

## CHAPTER 7

# AIRCRAFT AVIONICS

### INTRODUCTION

Modern naval aircraft have a wide variety of missions. The electronic equipment these aircraft carry enables them to perform these missions. We refer to this equipment as aviation electronics (avionics). The purpose of this chapter is to familiarize you with the most widely used avionics in the Navy.

Aircraft have two primary sources of electrical energy. The first is the generator, which converts mechanical energy into electrical energy. The second is the battery, which converts chemical energy into electrical energy. The generator is the main source and the battery is the auxiliary source. The Aviation Electrician's Mate (AE) rating maintains aircraft electrical systems.

### AIRCRAFT STORAGE BATTERIES

**LEARNING OBJECTIVE:** Identify the basic operating principles and safety precautions for working around aircraft batteries.

The aircraft storage battery provides a reserve source of electrical power for selected electrical systems. During normal aircraft operation, the generator maintains the battery in a charged state.

Batteries can be dangerous; therefore, you need to use extreme care when working around them. Maintain the batteries in perfect condition. Batteries are the emergency power source for the aircraft. Do not use the batteries for starting engines or servicing equipment if another source of power is available. Unnecessary usage will shorten the battery life and decrease the power available for emergency operation. Batteries also require a great deal of care because of the unusual conditions under which they operate. Therefore, batteries are usually shielded by enclosing them in a grounded, metal-covered housing, as shown in figure 7-1.

Most aircraft batteries use a quick-disconnect receptacle and plug, as shown in figure 7-1. This unit is a heavy-duty connector with a handle attached to a threaded post. You can disconnect the battery cables

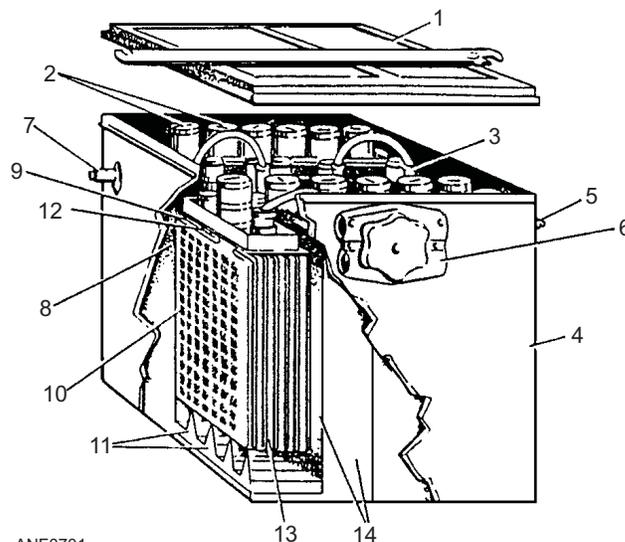
from the battery posts simply by turning the handle and pulling the quick-disconnect unit.

### LEAD-ACID BATTERY

Fundamentally, there is no difference between the lead-acid aircraft battery and the lead-acid automobile battery. Both have lead plates in a solution of sulfuric acid and water (electrolyte). Both operate on the same basic principles. The lead-acid battery consists of cells connected in series. Each cell contains positive plates of lead peroxide and negative plates of spongy lead.

### NICKEL-CADMIUM BATTERY

The nickel-cadmium battery gets its name from the composition of its plates: nickel oxide on the positive plate and metallic cadmium on the negative plates. The electrolyte consists of potassium hydroxide and water. The fundamental unit of the nickel-cadmium aircraft storage battery is the cell. The sintered-plate



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- |   |                                |
|---|--------------------------------|
| 1. Metal cover                          | 8. Cell container              |
| 2. Fillercap and vent plug              | 9. Positive plate group strap  |
| 3. Cell connectors                      | 10. Plate                      |
| 4. Metal container                      | 11. Plate supports             |
| 5. Vent                                 | 12. Negative plate group strap |
| 6. Quick-disconnect receptacle and plug | 13. Separators                 |
| 7. Vent                                 | 14. Cells                      |

Figure 7-1.—Typical aircraft lead-acid storage battery.

nickel-cadmium cells used in the battery consist of two basic types—vented and sealed cells. Most naval aircraft nickel-cadmium storage batteries employ rectangular vented-type cells. Sealed cells have limited applications and come in both the rectangular and cylindrical types.

## BATTERY SAFETY PRECAUTIONS

The principal hazard in working with lead-acid batteries is acid burns when you are refilling or handling them. You can prevent getting burned by wearing eyeshields, rubber gloves, rubber aprons, and rubber boots with nonslip soles. Rubber boots and aprons are only needed when you are refilling batteries. You should wear eyeshields whenever you are working around batteries. Eyeshields will prevent acid burns to your eyes. Wood slat floorboards, in good condition, will help prevent slips and falls. Additionally, electric shock from the high-voltage side of charging equipment is reduced.

Another hazard of working with batteries is the chance of an explosion. Hydrogen gas, a high explosive, collects while batteries are charging and can cause an explosion during battery charging. This is especially true when using the accelerated charging method. The charging rate should be held to a point that prevents the rapid release of hydrogen gas. Follow the manufacturers' recommendations for the charging rates. Be careful to prevent short circuits while batteries are being charged, tested, or handled. A spark from a shorted circuit could easily ignite the explosive gases. This danger is also true for personnel performing aircraft maintenance near batteries. Open flames or smoking are not permitted in the battery charging room. Use a shop exhaust system to remove the gases.

Use extreme caution when you are installing or removing an aircraft battery. Batteries are heavy for their size and awkward to handle. These characteristics require the use of proper safety precautions.

Aircraft batteries may overheat because of internal shorting or thermal runaway. In either case, an overheated battery causes a hazardous condition. When an overheated battery is detected, crash crew personnel should open the battery compartment and check for the following conditions:

- Flame—If present, use CO<sub>2</sub> extinguisher.
- No flame—If smoke, fumes, or electrolyte is coming from the battery or vent tubes, spray

the battery with low-velocity water fog. This will lower the battery temperature.

### WARNING

CO<sub>2</sub> is a good fire-extinguishing agent once a fire has started. Never spray CO<sub>2</sub> from a portable fire extinguisher into a battery compartment for cooling or to displace explosive gases. The static electricity generated by the discharge of the extinguisher could explode the gases trapped in the battery compartment.

Following a visual check, allow crash crew personnel to remove the battery. If additional battery cooling is required, use low-velocity water fog.

You may use the above procedures on all types of aircraft batteries installed in all types of aircraft.

### CAUTION

If acid or electrolyte from a lead-acid battery touches your skin or eyes, flush the affected area with large quantities of fresh water. Report immediately for medical examination and treatment.

### CAUTION

If the electrolyte from a nickel-cadmium (NICAD) battery touches your skin or eyes, flush the affected area thoroughly with large quantities of fresh water. Neutralize with vinegar or a weak solution (3%) of boric acid. Report immediately for medical examination and treatment.

- Q7-1. What are the two primary sources of electrical energy for an aircraft?*
- Q7-2. During normal aircraft operation, what component maintains the battery in a charged state?*
- Q7-3. What are the principal hazards of working with batteries?*
- Q7-4. What can cause aircraft batteries to overheat?*
- Q7-5. What should you do if acid or electrolyte from a lead acid battery comes in contact with your skin?*
- Q7-6. What are the two ways to neutralize electrolyte from a nickel-cadmium (NICAD) battery if it contacts your skin?*

## ALTERNATING CURRENT (AC) SYSTEMS

**LEARNING OBJECTIVES:** Identify the basic purpose and operating principles for aircraft ac electrical systems. Identify the purpose of gyroscopes. Identify navigational instruments and recognize their purpose.

As you just learned, energy for operating most electrical equipment in an aircraft depends primarily on energy supplied by a generator. A generator converts mechanical energy into electrical energy. Generators that produce ac are called *ac generators* or *alternators*. Most naval aircraft use ac electrical systems as the primary source of power. Most equipment aboard is ac powered. The few requirements that remain for direct current (dc) are normally supplied by a system of rectifiers. A rectifier converts ac power to dc power. Auxiliary power units (APUs), discussed later in this chapter, provide ground service and emergency power. (See Navy Electricity and Electronics Training Series (NEETS), Module 5, NAVEDTRA 172-05-00-79, for detailed information on the construction and operation of ac generators and motors. Module 5 also discusses the principles of rectification and voltage regulation.)

## EMERGENCY ELECTRICAL POWER

For many years, the storage battery was the only source of emergency electrical power. Recent advancements in avionics equipment have caused emergency electrical loads to exceed the capability of storage batteries. Also, the aircraft storage battery with its highly corrosive electrolyte damages precision equipment and precious metals used in today's aircraft. For these reasons, there are new methods of providing emergency electrical power.

### EMERGENCY POWER GENERATORS

Many jet aircraft have emergency generators. These generators provide emergency electrical power in the event of main electrical power failure.

In some aircraft, a power package positioned outside the aircraft provides emergency electrical power. When required, the pilot operates a lever that causes the package to stick out into the airflow. The ram-air effect of the airflow provides the turning power for a turbine. The turbine, in turn, rotates the generator's armature (fig. 7-2) that produces the electrical power.

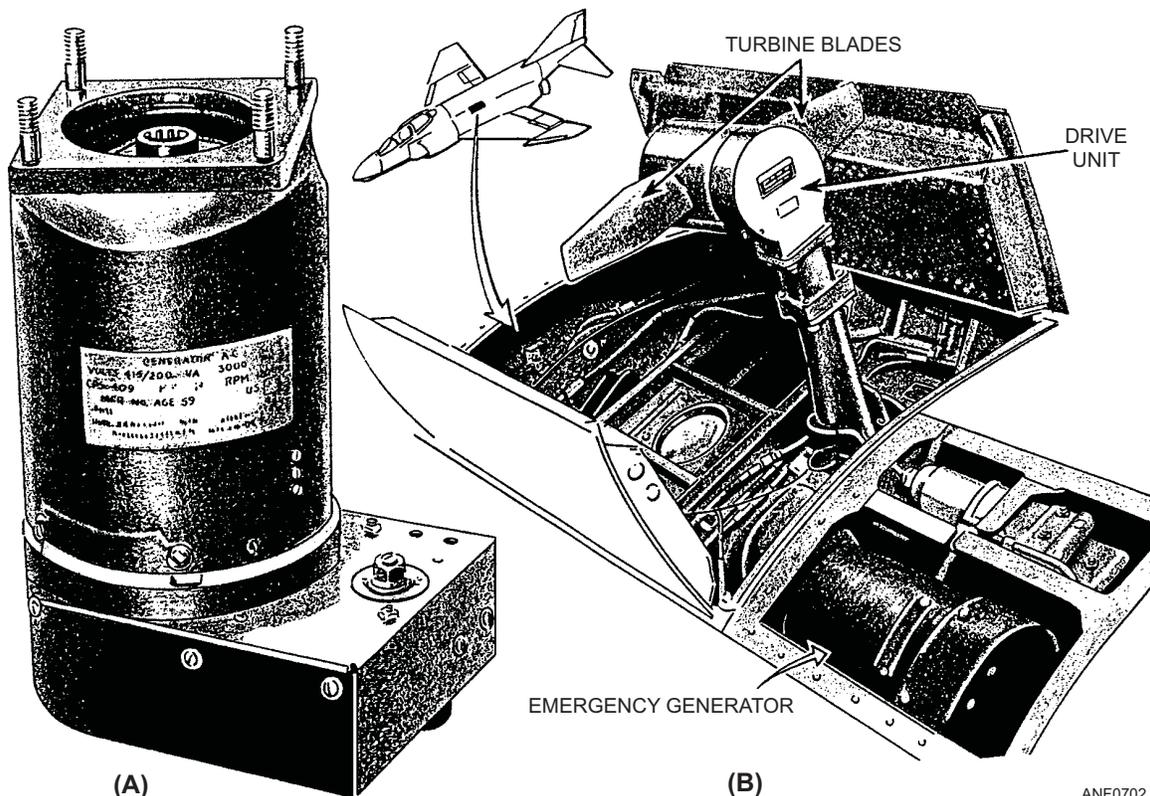


Figure 7-2.—(A) Emergency generator; (B) emergency generator installation.

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## AIRBORNE AUXILIARY POWER UNITS (APU)

Most larger aircraft use APUs. These power units furnish electrical power when engine-driven generators are not operating or when external power is not available. The power output from the APU supplies a constant voltage at a constant frequency. The APU does not depend on engine rpm.

Most units use a gas turbine (fig. 7-3) to drive the generator. The gas turbine provides compressed air for air conditioning and pneumatic engine starting. This makes the aircraft independent of the need for ground power units to carry out its mission.

## CARRIER AIRCRAFT ELECTRICAL POWER SERVICING SYSTEM

The deck-edge electrical power system on aircraft carriers provides servicing power to aircraft. Twenty-eight volt dc power is supplied by rectified ac or by motor-generators. Ac generators usually supply the 400-hertz, three-phase, ac servicing voltage. Figure 7-4 shows an electrical power service system found on modern carriers. Power is supplied by service outlets located at the edge of the flight deck or from recesses in the flight deck. Additionally, receptacles are located throughout the hanger bay. All systems have standard remote control switches, service outlet boxes, and

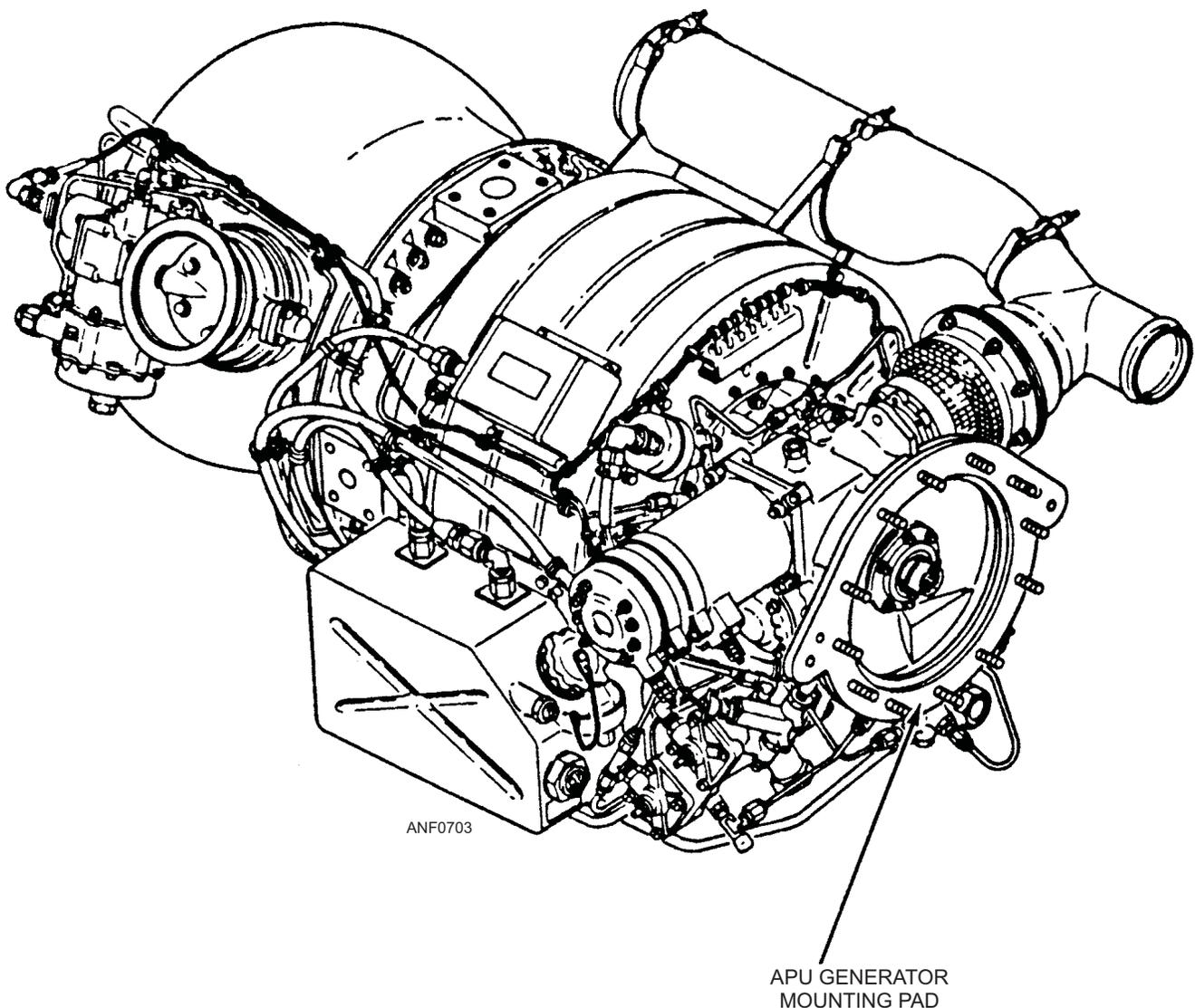


Figure 7-3.—Gas turbine power plant unit.

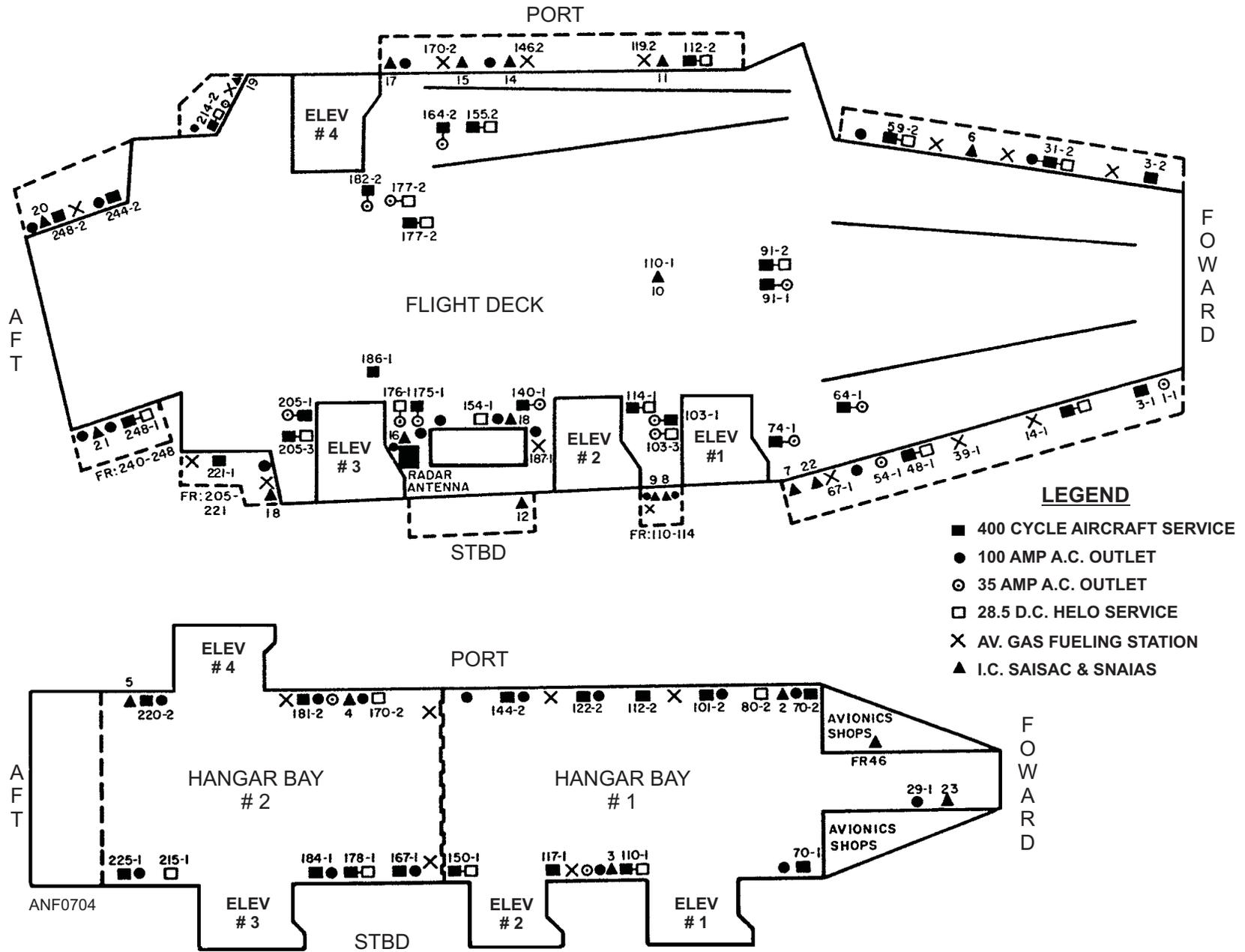


Figure 7-4.—Carrier aircraft servicing system.

power cables. Figure 7-5 shows typical deck-edge electrical installations.

The dc service cable is oval-shaped and contains three female pins that mate to male pins on the aircraft. The ac service cable is rectangular-shaped and contains six female pins that mate to male pins on the aircraft.

Use the following safety precautions when you work with deck-edge electrical power systems:

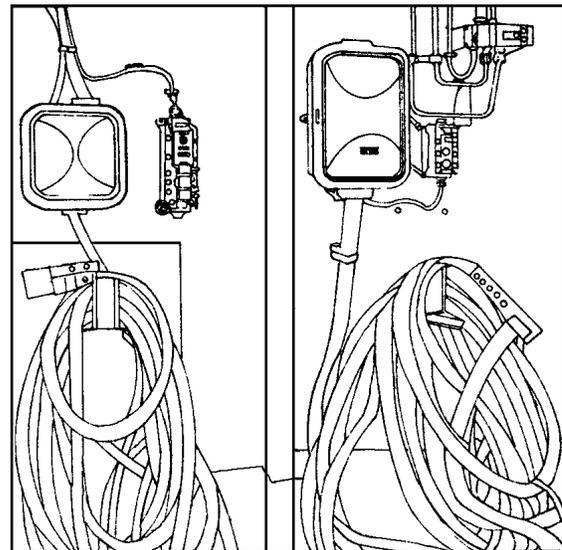
- Use care when you are connecting the heavy cables to the aircraft. Damage to the aircraft power receptacles may result if too little slack is left in the cables.
- Be sure that the remote switches are turned off prior to connecting or disconnecting service cables to the aircraft.
- The flush deck outlets often get water in them because of rain or heavy seas. Do not use these outlets if water is present. You will get shocked.

### PITOT-STATIC SYSTEM

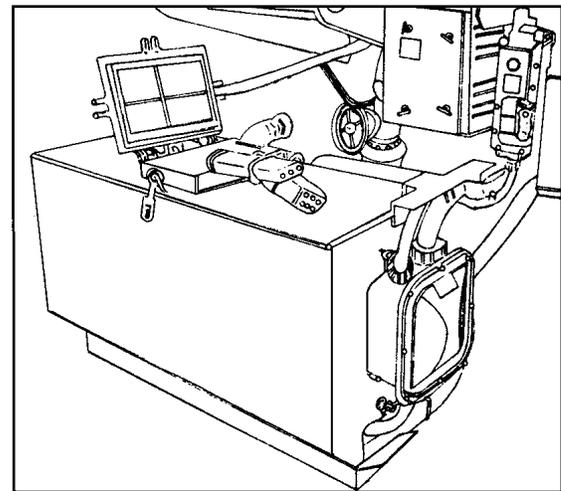
The Aviation Electrician's Mate (AE) rating maintains the pitot-static system and most aircraft instruments. The pitot-static system in an aircraft includes some of the instruments that operate on the principle of the barometer. It consists of a pitot-static tube and three indicators, all connected with tubing that carries air. The three indicators are the altimeter, the airspeed and Mach number indicator, and the rate-of-climb indicator. The airspeed indicator displays the speed of the aircraft. The altimeter displays the altitude of the aircraft. The rate-of-climb indicator shows how fast the aircraft is climbing or descending. Each instrument operates on air taken from outside the aircraft during flight. The relationship between the pitot-static tube, the airspeed indicator, the altimeter, and the rate-of-climb indicator is shown in figure 7-6.

The pitot tube is mounted on the outside of the aircraft at a point where the air is least likely to be turbulent. It points in a forward direction parallel to the aircraft's line of flight. One general type of airspeed tube mounts on a mast extending below the nose of the fuselage. Another is on a boom extending forward of the leading edge of the wing. Although there is a slight difference in their construction, their operation is the same.

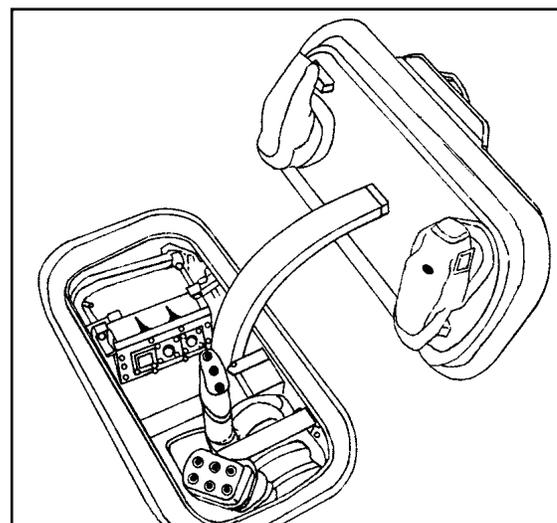
Static means stationary or not changing. The static port introduces outside air, at its normal outside atmospheric pressure, as though the aircraft were standing still in the air. The static line applies this outside air to the airspeed indicator, the altimeter, and the rate-of-climb indicator.



A



B



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C

Figure 7-5.—Typical deck-edge electrical installations. (A) Hangar deck; (B) catwalk; (C) flush deck.

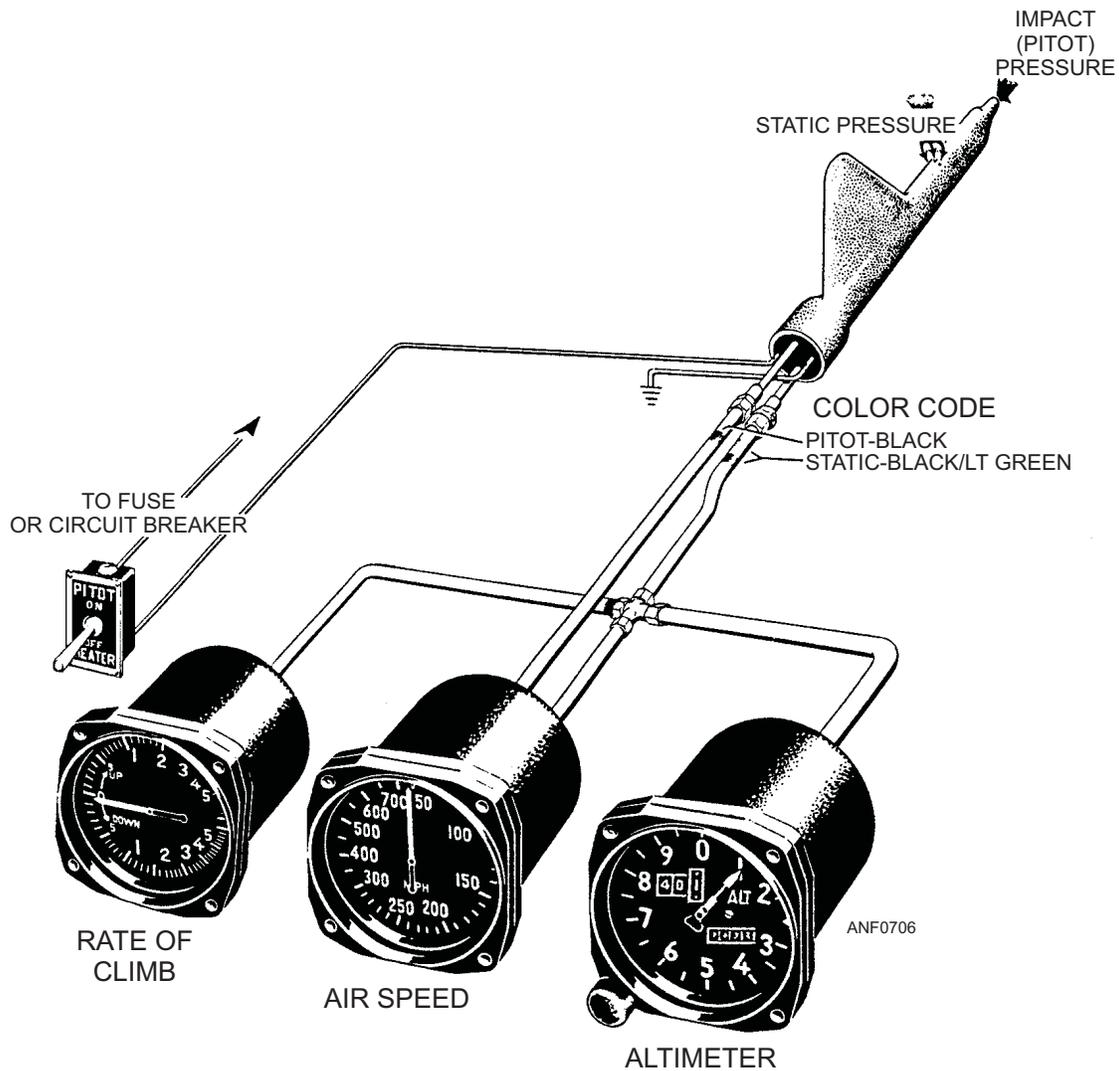


Figure 7-6.—Pressure measuring instruments.

The tube or line from the pitot tube to the airspeed indicator applies the pressure of the outside air to the indicator. The indicator is calibrated so various air pressures cause different readings on the dial. The indicator interprets air pressure from the pitot tube and reflects airspeed in knots.

When working on or around the pitot tube or static ports, do not obstruct the openings. Obstructed openings restrict the supply of air to the indicators and cause false readings.

**CAUTION**

Severe burns may result from touching a pitot tube with the pitot tube heaters on. Be sure the pitot tube heaters are off before installing protective covers.

**Altimeter**

The altimeter (fig. 7-7) shows the height of the aircraft above sea level. The face of the instrument is

calibrated so the counter/pointer displays the correct altitude of the aircraft.

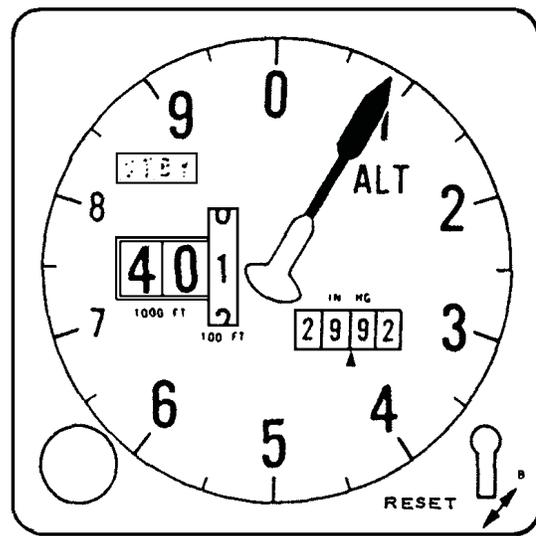


Figure 7-7.—Counter/pointer altimeter.

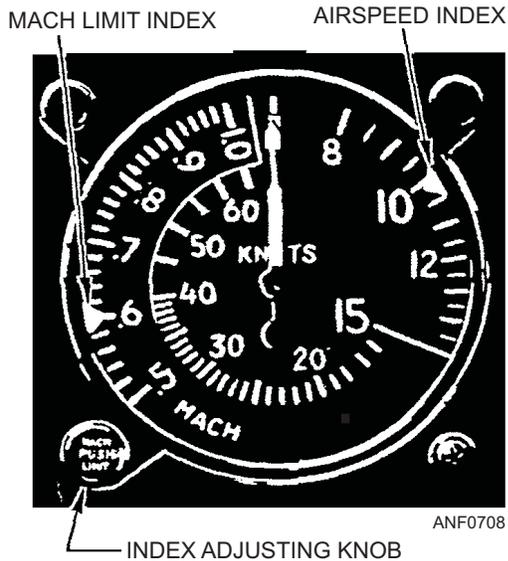


Figure 7-8.—Airspeed and Mach number indicator.

### Airspeed and Mach Number Indicator

The airspeed and mach number indicator (fig. 7-8) displays the speed of the aircraft in relation to the air in which it is flying. In some instances, the speed of an aircraft is shown in Mach numbers. The Mach number of any moving body is its speed compared to the speed of sound in the surrounding medium (local speed). For example, if an aircraft is flying at a speed equal to one-half the local speed of sound, it is flying at Mach 0.5. If it moves at twice the local speed of sound, its speed is at Mach 2.

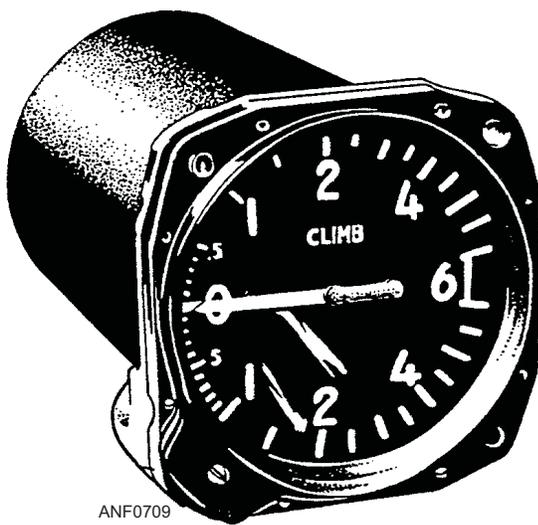


Figure 7-9.—Rate-of-climb indicator.

### Rate-of-Climb Indicator

The rate-of-climb indicator (fig. 7-9) shows the rate at which an aircraft is climbing or descending. The case of a climb indicator is airtight except for a small connection through a restricted passage to the static line. Changes in atmospheric pressure move the operating mechanism that displays the rate of change. This change occurs only when the aircraft is ascending or descending. When the aircraft ceases to climb or dive, the airflow through the metering units equalizes and the pointer returns to zero.

### PRESSURE INDICATING GAUGES

Electrical signals from a pressure transmitter activate a variety of aircraft instrument systems. Electrically activated instruments are usually in the form of small voltmeters with calibrated dials. These dials are calibrated to display a variety of conditions such as oil pressure, fuel pressure, and hydraulic pressure.

### Oil Pressure Indicator

Oil pressure instruments (fig. 7-10) show the pressure of the oil. Drops in oil pressure (below normal conditions) signal possible engine failure caused by lack of oil.

### Fuel Pressure Indicator

The fuel pressure indicator provides a check on the operation of the fuel system. It shows if fuel is being supplied steadily under the correct operating pressure.

### Hydraulic Pressure Indicator

The pressures of hydraulic systems vary for different models of aircraft. In most pressure systems,



Figure 7-10.—Oil pressure indicator.

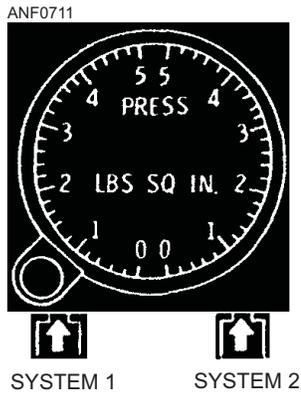


Figure 7-11.—Hydraulic pressure indicator.

the gauges register from 0 to 3,000 psi. Figure 7-11 shows the hydraulic pressure indicator of a late model naval aircraft. The indicator provides a continuous pressure reading on the number 1 and number 2 flight control systems. The pressure indicator contains two synchros mechanically attached to two separate pointers. The pointers show the pressure in each system.

## ENGINE INSTRUMENTS

To properly operate an aircraft, the pilot must monitor many engine instruments. Among these are temperature indicators, the tachometer, the fuel quantity indicator, and the vertical scale indicator.



Figure 7-12.—Turbine inlet temperature indicator.

### Turbine Inlet Temperature Indicator

A turbine inlet temperature indicator (fig. 7-12) provides a visual display of the temperature of gases entering the turbine. Dual-unit thermocouples installed in the inlet casing measure the temperature of each inlet. The indicator scale is calibrated in degrees Celsius ( $^{\circ}\text{C}$ ) from 0 to 12 (times 100). The digital indicator reads from 0 to 1,200 $^{\circ}\text{C}$ , in 2-degree increments.

### Exhaust Gas Temperature Indicator

The exhaust gas temperature indicator provides a visual display of the engine's exhaust gases as they leave the turbine unit. A typical exhaust gas temperature indicating system for a modern naval jet aircraft is shown in figure 7-13.

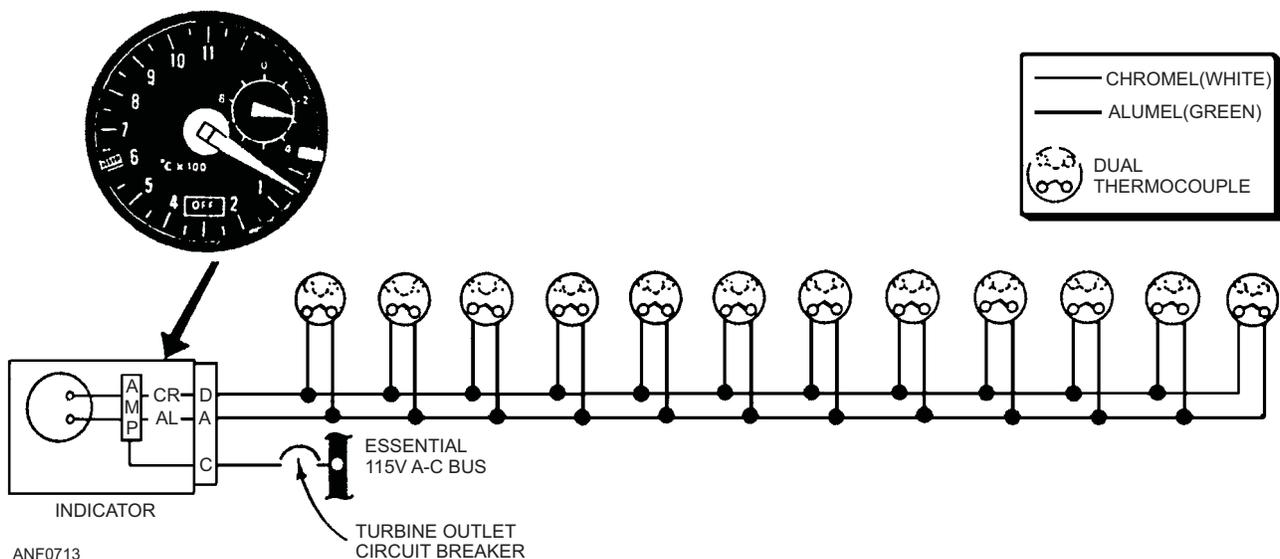


Figure 7-13.—Exhaust gas temperature indicating system.

## Tachometer

The tachometer (fig. 7-14) is an instrument for showing the speed of the power section of a gas turbine engine. A small alternator or generator attached to the engine's accessory section produces a voltage proportional to the speed of the power section. This voltage powers the pointer on the tachometer and registers the percent of rpm being developed.

A dual tachometer is used in turbojet and multiengine aircraft.

## Fuel Quantity Indicator

The fuel quantity indicator (fig. 7-15) is a capacitor-type gauge system. An electronic fuel-measuring device displays fuel quantity in pounds. The dial of the indicator is calibrated from 0 to 6 (times 1,000) with line increments every 100 pounds.

## Vertical Scale Indicator

On most new model naval aircraft, radial dial indicators have been replaced by vertical scale indicators. The vertical scale indicator is used to show engine performance data, fuel flow, engine speed, exhaust gas temperatures, and accelerometer readings. Vertical scale indicators are compact, lightweight, and easily read. Figure 7-16 shows a few examples of the vertical scale indicators now in use.



Figure 7-14.—Tachometer, jet engine type.

## GYROSCOPES

If not for using the properties of a spinning wheel, precise navigation and instrument flying would be very difficult. Two very important instruments that use the properties of a gyroscope are the attitude indicator and the turn and bank indicator.

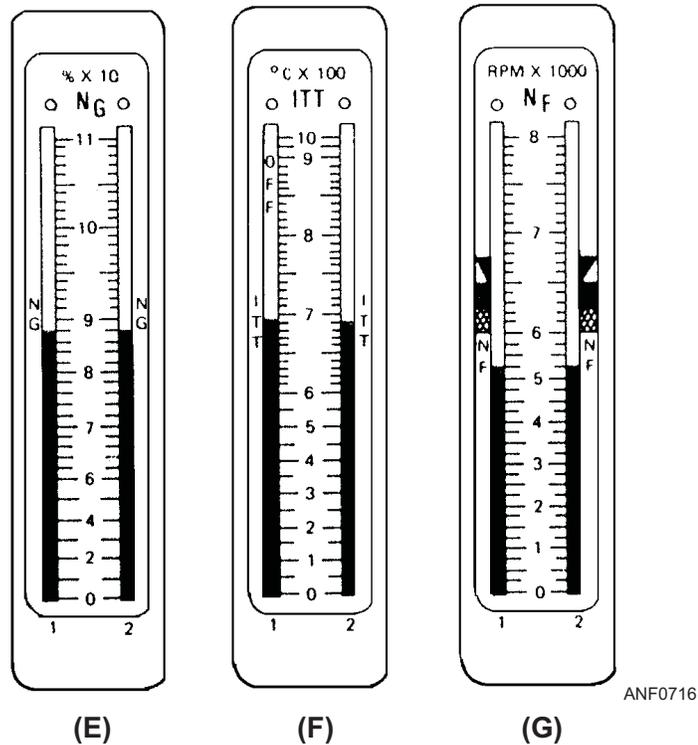
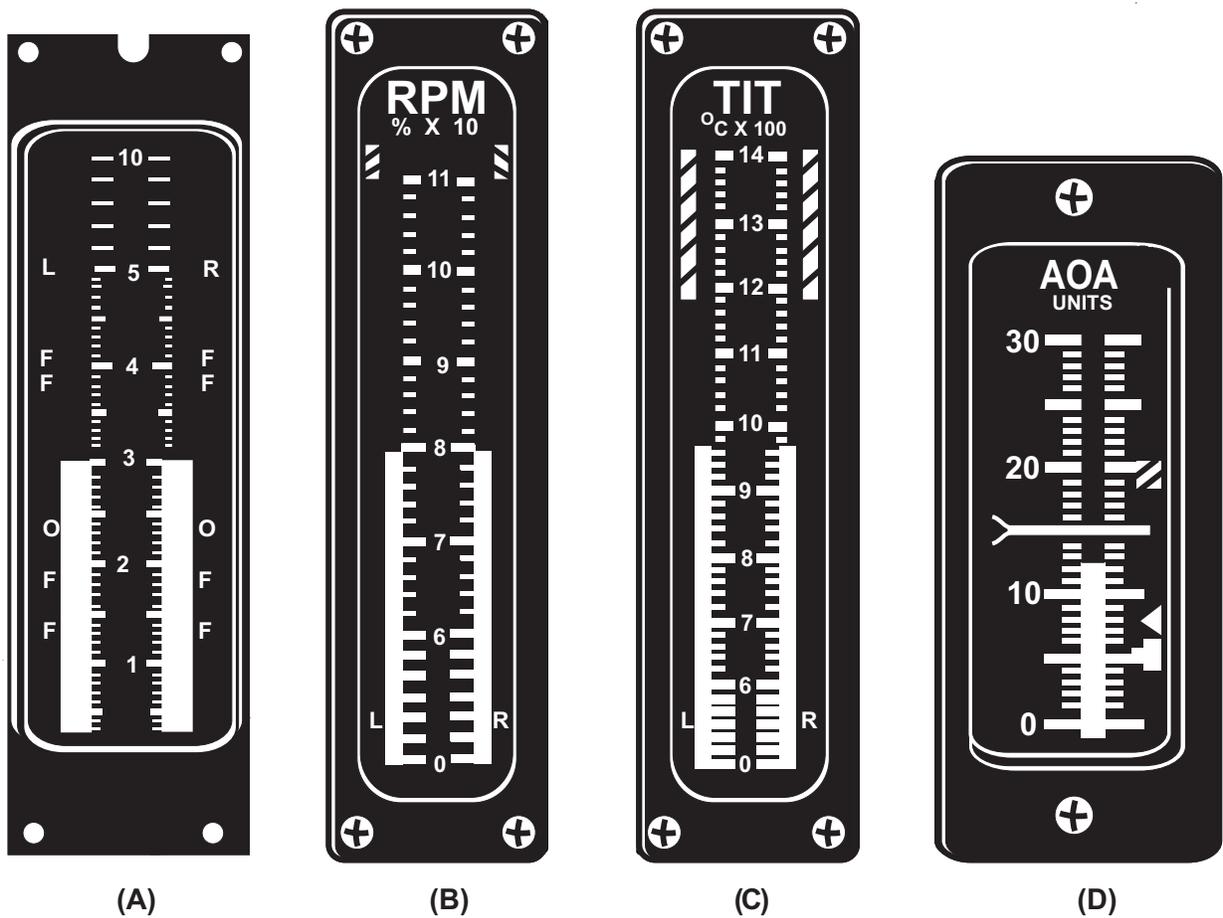
## Attitude Indicator

A pilot determines aircraft attitude by referring to the horizon. Often, the horizon is not visible. When it is dark, overcast, smoky, or dusty, you cannot see to use the earth's horizon as a reference. When one or more of these conditions exists, the pilot refers to the attitude indicator. The attitude indicator is also known as a *vertical gyro indicator (VGI)*, *artificial horizon*, or *gyro horizon*. Attitude indicators show the pilot the relative position of the aircraft compared to the earth's horizon.

Attitude indicators may be different in size and appearance, but they all have the same components and present the same basic information. As shown in figure 7-17, a miniature aircraft represents the nose (pitch) and wing (bank) attitude of the aircraft with respect to the earth's horizon. A band on the face of the indicator shows the degree of bank. The sphere is shaded light on the upper half and dark on the lower half to show the difference between sky and ground. The calibration marks on the sphere show degrees of pitch. Each indicator has a pitch trim adjustment so the pilot can center the horizon as necessary.



Figure 7-15.—Fuel quantity indicator.



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Figure 7-16.—Vertical scale indicators. (A) Fuel flow indicator; (B) tachometer rpm indicator; (C) turbine inlet temperature indicator; (D) angle-of-attack indicator; (E) gas generator speed indicator; (F) interturbine temperature indicator; (G) fan speed indicator.

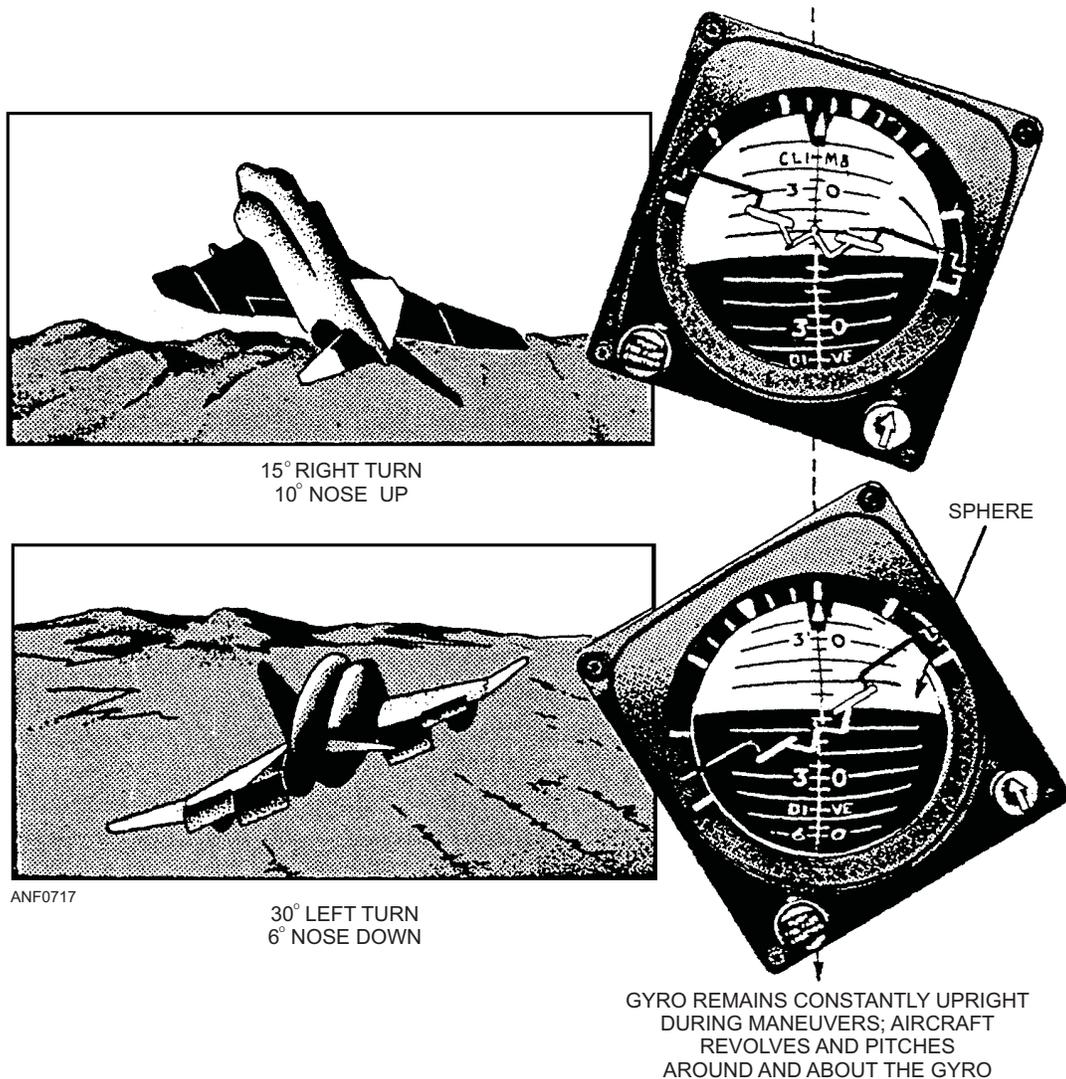


Figure 7-17.—Roll and pitch indications.

### Turn and Bank Indicator

The turn and bank indicator (fig. 7-18) shows the correct execution of a turn and bank. It also shows the lateral attitude of the aircraft in straight flight.

A turn and bank indicator is really two instruments mounted as a single unit. The turn indicator is a gyro mounted in a frame that is pivoted to turn on a longitudinal axis. The direction of a turn is shown on the dial by a pointer. The distance the pointer moves to the right or left is proportional to the rate of the turn.

The other half of the instrument, the bank indicator, is not a gyro instrument. It consists of a glass ball that moves in a curved glass tube filled with a liquid, consisting of 50% alcohol and 50% glycerin. The tube

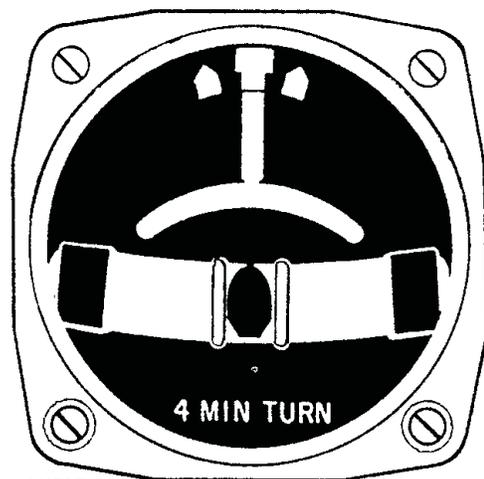


Figure 7-18.—Turn and bank indicator.

is mounted horizontally below the center of the dial, as shown in figure 7-18.

When the pilot is executing a properly banked turn, the ball stays in the center position. If the ball moves from the center position, it shows the aircraft is slipping to the inside or the outside of the turn. Centrifugal force and gravity determine the position in which the ball rests.

## NAVIGATIONAL INSTRUMENTS

The following navigational instruments direct, plot, and control the course or position of aircraft.

### Magnetic (Standby) Compass

A direct-reading magnetic compass (fig. 7-19) is mounted on the instrument panel. The face of the compass is read like the dial of a gauge.

### Gyro Compass

The gyro compass is used in many naval aircraft. The system provides an accurate indication of aircraft headings through 360° of azimuth.

### Horizontal Situation Indicator

The newest naval aircraft use the horizontal situation indicator (fig. 7-20). It shows the pilot the navigational situation of the aircraft.

*Q7-7. Generators that produce alternating current (ac) for aircraft are known as what type of generators?*

*Q7-8. Most naval aircraft use what type of system as their primary source of power?*

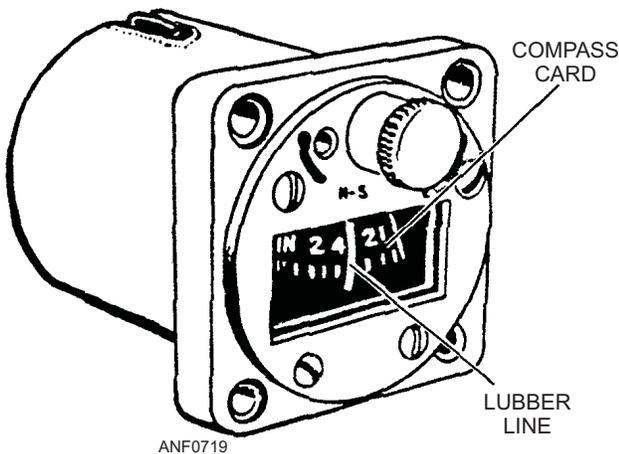


Figure 7-19.—Magnetic (standby) compass.

*Q7-9. What is the purpose of airborne auxiliary power units (APUs)?*

*Q7-10. The pitot-static consists of a pitot-static tube and three indicators. What are the three indicators?*

*Q7-11. What is the function of the altimeter?*

*Q7-12. Define the Mach number of any moving body.*

*Q7-13. What information does the attitude indicator provide to the pilot?*

*Q7-14. What information does the turn and bank indicator provide to the pilot?*

*Q7-15. What are the three navigational instruments that direct, plot, and control the course or position of an aircraft?*

## COMMUNICATIONS AND NAVIGATION EQUIPMENT

**LEARNING OBJECTIVES:** Recognize the general characteristics and uses of communications and navigation equipment. Identify the basic purposes of navigational systems and equipment to include TACAN, Global Positioning System (GPS), and navigation computer systems.

This section presents information on airborne uses of radio communications and navigation. Radio equipment does not require interconnecting wires between the sending and receiving stations. It is the

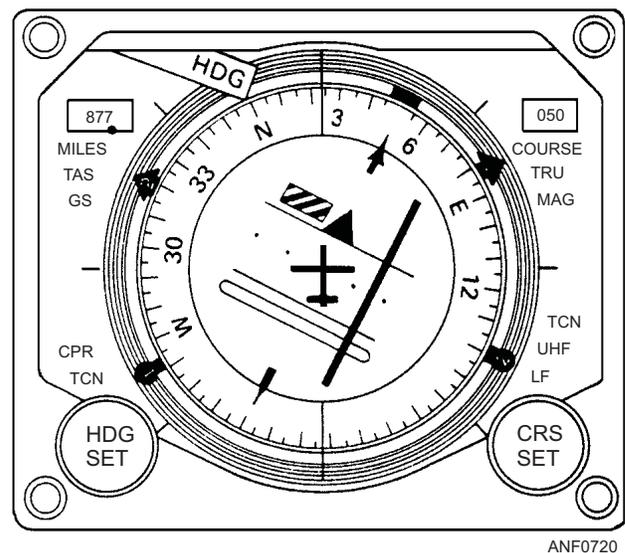


Figure 7-20.—Horizontal situation indicator.

only practical means of communicating with moving vehicles, such as ships or aircraft. Also, radio communication can span great distances in any or all directions. It is the most practical system to use for sending information to many points, as in broadcasting to large numbers of ships or aircraft.

Modern aircraft use radio equipment as navigational aids. Navigation aids consist of many types and are of varying complexity. They range from simple radio direction finders to complex navigational systems. Some systems use computers and other advanced electronic equipment to solve navigational problems automatically. The Aviation Electronics Technician (AT) rating normally maintains communications and navigational equipment.

## **AIRBORNE COMMUNICATIONS EQUIPMENT**

Several means of radio communications are in use today. Some of these radio communications methods are:

- Radiotelegraphy—The transmission of intelligible coded radio-frequency waves as Morse code.
- Radiotelephony—The transmission of sound intelligence (voice, music, or tones) by continuous radio-frequency waves.
- Radiofacsimile—The transmission of still images (weather maps, photographs, sketches, and so forth) over a radio-frequency channel.
- Radioteletype—The transmission of typewritten messages over a radio-frequency channel.
- Radiotelevision—The transmission of a rapid succession of images (still or moving) over a radio-frequency channel.

Airborne communications equipment usually consists of equipment that can use either or both radiotelegraphy or radiotelephony. Radiotelegraphy and radiotelephony are called Morse code and continuous wave (CW) voice communications, respectively.

### **Long-range Communications**

Airborne long-range communications sets normally operate in a band of frequencies from about 3 MHz to 30 MHz. Frequencies within this band are called the HF or high-frequency band. Radio frequencies within this band have characteristics that make them highly useful. The radiated waves

transmitted along the surface of the earth bend around objects in its path. In addition, radio waves that are transmitted skyward bounce off the ionosphere and return to earth at extreme distances from the transmitting station. This allows the waves to travel extremely long distances.

Most long-range communications sets are designed for both voice and CW (Morse code) operation. It is often necessary to have a long antenna for long-range communications. A weighted antenna wire (trailing wire antenna) is installed in some large aircraft. The wire is reeled out to provide an antenna of the desired length.

### **Short-range Communications**

Short-range airborne communications sets operate in the frequency range from about 30 MHz to 3 GHz. The lower portion of this band is the very-high-frequency (VHF) band; the higher portion is the ultra-high-frequency (UHF) band. The VHF/UHF frequency bands have transmission characteristics that differ from those frequencies in the HF band. Radio waves transmitted at these frequencies travel in a straight line. This limits the transmission to line-of-sight. VHF/UHF communications sets are called line-of-sight communications sets. Radio waves at these frequencies normally do not return to earth. Therefore, VHF/UHF transceivers are mainly used for air-to-air and air-to-ground contact in close range operations. Landings and takeoffs are typical situations using air-to-ground VHF/UHF transmissions.

Special situations exist where VHF/UHF equipment is involved in long-distance communications. An example of this is the network of remote-controlled transceivers installed along the airways system in the United States. Pilots of aircraft traveling the airways can talk directly to controllers in distant aviation activities. A system of telephone lines and relay stations connect the remote transceiver sites. The radio part of the transmission takes place over a relatively short distance.

## **NAVIGATIONAL EQUIPMENT**

Modern naval aircraft use a lot of navigational equipment. Radio receivers and transmitters are used to handle signals that determine bearing and/or distance. The tactical air navigation (TACAN) system, Global Positioning system (GPS), and navigation computer systems are discussed briefly in the following paragraphs.

## **Tactical Air Navigation (TACAN) System**

TACAN is a radio navigational set that provides slant range and relative bearing to a transmitting ground (surface) station. It has Distance Measuring Equipment (DME) that provides continuous slant range information. The Bearing Distance Heading Indicator (BDHI) provides a visual indication of the navigational situation for that aircraft.

## **Global Positioning System (GPS)**

The Global Positioning System (GPS) is a space-based radio position and navigation system designed to provide highly accurate three-dimensional position, velocity, and time data to suitably equipped aircraft anywhere on or near the earth. The Satellite Vehicle (SV) consists of 24 operational satellites in six circular orbits (10,900 nmi) above the earth at an inclination angle of 55° with a 12-hour period. The satellites are spaced in orbit so that at any given time a minimum of four satellites will be in view to users anywhere in the world.

The GPS Navigation Set receives and processes SV signals, combines them with air data information, and then calculates and displays the aircraft position for navigation. The information includes present aircraft position, course information, distance and time to waypoint and desired track, along with other navigation information. GPS consists of three independent segments—the satellite segment, ground segment, and the user segment.

## **Navigation Computers**

A new and complex group of electronic navigational equipment is now in use in naval aviation. This equipment does not use a radio receiver as the basic component. Included in this group are navigational computers, Doppler navigation equipment, and inertial navigation equipment.

**NAVIGATIONAL COMPUTERS.**—One of the navigational aids now in use is a latitude and longitude type of airborne computer system. This system can make the following computations during flight:

- The latitude and longitude of the present position of the aircraft. This information is continually displayed on the pilot's console.
- The aircraft ground track angle, relative to true heading.
- The distance from the present position of the aircraft to a preset target or base, as selected on the control panel.

- The bearing of the preset target or base, as selected, relative to true heading.

The computer is an analog-type computer. It includes a group of servomechanisms that receive navigational information and, by solving trigonometric equations, produces output information. Data input consists of the following:

- Compass heading
- True airspeed
- Magnetic variation
- Windspeed
- Base position latitude and longitude (usually the starting position)
- Target position latitude and longitude
- Aircraft's latitude and longitude (if not identical to base)

The magnetic compass and the true airspeed transmitter automatically furnish compass heading and true airspeed. The remaining inputs are set manually by control knobs on the counter-control panel. The computer sections continuously reposition the POSITION-LATITUDE and LONGITUDE counters to show the aircraft's present position and/or the intended target's position.

## **DOPPLER NAVIGATION EQUIPMENT.**—

Doppler navigation is based on a radar wave transmission beamed toward the earth behind the aircraft. This radar does not sense range and bearing (direction) as ordinary search radar does. Instead it uses a continuous wave (CW) transmission to measure the ground-speed and drift angle of the aircraft. The Doppler navigation system operates anywhere. It is relatively unaffected by weather conditions, and is independent of ground-based navigation aids. This permits an aircraft crew to compute an aircraft's track. The track is projected on the ground from any known position (usually the position of takeoff) to any position desired. Therefore, long-distance navigation is possible.

## **INERTIAL NAVIGATION EQUIPMENT.**—

An inertial navigation system (INS) is an automatic aid to navigation that is independent of outside references. An INS is a portion of the overall tactical system that provides accurate velocity, attitude, and heading data to a digital data processing system. This overall system permits accurate weapons delivery. To function properly, the system must be aligned with reference to initial conditions of altitude, latitude, and longitude.

The aircraft gyros, accelerometers, synchros, servos, and computers continually monitor aircraft heading, attitude, and horizontal and vertical velocities. Any change in the aircraft's latitude, longitude, or altitude involves a change in its speed or direction of motion. The inertia of extremely sensitive accelerometers resists these changes. This resistance is measured and recorded by the synchros, servos, and computers. The computers continually recalculate the movement of the aircraft based on the latest changes recorded by the accelerometers. The computers use these calculations to provide a constantly updated readout of the aircraft's geographical position. When used with Doppler radar, an INS greatly improves overall system accuracy.

- Q7-16. Define the radio communication method known as "radiotelegraphy."
- Q7-17. Define the radio communication method known as "radiotelephony."
- Q7-18. Airborne long-range communications sets normally operate in a band of what frequency range?
- Q7-19. Airborne short-range communications sets operate in what frequency range?
- Q7-20. What is the primary navigational aid used by the Navy for carrier-based aircraft?
- Q7-21. The Global Positioning System (GPS) is a space-based radio position and navigation system designed to provide what type of information?
- Q7-22. The GPS Satellite Vehicle consists of how many operational satellites?

Q7-23. Doppler radar uses what type of transmission to measure the ground speed and drift angle of the aircraft?

## RADAR

**LEARNING OBJECTIVE:** Recognize the operating principles, types, and uses of radar.

The acronym *radar* means Radio Detection And Ranging. Radar is a radio device used to detect objects at distances much greater than is visually possible. Detectable objects include aircraft, ships, land areas, clouds, and storms. In addition to detecting these objects, the radar shows their range and relative position.

Radar was shrouded in secrecy all through World War II. It was one of our most important offensive and defensive weapons systems. Today, radar is used in most types of aircraft, and plays a major role in the mission of naval aviation. Modern developments have led to many specialized types of radar; however, the basic principle upon which it functions is simply echo waves.

### ECHO PRINCIPLES

Radar works on the echo principle, as shown in figure 7-21. If a person shouts toward a cliff, in a few seconds the voice returns as an echo. If a radio wave is sent towards a cliff from a radio transmitter through an antenna, it would echo and return to be picked up through the antenna and sent to the radio receiver.

Sound waves travel about 1,100 feet per second, while radio waves travel at the speed of light (about

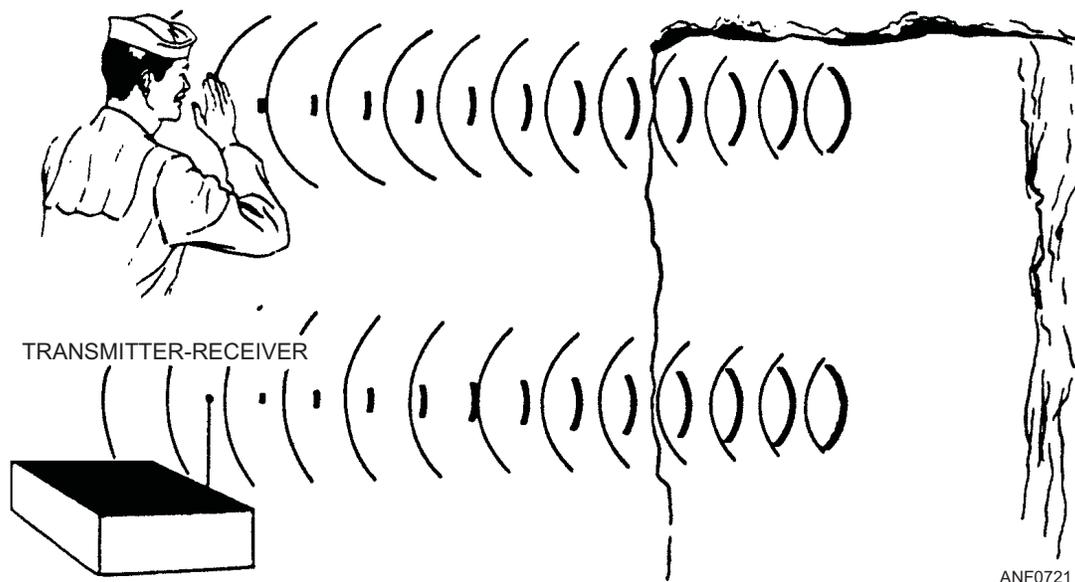


Figure 7-21.—Reflection of sound and radio waves.

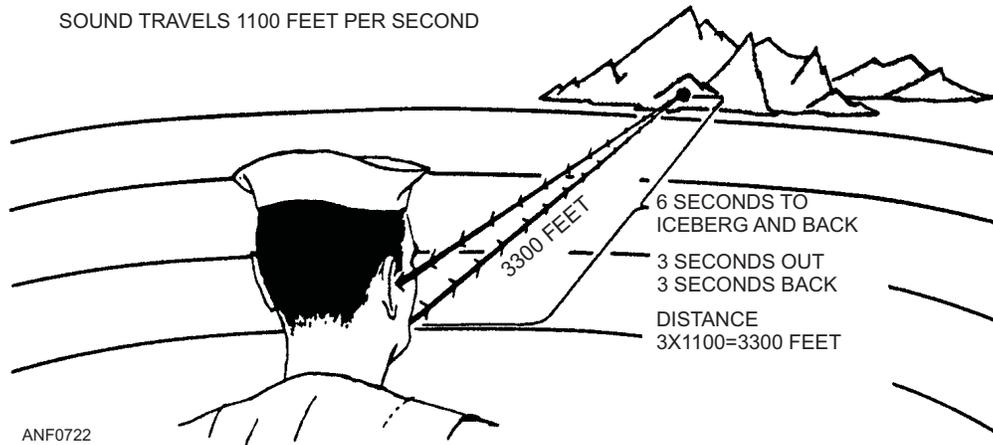


Figure 7-22.—Using voice echo to measure distance.

186,000 miles per second). By knowing the speeds of these waves and the time it takes them to return as an echo, you can measure distance.

Voice echo has been used to measure distance across canyons and the distance of icebergs from ships, as shown in figure 7-22. If it requires 6 seconds for a sound wave to reach an iceberg and return, the total distance traveled by the wave is 6,600 feet. The actual distance to the iceberg is only 3,300 feet. It requires

only one-half the time, or 3 seconds, for the sound to reach the iceberg. Therefore, the iceberg is  $1,100 \times 3$  or 3,300 feet away. Mathematically, the distance to the object is one-half the product of the velocity multiplied by the time in seconds. In this case, the velocity (1,100) is multiplied by the time in seconds (6). This divided by 2 equals 3,300 feet—the distance to the object.

Radar measures the distance to an object in much the same manner as the echo. (See fig. 7-23.) However,

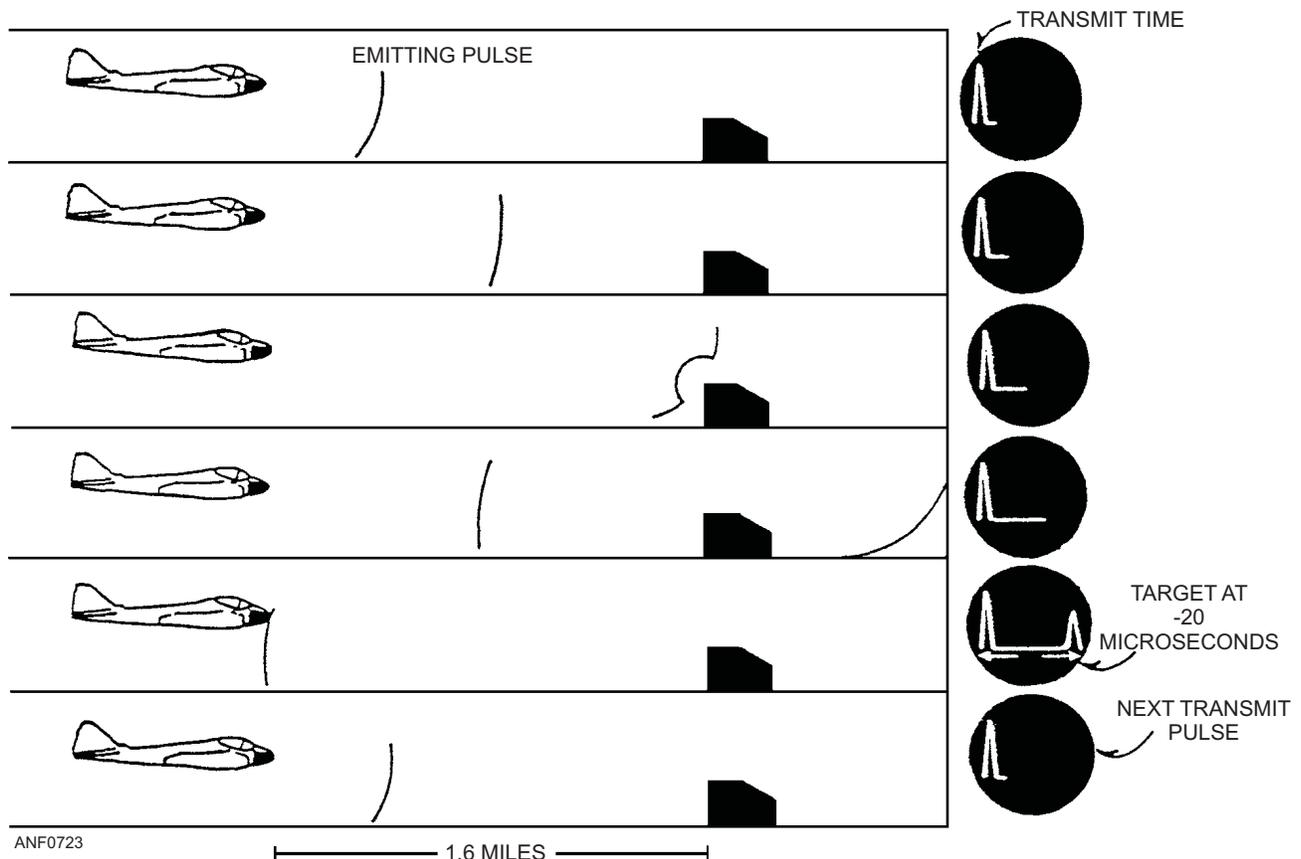


Figure 7-23.—Radar pulse detection.

radio waves travel much faster than sound waves. Radio waves travel about 330 yards in a millionth of a second. Therefore, the times involved in radar ranging are much shorter than for sound ranging.

### APPLICATIONS OF RADAR

Radar was originally devised as an instrument to detect approaching ships or aircraft. Practice and experience in reading the scope soon showed that radar could do much more. By plotting successive positions of enemy ships and aircraft, you could determine their course and speed. Further experience made it possible to determine whether the target was a battleship, destroyer, aircraft, or a group of targets. Also, an aircraft's altitude could be determined.

#### Use in Tactical Air Control

Both airborne and shipboard radar is a major link in an operational system. It directs fighter aircraft to a favorable position for intercepting enemy aircraft. The air control officer can determine the number of fighters so they can successfully attack and destroy the enemy.

Airborne early warning (AEW) aircraft, equipped with high-powered radars, are used in tactical air control. These aircraft extend the range of air control radar by operating in areas outside the range of the shipboard or land-based radar. The Aviation Electronics Technician (AT) rating maintains AEW equipment.

#### Use in Fire Control

The highly directional characteristics of radar make it suited for directing fire control systems. Focusing the radar energy into a narrow beam enables it to display target position with a high degree of accuracy. At the same time, it also displays target range.

The primary purpose of fire control radar is to determine the correct position and attitude the aircraft should be in to hit the specified target. Radar, in its early stages of development, was useful as an aid to the human eye under poor visibility conditions. It also provided a more accurate and faster means of range measurement. Presently, it provides a faster and more accurate method of directing fire control than is humanly possible. This feature is extremely important considering the high speeds of today's aircraft and missiles. The time available to launch an intercept weapon effectively is measured in fractions of a second.

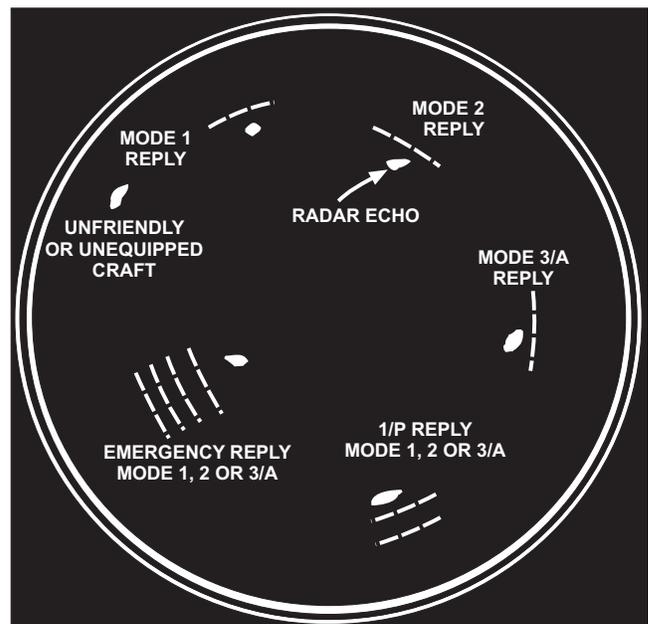
### IDENTIFICATION FRIEND OR FOE (IFF)

The problem of distinguishing friend from foe in warfare has increased because of the increased speed of aircraft and ships. Radar can detect both sea and air targets at long range. However, it displays both friend and enemy similarly on the scope. It is not practical to wait until the target has been visually identified to begin preparing for battle.

A method other than visual recognition must be used for early identification of the target. IFF is an electronic system that allows a friendly craft to identify itself automatically before approaching near enough to threaten the security of other naval units.

A transponder in the friendly aircraft receives a radio-wave challenge (interrogation). The transponder transmits a response to a proper challenge, as shown in figure 7-24. Upon receiving the proper challenge, the transponder automatically transmits a coded reply, which tells the challenger that a friend has been challenged. The transponder stays in a standby condition and transmits only when the proper challenge is received. The challenger's receiver accepts the reply of the challenged target and presents the replies on an indicator.

All operational aircraft and ships of the armed forces carry transponders to give their identity when challenged. For operations involving only friendly



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Figure 7-24.—Typical surface radar PPI composite display showing several IFF responses.

aircraft, it is important for air traffic control to know not only their location but their identity. The Selective Identification Feature (SIF) was developed to expand the IFF system. This increases its flexibility through a multiple-code transponder reply. By such means, selective and individual identification of aircraft is possible, with the following results:

- Ground control of friendly aircraft
- Operational flexibility in the identification process
- A measure of additional security in identification

## **ELECTRONIC COUNTERMEASURES**

A basic rule of warfare is that for each weapon used by one side, a counter-weapon will be developed by the other side. This rule is clearly seen in the development and use of electronic countermeasures (ECM). The objective of ECM is to gather intelligence from the enemy's electronic devices and make the devices ineffective. Electronic countermeasures consist of two general types of actions—passive and active.

### **Passive**

Passive ECM operations are those that cannot be directly detected by the enemy. These include search operations where enemy radar transmitters are detected, located, and as many of the signal characteristics as possible are determined. For example, ECM can detect a radar pulse transmission at 1 1/2 times the distance the radar return can detect a target. The signal characteristics determine if the radar is used for search, navigation, or fire control. Passive countermeasures also include evasive tactics taken to avoid detection and methods of controlling the radiations from friendly equipment. Such measures prevent the enemy from using the signals for homing, direction finding, or any other purpose.

### **Active**

Active ECM operations are actions that the enemy can detect. Active operations prevent effective use of the enemy's equipment. Electronic jamming interferes with enemy radar and communications. Active radar nonelectronic jamming is done by releasing strips of metallic foil (chaff or window) from aircraft. The falling strips cause many false targets or cause the enemy scope to cover with clutter that can mask targets from search and fire control radars.

*Q7-24. What is the meaning of the acronym radar?*

*Q7-25. A radar is a device used to detect objects at distances greater than the eye can see by the use of what basic principle?*

*Q7-26. Sound waves travel how many feet per second?*

*Q7-27. A system that allows a friendly aircraft to identify itself automatically before approaching near enough to threaten other naval units is known as what type of system?*

*Q7-28. What are the objectives of electronic countermeasures?*

## **ANTISUBMARINE WARFARE EQUIPMENT (ASW)**

**LEARNING OBJECTIVE:** Identify the purpose and uses of antisubmarine warfare equipment to include sonobuoys and magnetic anomaly detection equipment.

A major problem for the Navy is the detection of enemy submarines. Submarine detection devices include (**S**ound **N**avigation **R**anging (sonar), sonobuoys, and **M**agnetic **A**nomaly **D**etection (MAD) equipment. Surface ships, submarines, and harbor defense installations use sonar equipment. Aircraft use MAD equipment.

### **SONOBUOYS**

The sonobuoy is an expendable electronic listening device dropped into water from carrier-based and land-based patrol aircraft. The sonobuoy detects underwater sounds and transmits these sounds to aircraft.

A surfaced or snorkeling submarine is not likely to be detected by an aircraft's radar. The reason is the submarine's ECM detects the aircraft's radar at a greater distance than the aircraft can detect the submarine. The sonobuoy helps solve the submarine detection problem. The sonobuoy, housed in a cylindrically shaped tube, is designed to float upright in the water. Upon being dropped from an aircraft, the sonobuoy, stabilized by small blades, enters the water in an upright position. Upon striking the water, the stabilizing blades eject and a small transmitting antenna erects itself. The impact also causes the release of a hydrophone (underwater microphone). This underwater listening device connects to the end of a cable that permits it to sink to a predetermined depth. The hydrophone receives

underwater sounds and transmits them to the monitoring receiver in the aircraft. By dropping sonobuoys in a pattern over a large ocean area, the airborne sonobuoy receiver operator can determine the approximate location of a submarine. Often its course and speed can also be determined. These methods of detection are passive, and therefore give the aircraft an advantage. Other passive and active tactics use sonobuoys to localize the submarine to a point where attack by airborne weapons is possible.

The sonobuoy continues to float and gather information until a seawater soluble plug dissolves and lets the sonobuoy flood and sink. This action removes an obstruction in the water and permits the frequency of that sonobuoy to be used by another.

### MAGNETIC ANOMALY DETECTION (MAD)

Another method of localizing a submerged submarine is by using MAD equipment. This equipment uses the principle that a metallic submarine disturbs the magnetic lines of force of the earth.

Light, radar, or sound energy cannot pass from air into water and return to the air in any degree that is usable for airborne detection. However, lines of force in a magnetic field can make this change. Therefore, a submarine lying beneath the ocean's surface causes a distortion (anomaly) in the earth's magnetic field. The distortion can be detected from a position in the air above the submarine. Detection of this anomaly is the function of MAD equipment.

Figure 7-25, view A, shows the angular direction at which natural lines of magnetic force enter and leave the surface of the earth. View B represents an area of undisturbed natural magnetic strength. In views C and D, the submarine's magnetic field distorts the natural field. The density of the natural field is decreased in view C and increased in view D.

The MAD equipment in the aircraft allows the operator to search selected areas of ocean immediately and accurately. Upon detecting and evaluating a possible enemy, the operator relays the information to surface and airborne forces. Aviation Antisubmarine Warfare Operator (AW) ratings operate ASW equipment.

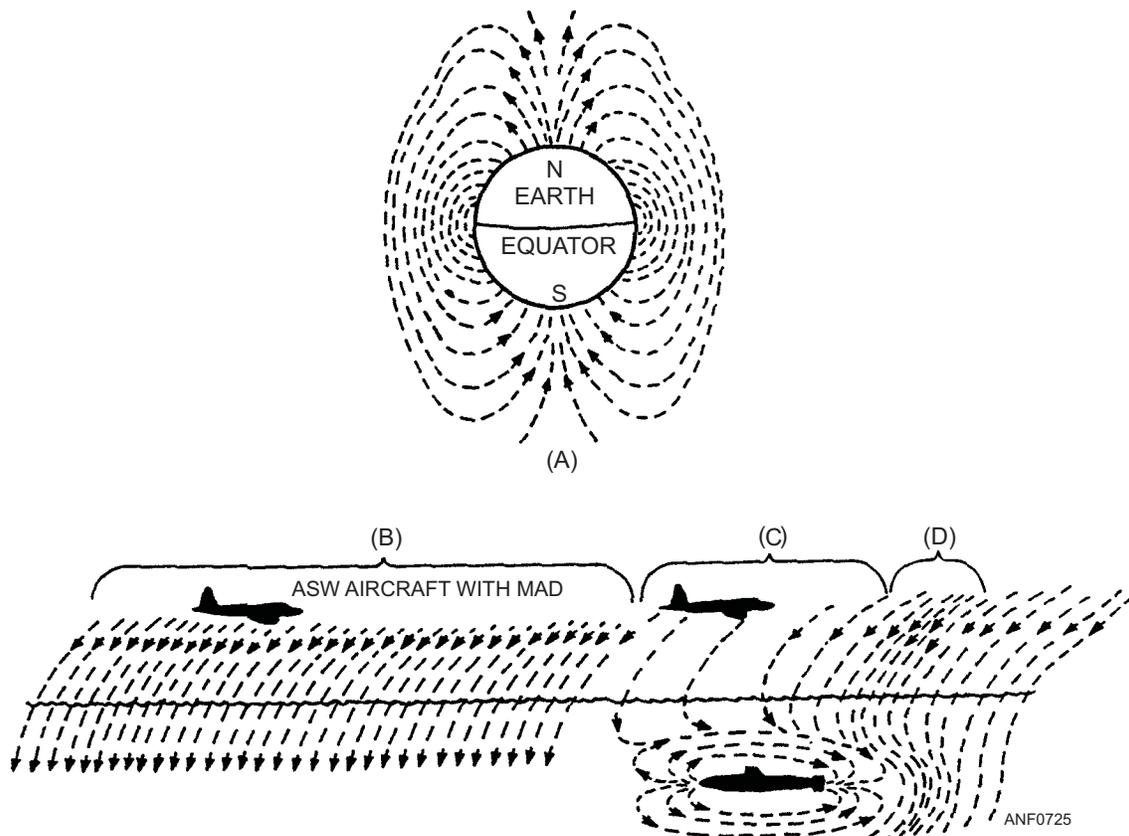


Figure 7-25.—Simplified comparison of natural field density and submarine anomaly.

*Q7-29. What is the function of a sonobuoy?*

*Q7-30. Detection of changes in the earth's magnetic field describes what antisubmarine warfare equipment's basic operating principle?*

## **SUMMARY**

In this chapter, you have learned about some of the avionics equipment that is used in modern aircraft. You also learned about the purpose of batteries and their use aboard ships, ac electrical systems, and aircraft gauges.

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# ASSIGNMENT 7

Textbook Assignment: "Aircraft Avionics," chapter 7, pages 7-1 through 7-21.

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- 7-1. What is an aircraft's first source of electrical energy?
1. Battery
  2. Generator
  3. Emergency generator
- 7-2. Which of the following statements is NOT true concerning aircraft batteries?
1. It is important to keep their weight to a minimum
  2. They require a great deal of care
  3. They usually have a large capacity
  4. They are usually enclosed in a grounded, metal-covered housing
- 7-3. The positive plates of a lead-acid battery are made of what material?
1. Lead peroxide
  2. Spongy lead
  3. Sulfuric acid fiber
  4. Water impregnated composite
- 7-4. Where does the nickel-cadmium battery get its name from?
1. The composition of its plates
  2. The type of electrolyte in the case
  3. The construction of the terminal post
  4. The rectangular type cells
- 7-5. What is the principal hazard in connection with the use of lead-acid batteries?
1. Fire
  2. Explosion
  3. Suffocation
  4. Acid burns
- 7-6. The manufacturer determines the correct charging rates for aircraft batteries.
1. True
  2. False
- 7-7. What does the term "thermal runaway" indicate concerning aircraft batteries?
1. The battery has been overcharged
  2. The battery has been rapidly cooled
  3. The battery is internally shorted because of overheating
  4. The battery has been totally discharged
- 7-8. CO<sub>2</sub> should NEVER be sprayed in the aircraft battery compartment to effect cooling or displace explosive gases.
1. True
  2. False
- 7-9. What is the purpose of rectifiers?
1. Converts ac to dc
  2. Converts dc to ac
  3. Converts mechanical to electrical energy
  4. Converts electrical to mechanical energy
- 7-10. Emergency power generators are used to provide power when the engine-driven generators fail.
1. True
  2. False
- 7-11. Auxiliary power units are used to furnish electrical power when which of the following problems occur?
1. Engine-driven generators are not operating
  2. External power is not available
  3. The engine-driven generator fails
  4. Each of the above
- 7-12. What rating maintains the pitot-static system?
1. AT
  2. AE
  3. AX
  4. AQ
- 7-13. What three aircraft instruments operate off of the pitot-static system?
1. Airspeed indicator, engine rpm, and altimeter
  2. Rate-of-climb indicator, airspeed indicator, and altimeter
  3. Engine oil indicator, engine rpm, and compressor speed indicator
  4. Oxygen, air-conditioning, and heating systems instruments
- 7-14. What does the air speed indicator interpret from the pitot tube?
1. Altitude
  2. Air density
  3. Air flow
  4. Air pressure

- 7-15. What precaution(s) must be observed while working around a pitot tube system?
1. Avoid touching the tubes when the heaters are on
  2. Do not obstruct the openings
  3. Be sure the tube heaters are off before installing protective covers
  4. Each of the above

IN ANSWERING QUESTION 7-16, REFER TO FIGURE 7-7 IN THE TEXT.

- 7-16. The altimeter indicates what altitude in feet?
1. 100
  2. 401
  3. 4,100
  4. 40,100
- 7-17. An aircraft flying at 0.5 Mach is flying at what speed?
1. One and one-half the speed of sound
  2. Twice the speed of sound
  3. Twice the local speed of sound
  4. One-half the local speed of sound
- 7-18. An aircraft flying level at 30,000 feet would indicate which of the following numbers on the rate-of-climb indicator?
1. 0
  2. 20
  3. 30
  4. 40

IN ANSWERING QUESTION 7-19, REFER TO FIGURE 7-11 IN THE TEXT.

- 7-19. What does the hydraulic pressure gauge indicate?
1. 0 to 5,000 psi for one system
  2. 0 to 5,000 psi for two systems
  3. 0 to 3,000 psi for one system
  4. 0 to 3,000 psi for two systems
- 7-20. At what location are the thermocouples for an exhaust gas temperature system?
1. The instrument panel
  2. The circuit breaker panel
  3. The inlet casing
  4. The aircraft frame
- 7-21. What engine component is the exhaust gases temperature measured from?
1. Compressor
  2. Tail pipe
  3. Engine inlet
  4. Turbine

- 7-22. The fuel quantity indicator displays the aircraft fuel load in what measurement?
1. Pounds
  2. Gallons
  3. Liters
  4. Quarts
- 7-23. Which of the following factors makes the vertical scale indicator more advantageous than the radial dial indicator on Navy aircraft?
1. It is compact
  2. It is light in weight
  3. It is easy to read
  4. Each of the above
- 7-24. Which of the following indicators works on the principle of a gyroscope?
1. Fuel quantity indicator
  2. Attitude indicator
  3. Hydraulic pressure indicator
  4. Rpm indicator
- 7-25. What instrument shows the pilot the relative position of the aircraft compared to the earth's horizon?
1. Turn and Bank indicator
  2. Altitude indicator
  3. Horizontal situation indicator
  4. Attitude indicator
- 7-26. A turn and bank indicator is really two instruments mounted as a single unit.
1. True
  2. False
- 7-27. Using the turn and bank indicator, a pilot making a properly banked turn to the right would see the ball move to what position on the indicator?
1. Left only
  2. Right only
  3. Center
  4. Left and then right
- 7-28. A gyro compass provides an accurate, stabilized indication of aircraft heading through what total number of degrees of azimuth?
1. 30°
  2. 60°
  3. 90°
  4. 360°

- 7-29. The horizontal situation indicator gives what information to the pilot?
1. Direct heading
  2. Rate of descent
  3. Navigational situation of the aircraft
  4. Aircraft attitude
- 7-30. What are the two major uses of airborne radios?
1. Communications and detection
  2. Communications and navigation
  3. Navigation and detection
  4. Detection and ranging
- 7-31. What rating normally maintains communications and navigational equipment?
1. AC
  2. AE
  3. AT
  4. AW
- 7-32. What means of radio communications transmits a rapid succession of images (still or moving) over a radio-frequency channel?
1. Radiofacsimile
  2. Radioteletype
  3. Radiotelephony
  4. Radiotelevision
- 7-33. Long-range airborne communications sets operate in what band of frequencies?
1. From 3 to 30 kilohertz
  2. From 3 to 30 megahertz
  3. From 30 to 300 megahertz
  4. From 30 to 300 kilohertz
- 7-34. What is the frequency band of short-range VHF/UHF communication sets?
1. 30 megahertz to 3 gigahertz
  2. 300 kilohertz to 3 megahertz
  3. 30 kilohertz to 300 kilohertz
  4. 30 gigahertz to 300 gigahertz
- 7-35. VHF/UHF communication sets are called line-of-sight communication sets.
1. True
  2. False
- 7-36. What is the primary navigational aid for carrier-based aircraft?
1. Loran
  2. Omega
  3. Dead reckoning
  4. TACAN
- 7-37. The main advantage of GPS over LORAN navigation is that GPS navigation provides highly accurate three-dimensional position, velocity, and time data.
1. True
  2. False
- 7-38. Which of the following computations is made by navigational computers?
1. Aircraft ground track angle
  2. Bearing to target
  3. Distance to target
  4. Each of the above
- 7-39. What does Doppler radar measure?
1. Ground speed only
  2. Drift angle only
  3. Ground speed and drift angle
  4. Latitude and longitude
- 7-40. The inertial navigation system is an automatic aid to navigation that is independent of outside references.
1. True
  2. False
- 7-41. Which of the following data does the inertial navigational system (INS) provide to the overall tactical system?
1. Accurate velocity
  2. Attitude
  3. Heading data
  4. Each of the above
- 7-42. Upon what principle does radar work?
1. Ranging
  2. Detection
  3. Echo
  4. Radio
- 7-43. Radio waves travel at what speed?
1. 1,100 feet per second
  2. 1,100 miles per hour
  3. 186,000 miles per hour
  4. 186,000 miles per second
- 7-44. If it takes 6 seconds for a sound wave to travel to an object and return, what is the distance of the object?
1. 1,100 feet
  2. 2,200 feet
  3. 3,300 feet
  4. 6,600 feet

- 7-45. Radio waves travel much faster than sound waves?
1. True
  2. False
- 7-46. What rating normally maintains AEW equipment?
1. AT
  2. AE
  3. AQ
  4. AW
- 7-47. What characteristics make radar suitable for directing fire control radar systems?
1. Range measurement
  2. Target display
  3. Narrow focused radar beam
  4. All of the above
- 7-48. What is the purpose of IFF?
1. Fire control
  2. Navigation
  3. Early warning
  4. Distinguishing friend from foe
- 7-49. Selective Identification Feature (SIF) was developed to expand the IFF system.
1. True
  2. False
- 7-50. What are the two types of electronic countermeasures?
1. Active and passive
  2. Active and progressive
  3. Passive and collective
  4. Passive and interceptor
- 7-51. What type of ECM uses jamming?
1. Passive only
  2. Active only
  3. Passive and active
  4. Passive and progressive
- 7-52. Which of the following detection devices is used to detect submarines?
1. Sonar
  2. Sonobuoy
  3. Magnetic Anomaly Detection (MAD) equipment
  4. Each of the above
- 7-53. Which of the following statements is NOT true concerning sonobuoys?
1. They are dropped from carrier-based aircraft
  2. They are dropped from land-based aircraft
  3. They are expendable
  4. They are nonexpendable
- 7-54. Upon what principle does MAD operate?
1. Light
  2. Radar
  3. Sound
  4. Magnetic field
- 7-55. What rating operates ASW equipment?
1. AE
  2. AT
  3. AQ
  4. AW