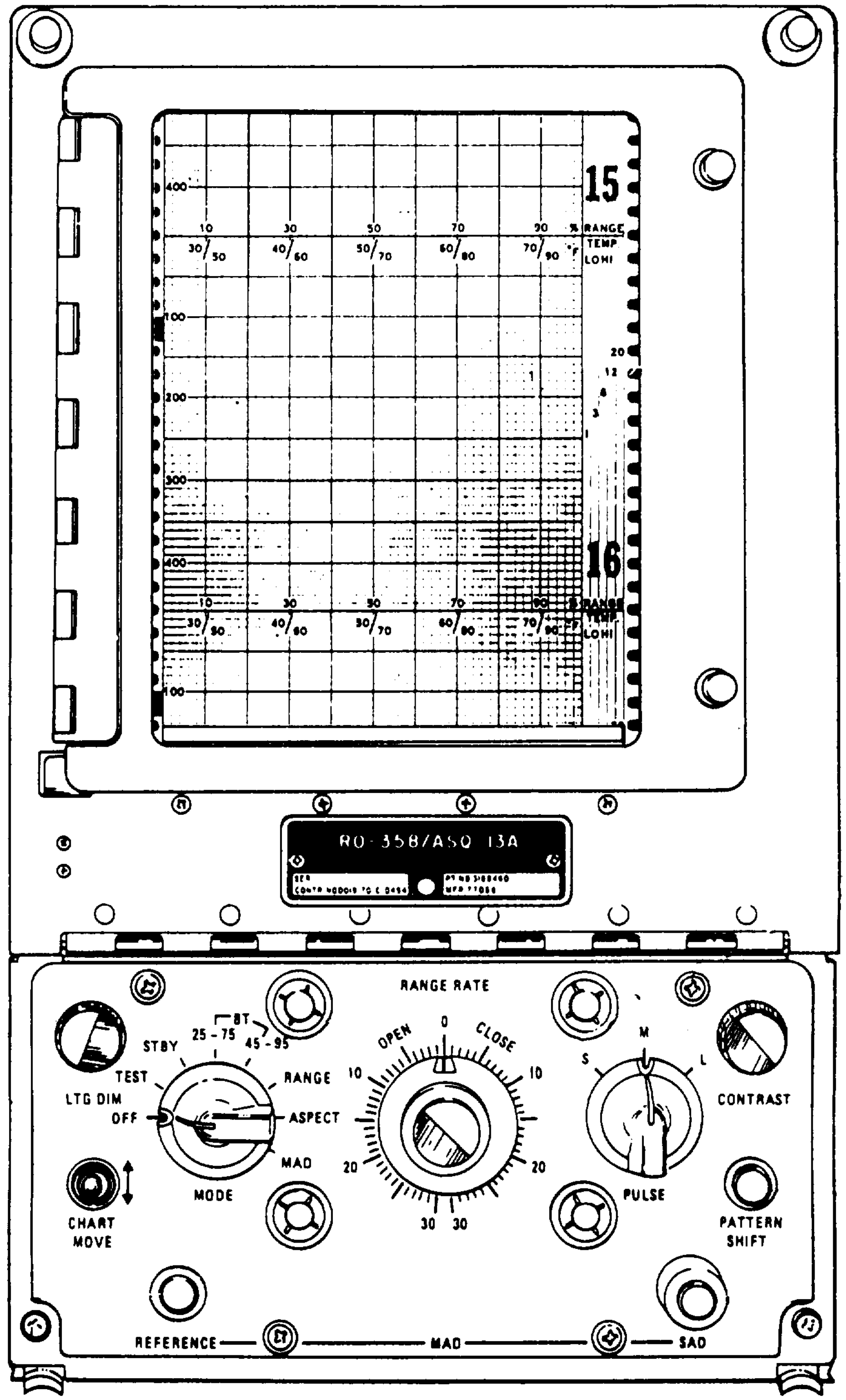

Figure 4-16.-RO-358/ASQ-13A.

mechanically connected, is referred to as the DOME (fig. 4-17).

The projector assembly of the dome contains a projector, a flux gate compass, and a pressure potentiometer. The projector is composed of six matched ceramic rings (barium titanate) and a tuning transformer. The projector converts the electrical pulses from the sonar transmitter to acoustic pulses that are radiated in an omnidirectional pattern through the water. The flux gate compass forms a portion of the display stabilization loop, providing an output to

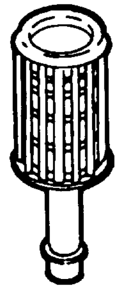

Figure 4-17.-Hydrophone and projector.

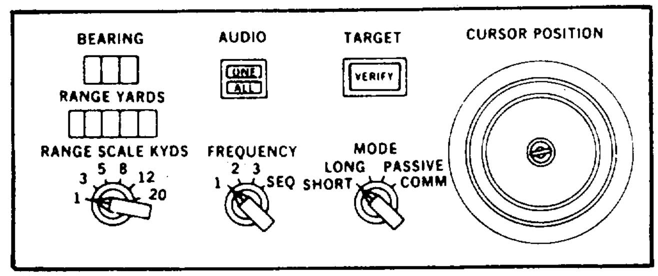

Figure 4-18.-Sonar receiver.

indicate the sonar dome azimuth deviation from magnetic north. The pressure potentiometer provides an output to indicate depth of the dome in water. The projector is covered with a black neoprene boot that is filled with oil.

The hydrophone assembly consists of 16 stave assemblies bolted to a cork-lined fiber glass barrel, an end bell, a temperature sensor, and an electronic package. The staves, filled with oil and hermetically sealed, convert the received acoustic pulses to low-level ac signals. These signals are amplified and applied through the special purpose electrical cable to the receiver located in the helicopter. The stave housings are stainless steel, each containing 12 matched ceramic rings with trimming capacitors, and they are mounted on a printed-circuit board. The output of each stave is applied to a preamplifier, which is on the electronics package. A temperature sensor for measuring temperature of the water is located on the end bell.

The dome requires no adjustments. All inputs and outputs are made through the special electrical connector on top of the electronic housing.

Sonar Receiver

The sonar receiver (fig. 4-18) consists of all electronic circuits required for the processing of input signals of the sonar set.

The following switches and indicators are mounted on the front panel of the receiver:

1. A RANGE SCALE-KYDS switch for selecting the desired operating range.

2. A MODE switch for selecting the operating mode of the sonar.

3. A FREQUENCY switch for selecting the desired frequency.

4. A dual CURSOR POSITION control for controlling the cursor circle on the CRT in both azimuth and range.

5. A three-digit BEARING display that indicates cursor circle bearing in degrees from magnetic north.

6. A five-digit RANGE-YARDS display that indicates the range of the cursor circle in yards.

7. An AUDIO switch/indicator for selecting audio from all eight sectors, or only the sector selected by the cursor circle position.

8. A TARGET switch/indicator for applying bearing and range information to the pilot's bearing and range indicator.

Sonar Transmitter

The transmitter (fig. 4-19) develops the signals to be transmitted by the system. A POWER circuit breaker, located on the front cover of the transmitter,

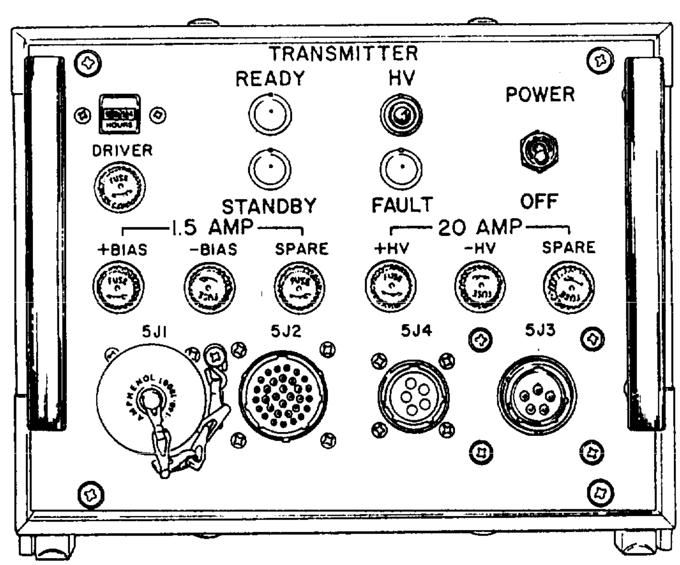

Figure 4-19.-Sonar transmitter.

applies 115 volts ac to the transmitter. When high voltage is being used, the HV indicator will be lit, The READY indicator shows when the transmitter is ready for operation. There are also STANDBY and FAULT indicators to show when there is a malfunction in the transmitter.

Sonar Data Computer

The sonar data computer is used with the sonar set to provide processing and display of LOFAR, DIFAR, and CASS sonobuoy signals on the sonar's CRT. These sonobuoys will be discussed later in this chapter. The sonar data computer is also used to provide a more accurate fix on the target by providing a digital readout of target range, speed, and bearing.

MODES OF OPERATION

The sonar set provides three operational modes of operation: echo ranging (LONG and SHORT), PASSIVE, and COMM. A fourth mode, TEST, is used to determine that the sonar set is in operational status. Three recording modes are also available: low (25°F to 75°F) or high (45°F to 95°F) BT (bathythermograph), RANGE, and ASPECT. A fourth recording mode, TEST, is used to determine that the recorder is in operational status.

Echo-Ranging Mode

The sonar set produces recurrent 3.5- (SHORT) or 35- (LONG) millisecond acoustic pulses that are radiated through the water from the projector portion of the dome. Returning target echoes are received by the hydrophone and processed into a left and right half-beam for each sector. Target bearing is determined by the phase difference existing between the left and right half-beams formed for each sector seamed. Bearing of the target is resolved from the edge of each of the eight 45-degree sectors scanned. Target range is determined from the elapsed time between transmission of a given pulse and the return of the target echo. Target and range are presented simultaneously as a single target pip on the CRT. Variations of the speed of sound in water due to the temperature of the water surrounding the dome are compensated for automatically.

An audio signal is developed for each returning target echo. These audio signals are applied to the helicopter's intercommunication system in such a manner that signals representing the left four sectors of the CRT are applied to the left earphone, and the signals for the right four are applied to the right earphone. A different nonharmonic tone is generated for each of the four sectors in each CRT half when the AUDIO switch is in the ALL position. In the ONE position, the audio representing the CRT sector in which the cursor is positioned is applied to both earphones.

The nature of the object causing the echo can be determined by the outline and intensity of the target display on the CRT, as well as by the quality and intensity of the audio. The opening or closing speed of the target within the cursor circle is displayed automatically on the RANGE RATE-KNOTS meter.

Passive Mode

In the passive mode, active echo-ranging is disabled, and underwater sounds may be received and displayed on the CRT. Bearing information is presented in this mode of operation and appears in the form of a noise spoke on the CRT. Audio is presented in the same manner as in the echo-ranging mode.

Communication Mode

The COMM mode is used for two-way underwater voice communication with other appropriately equipped helicopters, ships, or submarines operating within range.

Voice communication operation is activated by placing the MODE switch to COMM. Voice transmission is accomplished by depressing a foot switch and speaking into the microphone. Releasing the foot switch permits monitoring voice signals from other similar underwater communications systems.

When the audio switch is set to ONE, reception of underwater voice signals is accomplished by placing the cursor circle in the CRT sector in which the noise spoke appears and by regulating the AUDIO GAIN control.

Test Modes

The test modes check the operational status of the system as a whole and the various components of the system as individual units. These test modes use internally generated signals.

During normal operation, the test circuits sample major system functions and voltages. If a sampled function exceeds preset limits, the FAULT indicator illuminates for the length of time that the fault exists.

Recorder Bathythermographic Mode

The recorder bathythermographic (BT) mode is used to obtain graphs of temperature gradients appearing beneath the surface of the surrounding water to depths of 450 feet. Temperature and depth signals obtained from the dome are processed by the receiver and dome control. These signals are applied to the recorder circuits when the recorder MODE selector switch is moved to the BT position. The recorder chart drive circuits automatically position the chart paper to provide correct chart registration. Recorded scale marks on the chart paper denote the temperature scale being used for each temperature recording. The recorder plots temperature on the vertical axis and depth on the horizontal axis of the moving chart.

Recorder Range Mode

The recorder RANGE mode is used to obtain continuous strip-chart displays of target echo ranges. Range scale control signals from the receiver RANGE SCALE-KYDS switch are accepted by the recorder sweep circuits to correlate the range sweeps. As the chart paper moves, range scale marks are recorded on the chart paper to denote the range scale being used for each range recording. Target echo video signals are applied to the styluses when they appear in time, as related to the range sweep. The video signals are recorded each time a stylus passes over the range position of a target. The chart advances a small increment for each stylus sweep.

Recorder Aspect Mode

The recorder ASPECT mode is used to obtain continuous strip-chart displays of target echo signals. Timing and control signals, generated within the recorder, slave the receiver timing circuits to alternate sweep ramps between transmit and receive cycles. During each transmit sweep ramp, a train of short keying pulses is generated, and pulsewidth is regulated in the recorder. This pulse train is applied to the receiver. During each receive sweep ramp, the train of received target echo video pulses is applied to the recorder styluses. Target echo signal level is neither limited nor affected in the system. This permits varying intensity recordings (highlights) of target structural characteristics for optimum target classification.

Recorder Test Mode

The sonar operator uses the recorder TEST mode to check the operational status of the recorder. The TEST mode effectively checks the operation of the recorder stylus drive, stylus write, and chart drive operations. In addition, all front panel controls on the recorder can be checked by the operator for operational compliance and accuracy.

MAGNETIC ANOMALY DETECTION

Learning Objective: *Recognize components and operating principles of magnetic anomaly detection (MAD).*

By the beginning of World War II, it had become apparent that the aircraft was a deadly antisubmarine weapon. This was true even though the ability to search and detect submarines was solely dependent on visual sightings. The development of radar extended the usefulness of airborne antisubmarine measures, making detection of submarines possible at night or under conditions of poor visibility. However, visual or radar detection was possible only when the submarine was surfaced. Thus, some method of detecting submerged subs from an aircraft was needed. The use of sonar wasn't feasible because there was no direct contact between the fast-moving aircraft and the surface of the water. The most feasible way of detecting a submerged submarine was to detect its disturbance of the local magnetic field of the earth.

PRINCIPLES OF MAGNETIC DETECTION

Light, radar, and sound energy cannot pass from air into water and return to the air in any degree that is usable for airborne detection. On the other hand, lines of force in a magnetic field are able to make this transition almost undisturbed because the magnetic permeability of water and air are practically the same. Specifically, the lines of force in the earth's magnetic field pass through the surface of the ocean essentially undeviated by the change of medium, and undiminished in strength. Consequently, an object under the water can be detected from a position in the air above if the object has magnetic properties that distort the earth's magnetic field. A submarine has sufficient ferrous mass and electrical equipment to cause a detectable distortion (anomaly) in the earth's field. The function of the MAD equipment is to detect this anomaly.

Magnetic Anomaly

The lines comprising the earth's natural magnetic field do not always run straight north and south. If traced along atypical 100-mile path, the field twists at places to east and west, and assumes different angles with the horizontal. Angles of change in the east-west direction are known as *angles of variation*, while angles between the lines of force and the horizontal

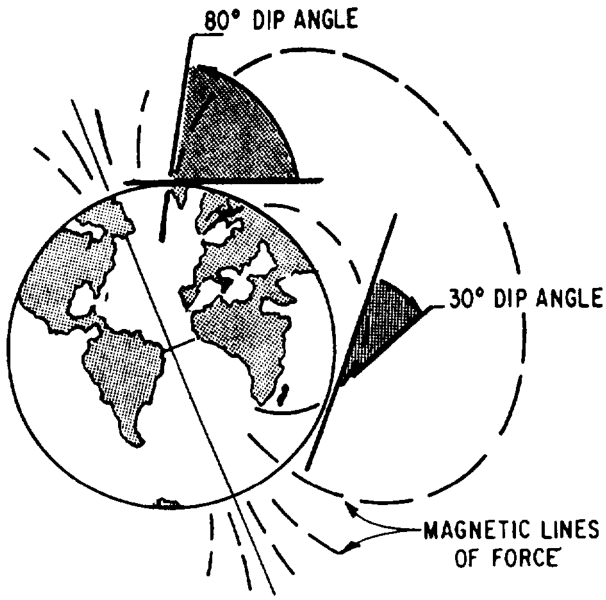

Figure 4-20.-Dip angles.

are known as *angles of dip* (fig. 4-20). At any given point between the equator and the magnetic poles, the relationship of the angle between the earth's surface and the magnetic lines of force is between 0° and 90°. This angle is determined by drawing an imaginary line tangent to the earth's surface and to the line of force where it enters the earth's surface. The angle thus formed is called the DIP ANGLE.

If the same lines are traced only a short distance, 300 feet for instance, their natural changes in variation and dip over such a short distance (short-trace) are almost impossible to measure. However, short-trace variation and dip in the area of a large mass of ferrous material, though still extremely minute, are measurable with a sensitive anomaly detector. This is shown in figure 4-21. The dashed lines represent lines of force in the earth's magnetic field.

View A shows the angular direction at which natural lines of magnetic force enter and leave the surface of the earth. Note that the angles of dip are considerably steeper in extreme northern and southern latitudes than they are near the equator. View B represents an area of undisturbed natural

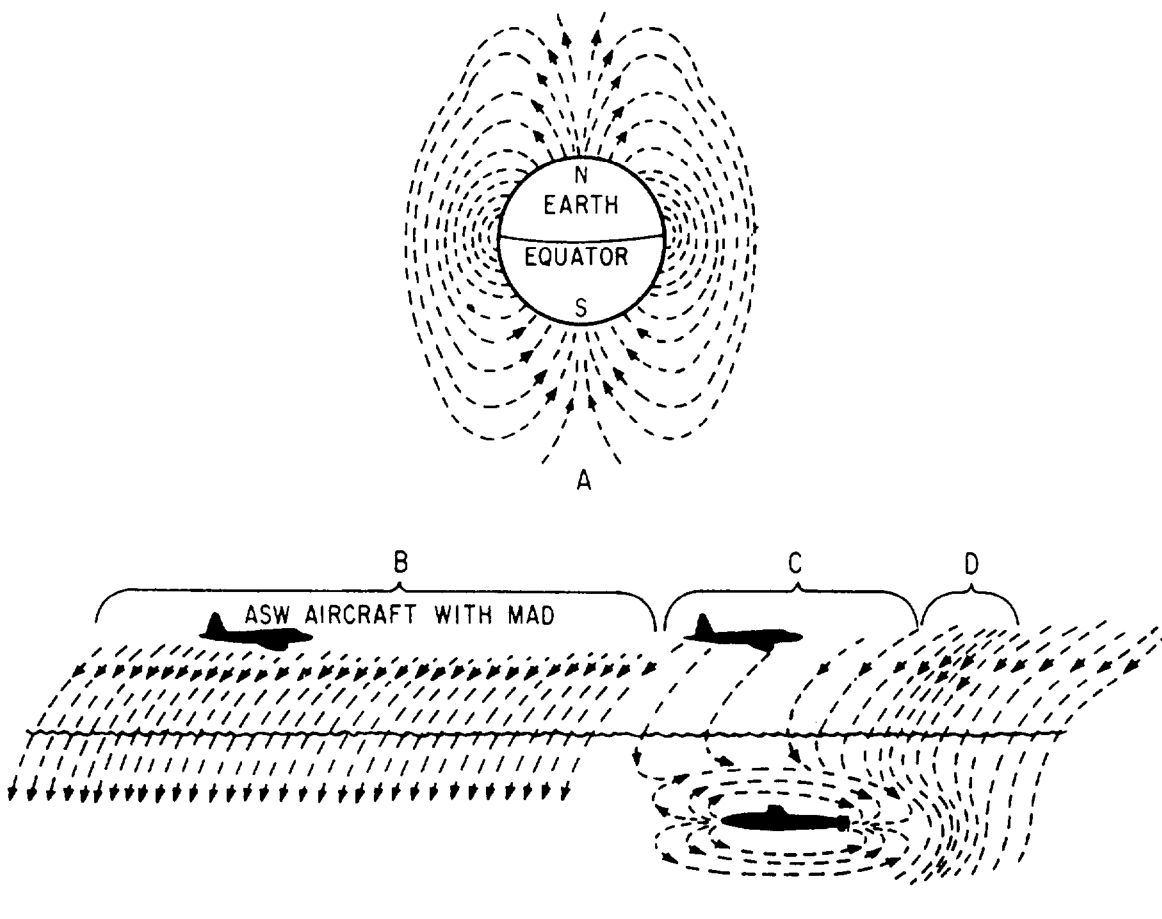

Figure 4-21.-Simplified comparison of natural field density and submarine anomaly.

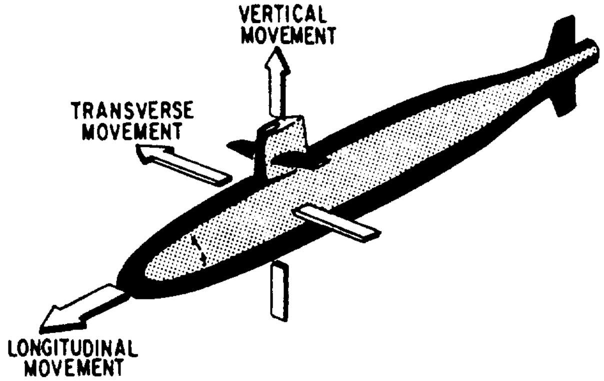

Figure 4-22.-Submarine's magnetic moment.

magnetic strength. In views C and D, the submarine's magnetic field distorts the natural field as shown. The density of the natural field is decreased in view C and increased in view D. The natural angle of dip is also affected, but only very slightly.

Submarine Anomaly

The maximum range at which a submarine may be detected is a function of both the intensity of its magnetic anomaly and the sensitivity of the detector.

A submarine's magnetic moment (magnetic intensity) (fig. 4-22) determines the intensity of the anomaly. It is dependent mainly on the submarine's alignment in the earth's field, its size, the latitude at which it is detected, and the degree of its permanent magnetization.

MAD equipment, in proper operating condition, is very sensitive; but the submarine's anomaly, even at a short distance, is normally very weak. The strength of a complex magnetic field (such as that associated with a submarine) varies as the inverse cube of the distance from the field's source. If the detectable strength of a field source has a given value at a given distance and the distance is doubled, the detectable strength of the source at the increased distance will then be one-eighth of its former value. Therefore, at least two facts should be clear. First, MAD equipment must be operated at a very low altitude to gain the greatest proximity possible to the enemy submarines. Second, the searching aircraft should fly at a predetermined speed and follow an estimated search pattern. This ensures systematic and thorough searching of the prescribed area so that no existing anomalies are missed.

Anomaly Strength

Up to this point, the inferred strength of a submarine's anomaly has been exaggerated for purposes of explanation. Its actual value is usually so small that MAD equipment must be capable of detecting a distortion of approximately one part in 60,000. This fact is made apparent by pointing out that the direction of alignment of the earth's magnetic lines of force is rarely changed more than one-half of 1 degree in a submarine anomaly.

Figure 4-23, view A, represents a contour map showing the degree of anomaly caused by a submarine. The straight line is approximately 800

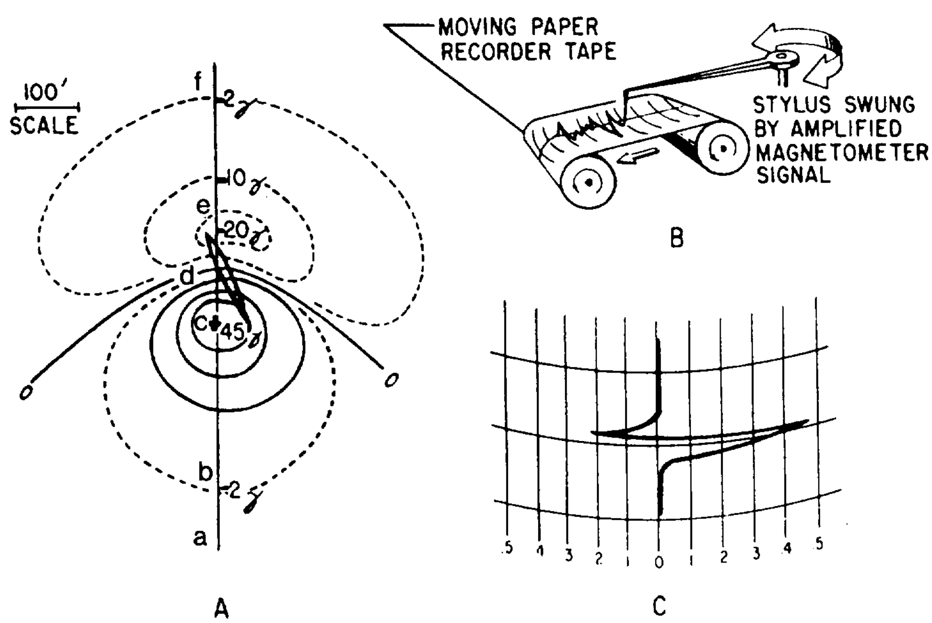

Figure 4-23.-A. Degree of anomaly. B. Anomaly stylus. C. Sample anomaly record.

feet in length and represents the flight path of a searching aircraft through the area of the submarine anomaly. If the submarine were not present, the undisturbed magnetic intensity in the area due to its assumed natural characteristics would be 60,000 gammas. (The gamma is the measure of magnetic intensity and is symbolized by the Greek letter γ.) All variations in the field, when the submarine is present, would then be above or below this natural intensity. Therefore, 60,000 gammas is the zero reference drawn on the moving paper tape shown in view C of figure 4-23.

Refer to view A of figure 4-23. Starting with the aircraft at point A, where the anomaly is undetectable, the earth's field concentration decreases to an intensity of 2γ(59,998) at point B. Its intensity then increases until a peak value of $+45\gamma$ is reached at point C. From that point it decreases to zero at point D. After point D, another zone of what amounts to magnetic rarefaction is encountered. The earth's field is less intense than its normal value. Consequently, anomalous values in this zone are considered as minus quantities. A peak minus intensity is reached at point E, and thereafter the signal rises back to its normal, or undetectable, intensity at point F.

As the varying degrees of intensity are encountered, they are amplified and used to drive a swinging stylus, as shown in figure 4-23, view B. The tip of the stylus rides against the moving paper tape, leaving an ink trace. The stylus is swung in one direction for positive γ, and the other for negative γ. The magnitude of its swing is determined by the intensity of the anomaly signal. Figure 4-23, view C, is a sample of paper recording tape showing the approximate trace caused by the anomaly in view A.

In the illustration just given, the search aircraft's altitude was 200 feet. At a lower altitude the anomaly would have been stronger, and at a higher altitude, it would have been weaker.

MAGNETIC NOISE

For the purposes of this discussion, any noise or disturbance in the aircraft or its equipment that could produce a signal on the recorder is classified as a magnetic noise.

In an aircraft there are many sources of magnetic fields, such as engines, struts, control cables, equipment, and ordnance. Many of these fields are of sufficient strength to seriously impair the operation of MAD equipment. Consequently, some means must be employed to compensate for "magnetic noise" fields. The noise sources fall into two major categories: maneuver noises and dc circuit noises.

Maneuver Noises

When the aircraft maneuvers, the magnetic field of the aircraft is changed, causing a change in the total magnetic field at the detecting element. The aircraft maneuver rates are such that the signals generated have their major frequency components within the bandpass of the MAD equipment. Maneuver noises may be caused by induced magnetic fields, eddy current fields, or the permanent field.

The variations in the induced magnetic field detected by the magnetometer are caused by changes in the aircraft's heading. This causes the aircraft to present a varying size to the earth's magnetic field, and only the portion of the aircraft parallel to the field is available for magnetic induction.

Eddy current fields produce maneuver noise because of currents that flow in the aircraft's skin and structural members. When an aircraft's maneuver causes an eddy current flow, a magnetic field is generated. The eddy current field is a function of the rate of the maneuver. If the maneuver is executed slowly, the effect of the eddy current field is negligible.

The structural parts of the aircraft exhibit permanent magnetic fields, and, as the aircraft maneuvers, its composite permanent field remains aligned with it. The angular displacement between the permanent field and the detector magnetometer during a maneuver produces a changing magnetic field, which the detector magnetometer is designed to detect.

DC Circuit Noise

The dc circuit noise in an aircraft comes from the standard practice in aircraft design of using a single-wire dc system, with the aircraft skin and structure as the ground return. The resulting current loop from the generator to load to generator serves as a large electromagnet that generates a magnetic field similar to a permanent magnetic field. Whenever the dc electrical load of the aircraft is abruptly changed, there is an abrupt change in the magnetic field at the detector.

COMPENSATION

Regardless of its source, strength, or direction, any magnetic field may be defined in terms of three axial coordinates. That is, it must act through any or all of three possible directions—longitudinal, lateral, or vertical—in relation to the magnetometer detector.

Compensation for magnetic noises is necessary to provide a magnetically clean environment so that the detecting system will not be limited to the magnetic signal associated with the aircraft itself.

Experience has shown that the induced fields and eddy current fields for a given type of aircraft are constant. That is, from one aircraft to another of the same type, the difference in fields is negligible. These fields may be expected to remain constant throughout the life of the aircraft, provided significant structural changes are not made. In view of these factors, it is present practice for the aircraft manufacturer to provide compensation for induced fields and eddy current fields.

Eddy current field compensation is usually achieved by placing the magnetometer (detecting head) in a relatively quiet magnetic area. In some aircraft the detecting head is placed at least 8 feet from the fuselage. This is done by enclosing the detecting head in a fixed boom (fig. 4-24, view A), or in an extendable boom (fig. 4-24, view B). Helicopters tow the detecting head by use of a cable (fig. 4-24, view C).

Induced magnetic field compensation is accomplished by using Permalloy strips. The aircraft is rotated to different compass headings, and the magnetic moment is measured. The polarity and the variation of the magnetic moment are noted for each heading, and Permalloy strips are oriented near the detector magnetometer to compensate for field changes due to aircraft rotation. Additional

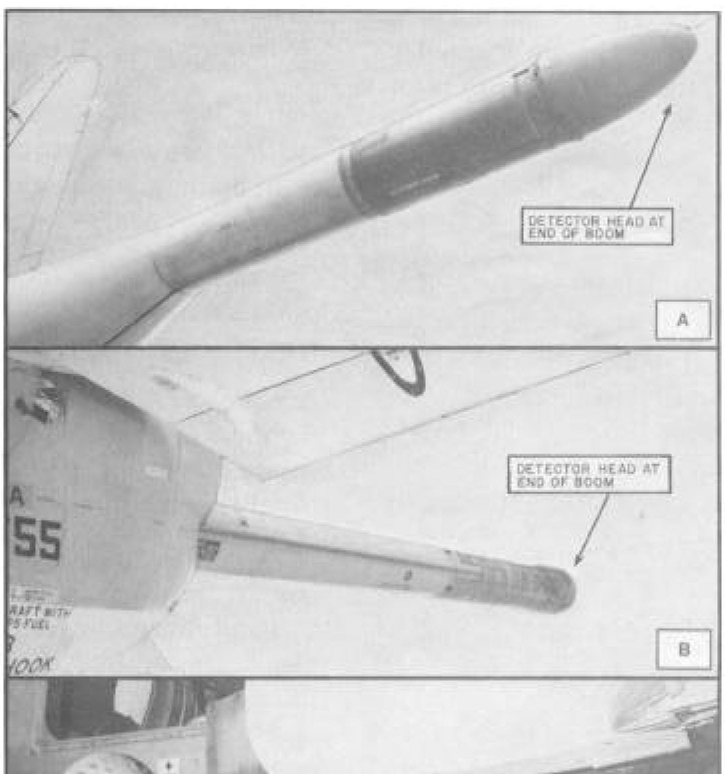

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Figure 4-24.—A. Stationary detector boom. B. Extendable detector boom. C. Cable-deployed towed detector.

compensation is needed for the longitudinal axis and is provided for by the development of outrigger compensators of Permalloy near the detecting element.

Permanent field compensation must be done in three dimensions rather than in two, and it is accomplished by three compensating coils mounted mutually perpendicular to each other (fig. 4-25, view A). The aircraft is rotated in 5-degree and 10-degree steps around its three axes. Adjustment of the field strength is accomplished by controlling the amount of direct current that flows through a particular coil. Figure 4-25, view B, shows a circuit for a single compensating coil.

Compensation for the dc magnetic field is accomplished by using electromagnetic compensating loops. The loops are arranged to provide horizontal, vertical, and longitudinal fields, and they are adjusted to be equal and opposite to the dc magnetic field caused by the load current. The compensating loops are connected across a variable resistor for a particular distribution center, and they are adjusted to allow current flow proportional to the load current for correct compensation. Different types of aircraft have several sets of compensation loops, depending upon the number of distribution centers. In newer aircraft, production changes have been made to use ground return wires to minimize loop size.

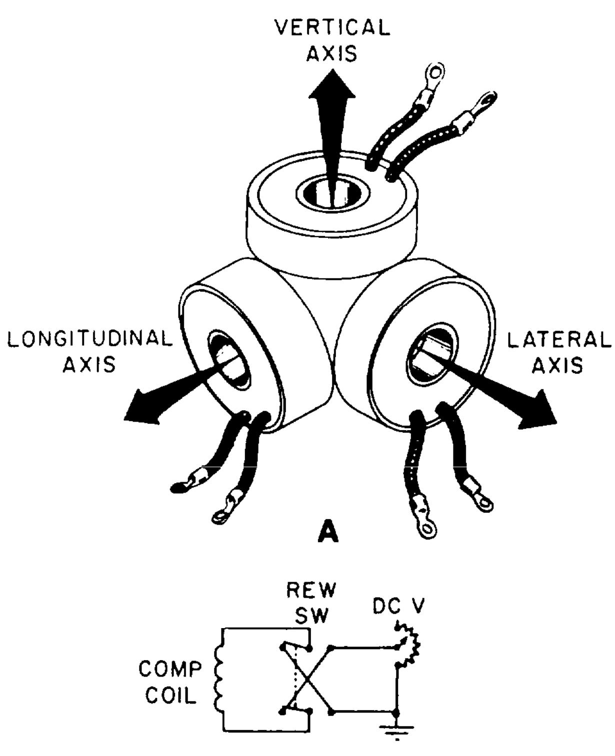

Figure 4-25.-A. Arrangement of compensating colts. B. Compensating coil circuit.

The procedure for adjustment of the dc compensation system makes use of straight and level flight on the four cardinal headings. For example, actuation of a cowl flap motor will cause dc field changes representative of those caused by any nacelle load. The load is energized, the size and polarity of the signal are noted, and the compensation control is adjusted. The load is reenergized, and the compensation control is adjusted again. Adjustments are continued until the resulting signals from the dc field are minimized.

Under ideal conditions, all magnetic fields that tend to act on the magnetometer head would be completely counterbalanced. In this state the effect on the magnetometer is the same as if there were no magnetic fields at all. This state exists only when the following ideal conditions exist:

1. The aircraft is flying a steady course through a magnetically quiet geographical area.

2. Electric or electronic circuits are not turned on or off during compensation.

3. Direct current of the proper intensity and direction has been set to flow through the compensation coils, so that all stray fields are balanced.

To approximate these conditions, the compensation of MAD equipment is usually performed in flight, well at sea. In this way, the equipment is compensated under operation conditions, which closely resemble those of actual ASW search flights.

From the foregoing, it should be clear that the objective of compensation is to gain a state of total balance of magnetic forces around the magnetometer. Thereafter, any sudden shift in one of the balanced forces (such as an anomaly in the earth's field force) upsets the total balance. This imbalance is indicated on the recorder. Unfortunately, a shift in ANY of the balanced forces will be indicated. Shift in any of the forces other than the earth's natural field are regarded as noise.

MAJOR COMPONENTS

The MAD system consists of the AN/ASQ-81 MAD set, AN/ASA-64 submarine anomaly detecting (SAD) group, AN/ASA-65 magnetic compensator group, AN/ASA-71 selector control group, and the RO-32/ASQ MAD recorder.

AN/ASQ-81 MAD Set

The AN/ASQ-81 set consists of the DT-323 magnetic detector, the AM-4535 amplifier-power supply, and the C-6983 detecting set control box.

DT-323 MAGNETIC DETECTOR.— The detection element includes six separate helium absorption cells and six IR detectors, arranged in pairs, with the pairs oriented at 90° to each other. This configuration ensures that one or more of the pairs is at least partially in line with the earth's field regardless of aircraft attitude or direction of flight. The signals from all three detector pairs are combined in a summing amplifier. The final output to the amplifier-power supply is not affected by aircraft maneuvers because of the arrangement.

AM-4535 AMPLIFIER-POWER SUPPLY.— The amplifier-power supply (fig. 4-26) serves two purposes. The first purpose is the power supply portion. This section provides the necessary power to the MAD subsystem. The amplifier section contains the necessary electronics to detect the anomaly signal from the detector output signal.

There are three fail indicators on the amplifier-power supply. The FAIL light comes on when there is a fault in the assembly being tested with the BITE switch. The FAIL DETECTOR and the FAIL AMP PWR SUPPLY lights indicate failure of the magnetic detector or the amplifier-power supply. The ALT COMP dial is used to vary the amplitude of the altitude compensation signal. The BUILT IN TEST switch provides a self-test of quick replaceable assemblies in the amplifier-power supply. The two circuit breakers provide circuit protection for the dc power to the magnetic detector and the 115-volt ac power to the amplifier-power supply.

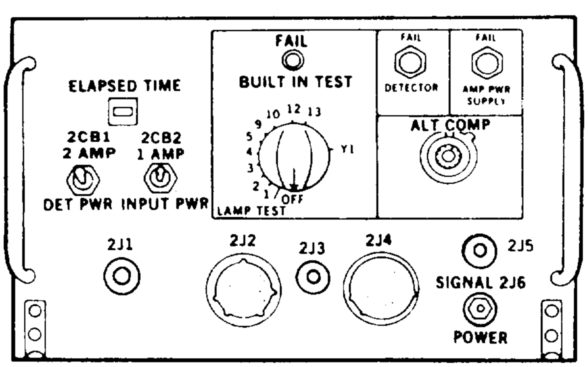

Figure 4-26.-AM-4535 amplifier-power supply.

On the right side of the amplifier-power supply, there is a hinged door that covers a maintenance panel. When this door is closed, the equipment operates in the normal mode. On the maintenance panel there is a RES OSC ADJ switch that is used to manually adjust the resonance oscillator frequency during maintenance procedures. There is also a MODE SELECT switch that selects various system configurations necessary for proper maintenance and troubleshooting.

C-6983 CONTROL BOX.— The detecting set control box (fig. 4-27) contains the operating switches and indicators for the MAD system. Across the top of the faceplate are five indicators that indicate faults in the other units. The indicator labeled 3 indicates a magnetic detector failure when lit. The indicator labeled 2 indicates amplifier failure. The next two indicators indicate a control box fault. The SYS READY indicator illuminates when the system is ready for operation. This indicator will blink during warm-up.

There are three toggle switches across the middle portion of the control box. The one on the right is the power switch. This switch applies power to the system. The middle switch is labeled CAL. It selects the calibration signal for use. The switch on the left is

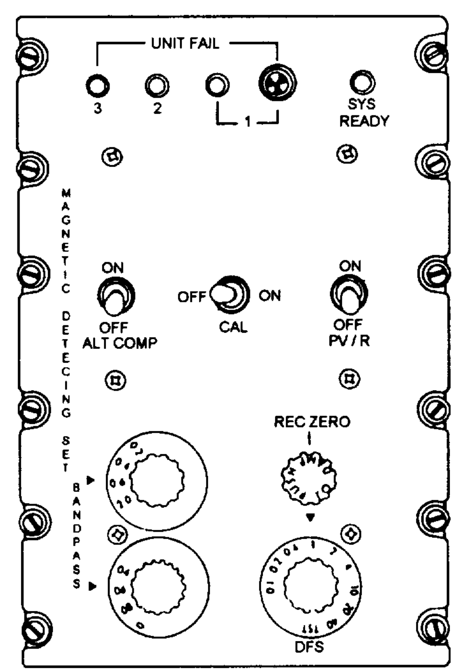

Figure 4-27.-C-6893 detecting set control.

labeled ALT COMP. This switch is used to connect the altitude compensator to the system.

The bottom portion of the control box contains four knobs. The two on the left side are labeled BANDPASS. These knobs select the high and low frequencies. The knob labeled REC ZERO is a dual-purpose knob. Turning this knob controls the pen deflection on the recorder. Depressing the knob inhibits system output. The bottom right knob is labeled **γFS,** and is used to select one of nine sensitivity ranges (from 0.1γ to 40γ full scale) or self-test. In the TST position, the self-test function will be initiated.

AN/ASA-64 SAD Group

The SAD group consists of only one unit-the ID-1559 magnetic variation indicator (MAG VAR indicator). This indicator receives the MAD signals from the ECA, along with roll attitude signals. These signals are processed and a SAD mark is generated, which is correlated with the roll input. In cases of excessive aircraft roll rate, the indicator will generate a SAD inhibit signal. This signal illuminates the SAD INHIBIT lights on the selector control panel and the pilot and copilot's navigation advisory panel, letting the operators know the SAD mark is unreliable.

AN/ASA-65 Magnetic Compensator Group

The magnetic compensator group consists of the AM-6459 electronic control amplifier (compensator ECA), C-8935 control-indicator, DT-355 magnetometer assembly, three compensating coils, CP-1390 magnetic field computer, and ID-2254 magnetic field indicator.

AM-6459 ELECTRONIC CONTROL AMPLIFIER.— The electronic control amplifier (ECA) processes standard magnetic anomaly detector signals from the MAD subsystems, operator compensation adjustments, and maneuver signals from the magnetometer. The ECA provides compensation currents, which are sent to the MAD boom compensation coils.

C-8935 COMPENSATOR CONTROL-INDICATOR.— This control-indicator (fig. 4-28) contains potentiometers for adjustment of the maneuver and correlated signals into compensating terms. The potentiometer outputs are routed back to the ECA to be amplified. From there they are sent to the compensator coil as compensation signals.

On the face of the control-indicator there are nine index counters. The top three provide the adjustment index for the potentiometers in the transverse, longitudinal, and vertical magnetometer circuits. They are labeled T (transverse), L (longitudinal), and V (vertical). The other six (labeled 1 to 6) provide compensation adjustment for the T, L, and V magnetometer circuits.

The MAG TERM knob selects the magnetic term to be compensated. This knob must be in the OFF position unless compensation is required. The RATE knob selects the speed of the servomotor with 1 being the slowest and 4 the fastest.

Across the bottom of the faceplate there are four toggle switches. The POWER-OFF switch provides power to the unit. The SERVO-OFF switch provides both ac and dc power to the servomotor system. This switch must be in the OFF position unless recompensation is required. The UP-DOWN switch provides voltage directly to the servomotor selected. The counter indication will increase or decrease depending on which way this switch is toggled. The +/OFF/– switch provides voltage to the servo system. In the OFF position, the servomotor is operated only by the UP-DOWN switch.

DT-355 MAGNETOMETER ASSEMBLY.— The magnetometer assembly contains three coils oriented to sense magnetic strength in each of the basic longitudinal, transverse, and vertical axes. This

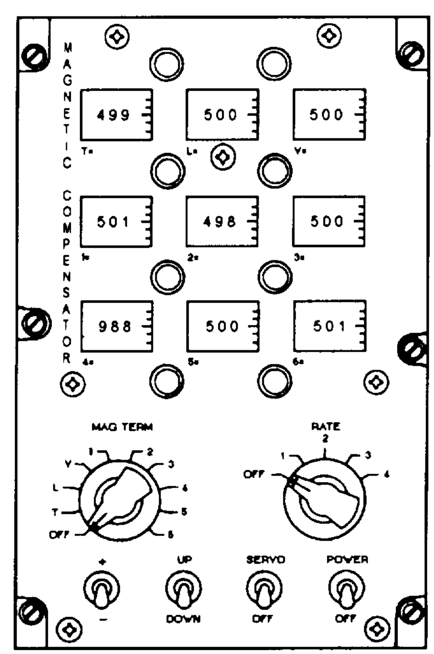

Figure 4-28.-Compensator control-indicator.

results in three output signals, which are sent to the ECA. These coils are located in the MAD boom.

COMPENSATION COILS.— There are three compensating coils located in the boom. These coils generate the magnetic field that opposes the aircraft-generated noise fields for compensation. There is one coil each for the transverse, vertical, and longitudinal fields.

CP-1390 MAGNETIC FIELD COMPUTER.— The magnetic field computer, along with the magnetic field indicator, computerizes the compensation procedure. The correlation portion of the system, the 2A5 board in the ECA, becomes redundant to the computer. The magnetic field computer receives the maneuver signals, MAD signals, and the potentiometer outputs. From these signals, it computes the adjustment values for the nine magnetic terms simultaneously.

ID-2254 MAGNETIC FIELD INDICATOR.— The magnetic field indicator (fig. 4-29) allows the operator to select various weapon loads and initiate the self-test, auto compensation, and weapon deployment programs. It also displays the most recent computer-calculated term difference value.

The PWR/OFF switch accesses aircraft power. The DISPLAY indicator is a four-digit numerical display and a polarity indicator. It shows the various BITE codes, term values, or calibration values. The EXEC push button initiates all commands. This button must be pressed after each selection of the MODE switch.

The MODE switch is a 14-position rotary switch that provides computer identification and control of fixed compensation functions. The OFF position means that there are no functions processed. The BITE position conducts a built-in test and reports the results via the digital readout. In the COMP position, pressing the EXEC button conducts the nine-term compensation program. The WD position enables the four-term weapon deployment compensation program. In the CAL position, a digital value measurement of the magnetic coils for calibration accuracy is initiated. The other nine positions report the most recent computer-calculated term difference value via the DISPLAY. Remember, after selecting any of the positions on the MODE switch, the EXEC button must be pressed.

The FAULT indicator illuminates whenever a fault condition exists. The WPN LOAD switch is a nine-position switch labeled 0-8. The number of weapons being carried is selected on this switch prior to compensation. This provides compensation for at least 80 percent of the weapons interference field.

AN/ASA-71 Selector Control Group

The selector control group consists of two units. These units are the MAD selector control panel and the selector control subassembly.

C-7693/ASA-71 SELECTOR CONTROL PANEL.— This selector control (fig. 4-30) selects the signal to be recorded on the MAD recorder and adjusts the threshold voltage for the SAD system. The two knobs labeled BLACK PEN and RED PEN

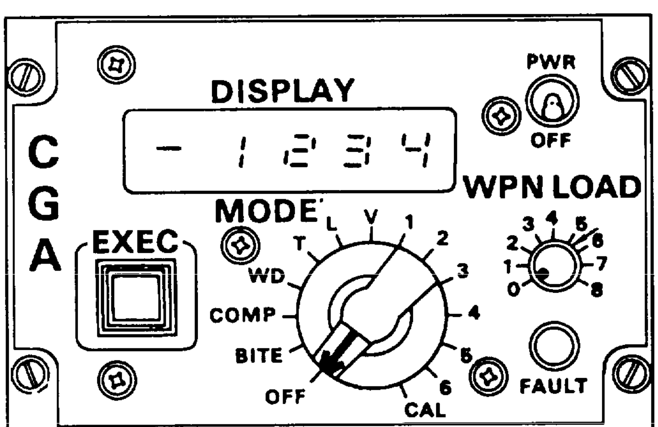

Figure 4-29.-ID-2254 magnetic field indicator.

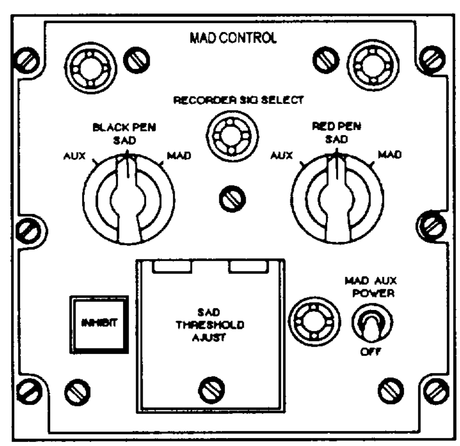

Figure 4-30.-C-7693/ASA-71 selector control panel.

select which signal goes to which pen on the recorder. The MAD AUX POWER-OFF switch supplies primary ac power to the SAD system and the selector control subassembly. The INHIBIT light indicates an inhibit signal from the SAD system.

MX-8109/ASA-71 SELECTOR CONTROL SUBASSEMBLY.— The MAD signals from the MAD control and the SAD mark from the MAG VAR indicator are routed to this subassembly. The selector control panel selects which one goes to which pen, and the subassembly routes the signal to the proper pen. A SAD mark 1-kHz tone is generated by the subassembly to be supplied to the ICS system for the SENSOR operator.

RO-32 MAD Recorder

The RO-32 recorder makes a hardcopy of MAD contacts and SAD marks. This recorder has two styluses, one black and one red, to differentiate between the two. The chart drive is removable to enable the operator to remove and replace the paper tape. here are three knobs on the faceplate. The first switch is the ON/OFF switch. The second controls the intensity of the internal lights. The third knob selects the operate mode along with the pen calibration modes.

When B is selected on the mode knob, the black pen should trace along the zero line on the paper tape. When the mode knob is switched to the +, the black pen should go to +4. When this knob is switched to the R position, the red pen traces along the zero line. When it goes to the +, the red pen should swing to the +4 line. Both pens are adjustable to these settings.

SONOBUOYS

Learning Objective: *Recognize the classifications and the operating principles of sonobuoys currently in use.*

The detection, localization, and identification of submarines is the primary mission of the Navy's airborne ASW forces. The ability of the Navy to complete this mission is dependent upon the sonobuoy. The sonobuoy has undergone a great deal of change in the past 25 years. These improvements have provided the fleet with large numbers of very reliable sonobuoys that perform various missions.

OPERATING PRINCIPLES

The sonobuoys are dropped from the aircraft into an area of the ocean thought to contain a submarine. The pattern in which the sonobuoys are dropped usually involve three or more buoys.

The sonobuoys detect underwater sounds, such as submarine noise and fish sounds. These sounds modulate an oscillator in the RF transmitter portion of the sonobuoy. The output of the transmitter is a frequency modulated VHF signal that is transmitted from the antenna. The signal is received by the aircraft, and then detected and processed by a sonobuoy receiver. By analyzing the detected sounds, the ASW operator can determine various characteristics of the detected submarine. The use of several sonobuoys operating on different VHF frequencies in a tactical pattern enables the ASW operator to localize, track, and classify a submerged submarine.

Each sonobuoy type is designed to meet a specific set of specifications that is unique to that particular sonobuoy. Even though different manufacturers, the specifications and operational performance characteristics are the same for all manufacturers. There are differences in the methods used for prelaunch selection of life and depth settings from one manufacturer to another for the same sonobuoy types. These differences are found in the *Sonobuoy Instruction Manual,* NAVAIR 28-SSQ-500-1. You should refer to this manual prior to storing, handling, or disposing of sonobuoys.

Sonobuoy Frequency Channels

Certain sonobuoy designs are equipped with an electronic function select (EFS) system. The EFS system provides each sonobuoy with a selectable 99-channel capability. EFS also provides each sonobuoy with 50 life and 50 depth setting selections. The operator must reset all three settings any time any of the three are changed.

With the older type of sonobuoy, the transmitter frequency is preset at the factory. here were 31 different channels used within the 162.25- to 173.5-MHz band. Transmitter frequency is designed to be within ±25 kHz. temperature extremes in hot or cold storage adversely affect these tolerances, especially in sonobuoys that are older.

External Markings

Each sonobuoy has marked on the sonobuoy case the following information: nomenclature or type, serial number, manufacturer's code number, RF channel number, contract lot number, weight, and prelaunch setting. Sonobuoy type and RF channel number are also stamped on each end of the buoy. Sonobuoys with EFS will have no RF channel number markings because the channel will be selected by the operator.

Deployment

The sonobuoy is aircraft deployable by any of four methods: spring, pneumatic, free-fall, or cartridge. Because descent velocities can exceed 120 feet per second, a descent-retarding device is used to increase aerodynamic stability and to reduce water-entry shock. A parachute or a rotating-blade assembly (rotochute) is used as the descent-retarding device. Because of the different descent characteristics of the parachute and rotochute, do not intermix the two. With intermixed sonobuoys, the spacing of the tactical pattern will not be right and submarines might be missed.

Water Entry and Activation

The force of water impact, or battery activation, initiates the deployment or jettison of-the various sonobuoy components. Jettisoning of the bottom plate allows the hydrophone and other internal components to descend to the preselected depth. Upon the release of the parachute or rotochute, the antenna is erected. In some sonobuoys, a seawater-activated battery fires a squib, which deploys a float containing the antenna. A termination mass and/or drogue stabilizes the hydrophone at the selected depth, while the buoyant sonobuoy section or float follows the motion of the waves. A section of elastic suspension cable isolates the hydrophone from the wave action on the buoyant section. Most of the sonobuoys in the fleet today are equipped with seawater-activated batteries, which provide the power required for the sonobuoy electronics. Data transmission from the buoys usually begins within 3 minutes after the buoy enters the water. In cold water and/or water with low salinity, the activation time might be increased. Some sonobuoys now have nonwater-activated lithium batteries.

Sonobuoy Operating Life

At the end of the preselected time, the sonobuoy transmitter is deactivated. The sonobuoy has either an electronic RF OFF timer, or, as is most common, the transmitter is deactivated when the buoy is scuttled. At the end of the sonobuoy life, or for some types of sonobuoys upon RF command, a mechanism allows seawater to flood the flotation section in the buoy. In some cases, the flotation balloon is deflated to scuttle the unit. Either way, the unit fills with seawater and sinks.

SONOBUOY CLASSIFICATION

Sonobuoys are grouped into three categories: passive, active, and special purpose. Passive sonobuoys are used in LOFAR and DIFAR systems. Active sonobuoys are used in CASS and DICASS systems. Special-purpose sonobuoys are used in missions other than ASW. These sonobuoys and acronyms, along with their meanings and relationships to each other, are discussed below.

Passive Sonobuoy

The passive sonobuoy is a listen-only buoy. The basic acoustic sensing system that uses the passive sonobuoy for detection and classification is known as the low-frequency analysis and recording (LOFAR) system.

LOFAR SYSTEM.— With this system, sounds emitted by the submarine are detected by a hydrophone that has been lowered from a passive omnidirectional sonobuoy. Data regarding the frequency and amplitude of these sounds are then transmitted by the sonobuoy antenna to the receiving station. At this station, normally on the aircraft, the sound data is analyzed, processed, displayed, and recorded. The basic LOFAR display plots the frequency of the sound waves against the intensity of their acoustic energy, and against the duration of the sound emission. This data can be displayed on a video screen and printed out. The data is also recorded on magnetic tape for storage and retrieval when desired.

DIFAR SYSTEM.— The directional low-frequency analysis and recording system (DIFAR) is an improved passive acoustic sensing system. Using the passive directional sonobuoy (fig. 4-31), DIFAR operates by detecting directional information, and then frequency multiplexing the information to the acoustic data. This signal is then transmitted to the aircraft where it is processed and the bearing is computed. Subsequent bearing information from the buoy can be used to pinpoint, by triangulation, the location of the sound or signal source.

Active Sonobuoy

The active sonobuoy is either self-timed (the sonar pulse is generated by the buoy at a fixed pulse length and interval) or command actuated. The command activated buoy is controlled by a UHF command signal from the aircraft. An active sonobuoy uses a transducer to radiate a sonar pulse that is reflected back from the target. The time interval between the ping (sound pulse) and the echo return to the sonobuoy is measured. Taking the Doppler effect on the pulse frequency into consideration, this time-measurement data is used to calculate both range and speed of the submarine relative to the sonobuoy.

RO SONOBUOYS.— Self-timed active sonobuoys, known as range-only (RO) sonobuoys, are set to ping for a limited period, starting from the time they are deployed. These buoys will provide information on range of targets only.

CASS SONOBUOYS.— The command activated sonobuoy system (CASS) allows the aircraft to deploy the sonobuoy, but the buoy will remain passive until commanded to ping. This allows the aircraft to surprise the submarine.

DICASS SONOBUOY.— The addition of a directional hydrophone turns the CASS sonobuoy into a DICASS buoy. A DICASS sonobuoy allows the aircraft acoustic analysis equipment to determine the range and bearing to the target with a single sonobuoy. DICASS sonobuoys are replacing the RO and CASS sonobuoys.

Special-Purpose Sonobuoys

There are three types of special-purpose sonobuoys in use today. These are the BT, SAR, and the ATAC sonobuoys. These sonobuoys are not designed for use in submarine detection or localization.

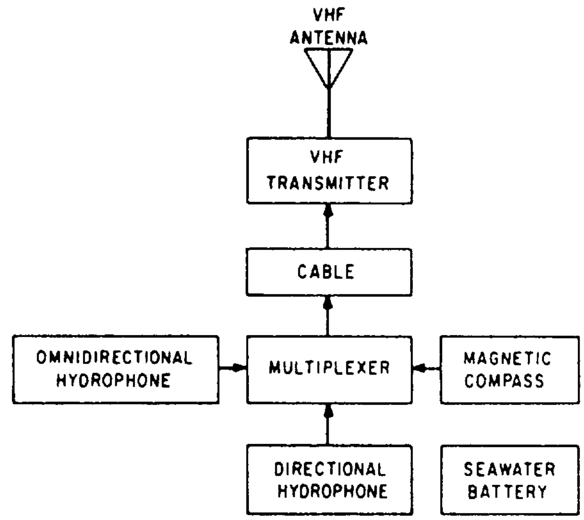

Figure 4-31.-Block diagram of the DIFAR sonobuoy.

BATHYTHERMOBUOY.— The bathythermobuoy (BT) is used to measure water temperature versus depth. The water depth is determined by timing the descent of a temperature probe. Once the BT buoy enters the water, the probe descends automatically at a constant 5 feet per second.

The probe uses a thermistor, a temperature-dependent electronic component, to measure the temperature. The electrical output of the probe is applied to a voltage-controlled oscillator. The oscillator's output signal frequency modulates the sonobuoy transmitter. The frequency of the transmitted signal is linearly proportional to the water temperature. The water temperature and depth are recorded on graph paper that is visible to the ASW operator. The sonobuoy signal is processed by the acoustic equipment on board the aircraft.

SAR BUOY.— The search and rescue (SAR) buoy is designed to operate as a floating RF beacon. As such, it is used to assist in marking the location of an aircraft crash site, a sunken ship, or survivors at sea. The buoy can be launched from aircraft equipped to launch sonobuoys or deployed over the side by hand. Nominal RF output is 1 watt for 60 hours on sonobuoy channel 15 (172.75 MHz). A floating microphone is provided for one-way voice communication. The RF beacon radiates automatically and continuously, regardless of whether the microphone is used. A flashing light and dye marker are incorporated in the buoy. The buoy also has an 8-foot tether line for attaching the buoy to a life raft or a person.

ATAC/DLC.— The air transportable communication (ATAC) and down-link communication (DLC) buoys are intended for use as a means of communication between an aircraft and a submarine. The ATAC buoy is commendable from the aircraft and provides up-link and down-link communications by a preselected code. The DLC buoy is not commandable and provides a down-link communications only by a preselected code.

SONOBUOY RECEIVERS

Learning Objective: *Recognize the operating principles and components of a typical sonobuoy receiver.*

The sonobuoy receiver set that will be discussed in this chapter is the AN/ARR-75. This set is used on the H-60 LAMPS helicopter.

The radio receiving set (RRS) receives, demodulates, and amplifies sonobuoy transmissions in the VHF bands, It provides channels A, B, C, and D acoustic data to the data link for transmission to the ship via the communications system control group. Channels E, F, G, and H acoustic data is provided direct to the data link for transmission to the ship. The acoustic data is also routed to the spectrum analyzer group for processing and display on board the aircraft. Simultaneous reception and demodulation of standard sonobuoy RF channels is possible. Any one of the received channels can be selected for aural monitoring. The RRS consists of two radio receiver groups.

The radio receiver groups each consist of four VHF radio receivers and a power supply. Each of the four receivers can operate on a separate channel, independent of the others. The RF signals received by the sonobuoy antennas are applied to each of the four receiver modules, where tuned filters select the signals for each module. The signals then pass through a series of amplifiers, filters, and mixers to produce the output audio signals. The output signals are supplied to the spectrum analyzer group and the data link system. The spectrum analyzer processes the signals to allow monitoring by the aircrew.

ACOUSTIC SYSTEM

Learning Objective: *Recognize components and operating principles of a typical acoustic system.*

The AN/UYS-1 single advanced signal processor system (SASP) processes sonobuoy acoustic audio and displays the resulting data in a format suitable for operator evaluation in the P3-C Update III aircraft.

OPERATING PRINCIPLES

The SASP processes sonobuoy audio in active and passive processing modes to provide long range search, detection, localization, and identification of submarines. The sonobuoys presently in use include the LOFAR, DIFAR, CASS, DICASS, and BT. The RF signals from the sonobuoys are received by the sonobuoy receivers and sent to the SASP. After processing, signals are sent to the displays and the recorders for operator use. The SASP also generates command tones for controlling the CASS and DICASS sonobuoys.

COMPONENTS

The major components include the TS-4008/UYS-1 spectrum analyzer (SA), PP-7467/UYS-1 power supply, and the C-11104/UYS-1 control-indicator (SASP power control).

TS-4008/UYS-1 Spectrum Analyzer

The TS-4008/UYS-1 spectrum analyzer is a high-speed signal processor designed to extract acoustic target information from both active and passive sonobuoy data. The SA determines frequency, amplitude, bearing, Doppler, range, and other characteristics for acoustic targets.

PP-7467/UYS-1 Power Supply

The PP-7467/UYS-1 power supply converts 115 volts ac into 120 volts dc operating voltages. The 120-volt dc power is then converted to low-level dc voltages for operation of individual circuits. A power interrupt unit protects the data against transient power interruptions that normally occur during airborne operations.

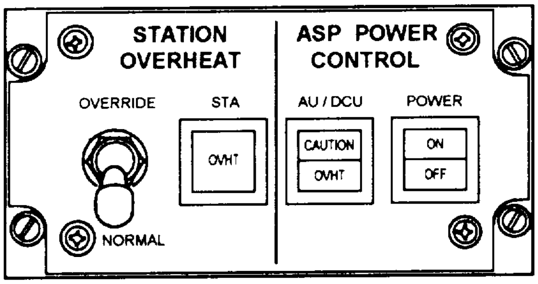

Figure 4-32.-SASP control-indicator.

C-11104/UYS-1 Control-Indicator

The C-11104/UYS-1 control-indicator (fig. 4-32) consists of one switch-indicator, two indicators, and one switch. The switch-indicator is labeled POWER ON/OFF. It controls the power to the SA, the display computer (DCU), the CASS transmitter, and the displays. The AU/DCU CAUTION/OVHT indicator indicates the temperature status in the SA and the DCU. The CAUTION section will flash on when the thermal warning is activated in either unit. The OVHT section indicates an overheat in either unit. The STA OVHT indicator indicates an overtemp condition exists at the sensor stations 1 and 2 consoles. The OVERRIDE-NORMAL switch will override the overheat warnings for the sensor stations 1 and 2 consoles.

REVIEW QUESTIONS

Q1. How was the word SONAR derived?

Q2. *In echo-ranging sonar, what is the source of the sound wave used?*

Q3. *What are the three main characteristics of seawater that affect the speed of a sound wave passing through it?*

Q4. On the azimuth and range indicator of the AN/ASQ-13E, what does the cursor intensity knob control?

Q5. What is the length of the special-purpose cable of the AN/ASQ-13E?

Q6. What are the staves of the hydrophone assembly filled with?

Q7. What is an anomaly?

Q8. What happens to the magnetic field of an aircraft as it maneuvers?

Q9. How many units are therein the ASA-64 SAD group?

Q10. With a sonobuoy equipped with EFS, how many depth settings are available?