GYROCOMPASS SYSTEMS

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

- *Discuss basic gyroscopic and gyrocompass theory.*
- *Identify the major components of the Mk 23 gyrocompass systems, and explain the procedures for starting, standing watch on, and securing the Mk 23 gyrocompasses.*
- *Identify the major components of the Mk 27 gyrocompass system, and explain the procedures for starting, standing watch on, and securing the Mk 27 gyrocompass.*
- *Identify the major components of the Mk 19 Mod 3 gyrocompass systems, and explain the procedures for starting, standing watch on, and securing the Mk 19 Mod 3 gyrocompasses.*
- *Identify the major components of the AN/WSN-2 stabilized gyrocompass set, and explain the procedures for starting, standing watch on, and securing the AN/WSN-2 stabilized gyrocompass set.*
- *Explain the purpose of the synchro signal amplifier used with the various gyrocompass systems.*
- *Explain the purpose of the ship's course indicators used with the various gyrocompass systems.*
- *Describe the entries to be made in the engineering logs, and the deck and watch logs to be kept when standing watch on gyrocompass systems.*

INTRODUCTION

The ship's gyrocompass and its associated equipment is an important part of an IC Electrician's responsibility. Gyrocompass systems provide information that is used for remote indicators and various navigational, radar, sonar, and fire control systems throughout a ship. As an IC3, you will be responsible for starting, standing watch on, and securing the ship's gyrocompass.

To understand how a gyrocompass operates, you should be familiar with gyroscopic and gyrocompass theory. A variety of gyrocompasses are presently in use throughout the Navy. In this chapter, we will discuss basic gyroscopic principles, and then we will develop the basic gyroscope into a basic gyrocompass. We will then discuss the operation of some of the more common gyrocompass systems installed on board Navy ships today. We will also discuss the associated equipment used in conjunction with the gyrocompass systems. The topics include descriptions of the components and functions of the master compass, gyro control systems, follow-up systems, alarm systems, and starting control systems. In addition, we will also point out the significant differences among the various modifications of the Mk 19 Mod 3 installation, and provide procedures for operating the gyrocompass in normal and auxiliary modes.

THE FREE GYROSCOPE

A free gyroscope is a universal-mounted, spinning mass. In its simplest form, the universal mounting is a system that allows three degrees of freedom of movement. The spinning mass is provided by a heavy rotor. Figure 4-1 illustrates a free gyroscope. As you can see in the figure, the rotor axle is supported by two bearings in the horizontal ring,. This ring is supported by two studs mounted in two bearings in the larger vertical ring. These two rings are called the inner gimbal and outer gimbal, respectively. The outer gimbal is then mounted with two studs and bearings to a larger frame called the case.

The rotor and both gimbals are pivoted and balanced about their axes. The axes (marked X, Y, and Z) are perpendicular to each other, and they intersect at the center of gravity of the rotor. The bearings of the rotor and two gimbals are essentially frictionless and have negligible effect on the operation of the gyroscope.

THREE DEGREES OF FREEDOM

As you can see in figure 4-1, the mounting of the gimbals allows movement in three separate directions, or three degrees of freedom: (1) freedom to spin, (2) freedom to tilt, and (3) freedom to turn. The three degrees of freedom allow the rotor to assume any position within the case. The rotor is free to spin on its own axis, or the X axis, the first degree of freedom. The inner gimbal is free to tilt about the horizontal or Y axle, the second degree of freedom. The outer gimbal ring is free to turn about the vertical or Z axis, the third degree of freedom.

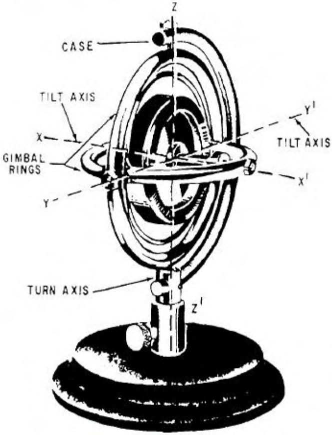

Figure 4-1.--The gyroscope

GYROSCOPIC PROPERTIES

When a gyroscope rotor is spinning, it develops two characteristics, or properties, that it does not possess when at rest: rigidity of plane and precession. These two properties make it possible to convert a free gyroscope into a gyrocompass.

Rigidity of Plane

When the rotor of the gyroscope is set spinning with its axle pointed in one direction (fig. 4-2, view A), it will

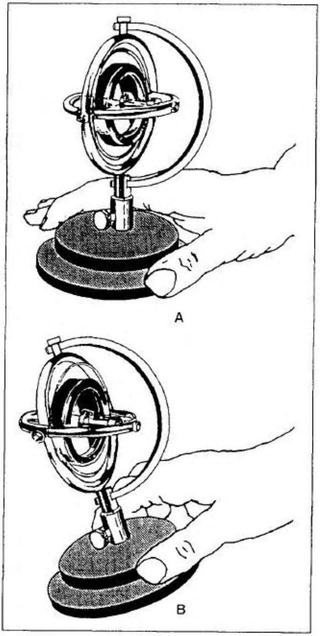

Figure 4-2.--Rigidity of plane of a spinning gyroscope

continue to spin with its axle pointed in that direction, no matter how the case of the gyroscope is positioned (fig. 4-2, view B). As long as the bearings are frictionless and the rotor is spinning, the rotor axle will maintain its plane of spin with respect to a point in space. This property of a free gyroscope is termed *rigidity of plane.*

Newton's first law of motion states that a body in motion continues to move in a straight line at a constant speed unless acted on by an outside force. Any point in a spinning wheel tries to move in a straight line but, being a part of the wheel, must travel in an orbit around its axle. Although each part of the wheel is forced to travel in a circle, it still resists change. Any attempt to change the alignment or angle of the wheel is resisted by both the mass of the wheel and the velocity of that mass. This combination of mass and velocity is the kinetic energy of the wheel, and kinetic energy gives the rotor rigidity of plane. *Gyroscopic inertia* is another term that is frequently used interchangeably with rigidity of plane.

A gyroscope can be made more rigid by making its rotor heavier, by causing the rotor to spin faster, and by concentrating most of the rotor weight near its circumference. If two rotors with cross sections like those shown in figure 4-3 are of equal weight and rotate at the same speed, the rotor in figure 4-3, view B, will have more rigidity than the rotor in figure 4-3, view A. This condition exists because the weight of the rotor in figure 4-3, view B, is concentrated near the circumference. Both gyroscope and gyrocompass rotors are shaped like the rotors shown in figure 4-3, view B.

Precession

Precession describes how a gyro reacts to any force that attempts to tilt or turn it. Though vector diagrams can help explain why precession occurs, it is more important to know how precession affects gyro performance.

The rotor of a gyro has one plane of rotation as long as its axle is aligned with, or pointed at, one point in space. When the axle tilts, turns, or wobbles, the plane of rotation of the rotor changes. Plane of rotation means the direction that the axle is aligned or pointed.

Torque is a force that tends to produce rotation. Force acts in a straight line, at or on a point. Torque occurs within a plane and about an axle or axis of rotation. If the force acts directly on the point of an axis, no torque is produced.

Because of precession, a gyro will react to the application of torque by moving at right angles to the direction of the torque. If the torque is applied downward against the end of the axle of a gyro that is horizontal, the gyro will swing to the right or left in response. The direction in which it will swing depends on the direction the rotor is turning.

A simple way to predict the direction of precession is shown in figure 4-4. The force that tends to change the plane of rotation of the rotor is applied to point A at the top of the wheel. This point does not move in the direction of the applied force, but a point displaced 90° in the direction of rotation moves in the direction of the applied force. This results in the rotor turning left about the Z axis and is the direction of precession.

Any force that tends to change the plane of rotation causes a gyroscop to precess. Precession continues as long as there is a force acting to change the plane of rotation, and precession ceases immediately when the force is removed. When a force (torque) is applied, the

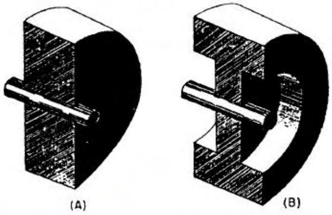

Figure 4-3.--Weight distribution in rotors.

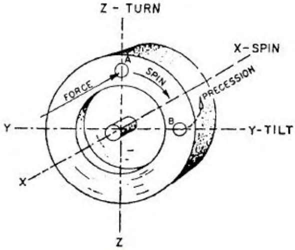

Figure 4-4.--Direction of precession.

gyroscope precesses until it is in the plane of the force. When this position is reached, the force is about the spinning axis and can cause no further precession.

If the plane in which the force acts moves at the same rate and in the same direction as the precession it causes, the precession will be continuous. This is illustrated by figure 4-5, in which the force attempting to change the plane of rotation is provided by a weight, W, suspended from the end of the spin axle, X. Although the weight is exerting a downward force, the torque is felt 90° away in the direction of rotation. If the wheel rotates clockwise, as seen from the weighted end, precession will occur in the direction of arrow P. As the gyroscope precesses, it carries the weight around with it so that forces F and F_1 continuously act at right angles to the plane of rotation, and precession continues indefinitely. In other words, the rotor will turn to the

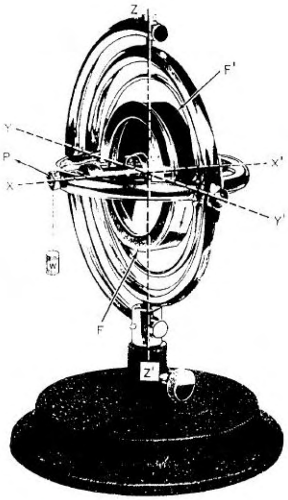

Figure 4-5.--Continuous precession.

right and continue turning until the weight is removed.

FORCE OF TRANSLATION

Any force operating through the center of gravity of the gyroscope does not change the angle of the plane of rotation but moves the gyroscope as a unit without changing its position in space. Such a force operating through the center of gravity is known as a force of translation. Thus, the spinning gyroscope may be moved freely in space by means of its supporting frame, or case, without disturbing the plane of rotation of the rotor. This condition exists because the force that is applied through the supporting frame acts through the center of gravity of the rotor and is a force of translation. It produces no torque on the gyro rotor.

EFFECT OF EARTH'S ROTATION

As just explained, a free-spinning gyroscope can be moved in any direction without altering the angle of its plane of rotation. If this free-spinning gyroscope is placed on the earth'is surface at the equator, with its spinning axis horizontal and aligned east and west, an observer in space below the South Pole would note that the earth rotates clockwise from west to east and carries the gyroscope along. As the earth rotates, rigidity of plane keeps the gyroscope wheel fixed in space and rotating in the same plane at all times. Figure 4-6 shows how this gyroscope would appear. Assume that the gyroscope is set spinning at 0000 hours with its spinning axis aligned east and west and parallel to the earth's surface. At 0600, 6 hours after the gyroscope was started, the earth has rotated 90° and the axle of the gyroscope is aligned with the original starting position. At 1200 the earth has rotated 180°, while the gyroscope returns to its original position. The figure shows how the gyro completes a full cycle in a 24-hour period.

APPARENT ROTATION OF THE GYROSCOPE

An observer on the earth's surface does not see the operation of the gyro in the same way as an observer in space does. On the earth, the gyro appears to rotate, while the earth appears to stand still. As the earth rotates, the observer moves with it, so the gyroscope seems to rotate around its horizontal axis. The effect the observer sees on the earth is called apparent rotation and also is referred

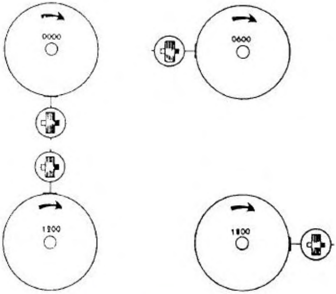

Figure 4-6.--Free gyroscope at the equator viewed from space.

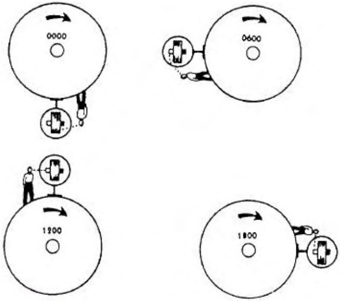

Figure 4-7.--Free gyroscope at the equator viewed from the earth's surface.

to as the horizontal earth rate effect. If the gyro were started with its axle vertical at one of the earth's poles, it would remain in that position and produce no apparent rotation around its horizontal axis. Figure 4-7 illustrates the effect of apparent rotation at the equator, as seen over a 24-hour period.

Now assume that the spinning gyroscope, with its spinning axis horizontal, is moved to the North Pole (fig. 4-8). To an observer on the earth's surface, the gyroscope appears to rotate about its vertical axis. To an observer in space, the gyroscope axle appears to remain fixed, and the earth appears to rotate under it. This apparent rotation about the vertical axis is referred to as vertical earth rate effect. It is maximum at the poles and zero at the equtator.

When the gyroscope axle is placed parallel to the earth's axis at any location on the earth's surface, the apparent rotation is about the axle of the gyroscope and cannot be observed. At any point between the equator and either pole, a gyroscope whose spinning axis is not parallel to the earth's spinning axis has an apparent rotation that is a combination of horizontal earth rate and vertical earth rate.

The combined earth rate effects at this point make the gyro appear to rotate partly about the horizontal axis and partly about the vertical axis. The horizontal earth rate causes the gyro to tilt, whereas the vertical earth rate causes it to turn in azimuth with respect to the earth. The magnitude of rotation depends on the latitude of the gyro.

Apparent rotation is illustrated by placing a spinning gyroscope with its axle on the meridian

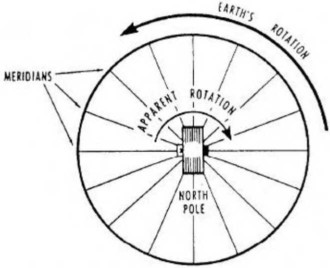

Figure 4-8.--Apparent rotation of a gyroscope at the North Pole.

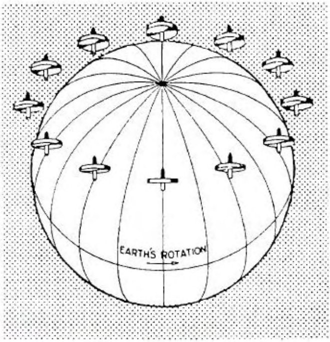

Figure 4-9.--Apparent rotation of a gyroscope at 45°N latitude.

(aligned north-south) and parallel to the earth's surface at 45° north latitude and 0° longitude (fig. 4-9).

A gyroscope, if set on any part of the earth's surface with the spinning axle not parallel to the earth's polar axis, appears to rotate, over a 24-hour period, about a line passing through the center of the gyroscope and parallel to the earth's axis. This apparent rotation is in a counterclockwise direction when viewed from south to north. The path that the north axle describes in space is indicated by the line EAWB back to E (fig. 4-10).

The effect of the earth's rotation causes the north end of the gyroscope axle to rise when east of the meridian and to fall when west of the meridian in any latitude. This tilling effect provides the means by which the gyroscope can be made into a north-seeking instrument.

MAKING THE GYROSCOPE INTO A GYROCOMPASS

Up to this point, we have discussed the basic properties of a free gyroscope. Now, we will discuss how we use these properties, rigidity of plane and precession, to make a gyroscope into a gyrocompass. The first step in changing the gyroscope to a gyrocompass is to make a change in the suspension system. The inner gimbal that holds the gyro rotor is modified by replacing it within a sphere or case (fig. 4-11, view A), a necessary feature that protects the rotor. A vacuum is formed inside the sphere to reduce air friction on the spinning rotor. The next step is to replace the simple gyroscopic hose with what is called a phantom ring (fig. 4-11, view A). The difference

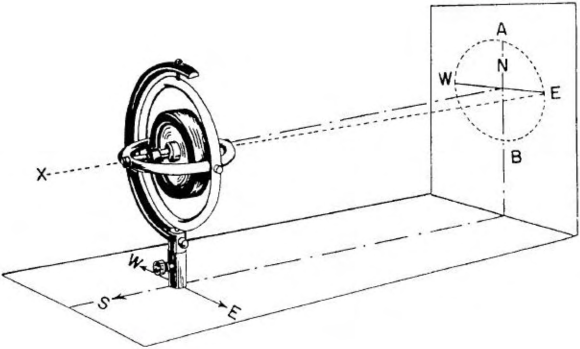

Figure 4-10.--Path of the spinning axis of a free gyroscope.

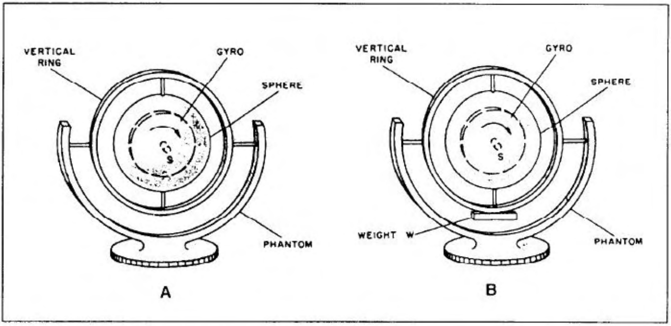

Figure 4-11.--A. Simple gyroscope. B. Modified gyroscope.

between the simple base and the phantom is that the phantom is turned by a servomechanism to follow the horizontal plane of the rotor's axle, while the simple base remains fixed in its position. The phantom ring allows the outer gimbal (vertical ring) (fig. 4-11, view A) the freedom to turn and to tilt. These modifications enable the gyroscope to maintain its plane of rotation as long as it spins and nothing touches it. We have modified the basic suspension system to enable us to convert the gyroscop to a gyrocompass. Now, we must make it seek out and point to true north.

For the purposes of this explanation, true north is the direction along the meridian from the point of observation to the North Pole.

To become a gyrocompass, a gyro must be modified so it can

1. align its axis on the meridian plane,

2. align its axis nearly horizontal, and

3. maintain its alignment both horizontally and on the meridian, once it is attained.

In figure 4-11, view B, a weight (pendulous weight) has been added to the bottom of the vertical ring, which makes it bottom heavy, or pendulous. The weight exerts a force on the gyro whenever the rotor is not level with the earth's surface.

In previous discussion, we talked about precession and vertical and horizontal earth rates. Now, we will see how we use the apparent rotation of the gyro rotor to make the modified gyroscope north-seeking. In figure 4-12, point A, the gyro axle is parallel to the earth's surface; however, as the earth rotates, the earth rate effect causes the gyro rotor axle to tilt in relation to the earth's surface, and the weight that we attached to the bottom of the vertical ring now applies a force to the bottom of the gyro. As we discussed earlier, precession occurs in the direction of rotation, but 90° away from the point of application; therefore, the weight applies a force to the bottom of the gyro but is felt about its horizontal axis, which causes the gyro to turn. As the gyro turns, the phantom follows the rotor axle. As you follow the gyro through one rotation on the earth's surface, you can see that the gyro rotor follows an elliptical path around the meridian. It actually points north twice in the ellipse; in other words, it has become north-seeking. The period of oscillation is actually much less than the 24 hours required of an unmodified gyro; the actual time is determined by the speed and weight of the rotor and the size of the pendulous weight. The next step, logically, is to make the north-seeking gyroscope north-indicating.

As you have seen, we made the gyroscope north-seeking by adding a pendulous weight, which caused the gyroscope to oscillate about north. To make it north-indicating, we must somehow dampen these oscillations. To do this, we must add another smaller weight, Wz, on the east side of the rotor. Both weights,

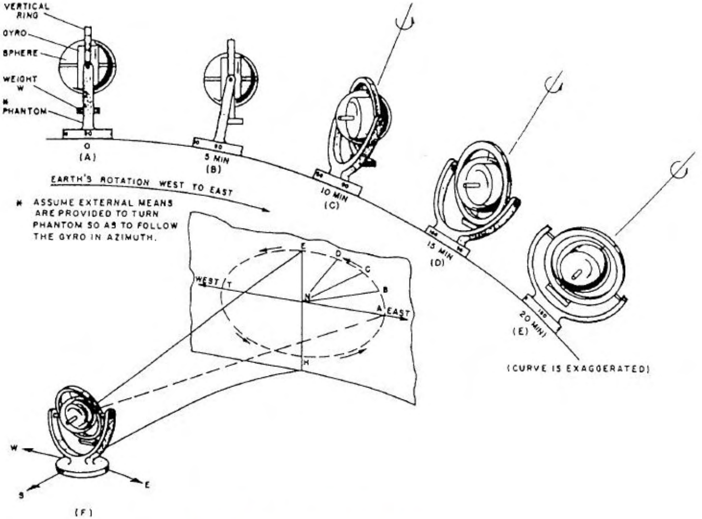

Figure 4-12.--Effect of weight and earth's rotation on the gyroscope.

W and W1, influence the gyro when it is not aligned with the meridian (fig. 4-13).

When the gyro is started while pointed away from the meridian, the effect of earth rate causes it to tilt. As

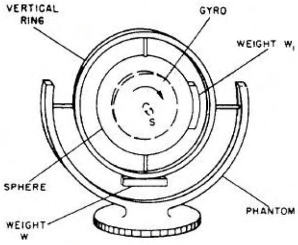

Figure 4-13.--Gyroscope with weights on the vertical ring and sphere.

soon as it tilts, weight W causes precession; however, now the smaller weight, W1, also causes the gyro to precess towards a more level position, which limits the effect of precession caused by weight W. The excursions from level continue, but the dampening effect of weight W1 causes each successive oscillation to be reduced; the path of the rotor axle then will be spiral shaped (fig. 4-14).

As you can see, the only position of rest for the gyro axle is level and on the meridian. The free gyroscope has now become a gyrocompass, able to settle only on the meridian (pointing north) and level.

This is a very basic gyrocompass, and it really operates satisfactorily only on the equator and when mounted on a stable platform; however, the principles and basic concepts are the same for all gyrocompasses.

To make a basic gyrocompass function properly over a wide range of latitudes, we must stabilize it with respect to the earth's surface instead of with the earth's axis, and we must damp out the effects of the ship's

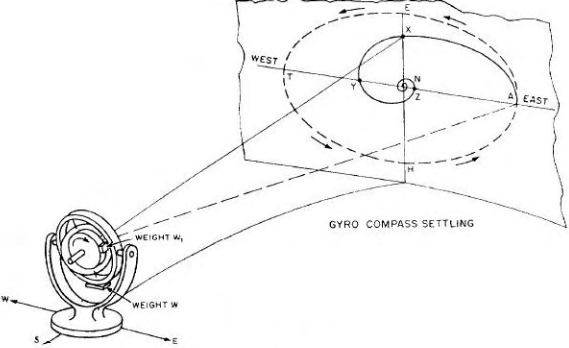

Figure 4-14.--Effect of weights on the gyroscope.

acceleration and deceleration. There are several methods used to do this. The method used depends on the type of gyrocompass. For further information on the method of damping used in the gyrocompasses installed on your ship, refer to the applicable manufacturer's technical manual.

GYROCOMPASS SYSTEMS

There are a wide variety of gyrocompass systems installed on Navy ships in the fleet today. Gyrocompasses are identified by the mark (Mk)modification (Mod) system. The Mk number designates a major development of a compass. The Mod number indicates a change to the major development. The most common type of gyrocompasses found in the fleet today are the electrical gyrocompass systems, such as the Sperry Mk 23, Sperry Mk 27, and the Sperry Mk 19 Mod 3.

There are also two new gyrocompass systems currently being installed on Navy ships today. These are the Stabilized Gyrocompass Set AN/WSN-2 and the Inertial Navigation Set AN/WSN-5. Operation of the AN/WSN-5 is classified; therefore, only the ANAVSN-2 will be discussed in this training manual.

SPERRY MK 23 GYROCOMPASS SYSTEMS

The Sperry Mk 23 gyrocompass is a small electrical compass that is used aboard many naval vessels to furnish heading data. On many of the small combatant vessels and larger auxiliary vessels, it is used as the master compass. On some of the larger combatant vessels, it is used as a backup compass. The compass is capable of indicating true north accurately in latitudes up to 75°N or S. The compass also can be used as a directional gyro when nearer the poles.

Unlike the mechanical gyrocompass, which uses weights that are affected by gravity to cause the desired period of damping, the Sperry Mk 23 gyrocompass uses a special type of electrolytic bubble level (gravity reference), which generates a signal proportional to the tilt of the gyro axle. This signal is then amplified and applied to an electromagnet which applies torque about the vertical and/or horizontal axes to give the compass the desired period and damping. The gyrocompass is compensated for speed error, latitude error, unbalance, and supply voltage fluctuations. An electronic follow-up system furnishes accurate transmission of heading data to remote indicators.

The original Sperry Mk 23 gyrocompass (Mod O) has had several minor modifications and one major modification (Mod C-3). Only the Mk 23 Mod O and the Mk 23 Mod C-3 will be discussed in this training manual.

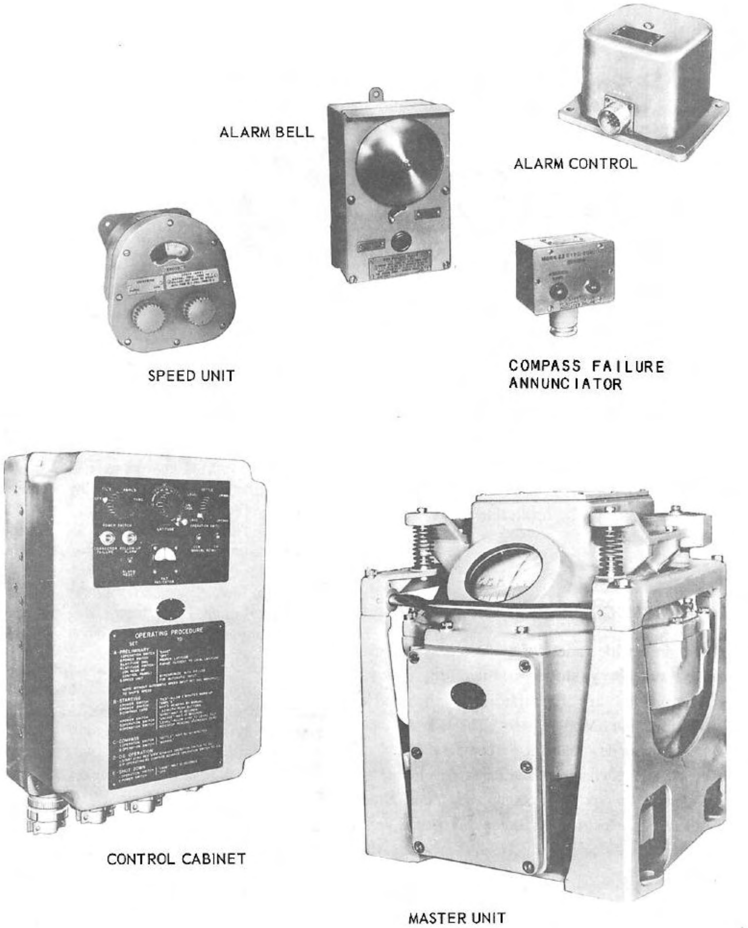

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Figure 4-15.--Mk 23 Mod 0 gyrocompass equipment.

MK 23 MOD 0 GYROCOMPASS SYSTEM

The Mk 23 Mod 0 gyrocompass system (fig. 4-15) consists of the master unit, control cabinet, speed unit, alarm control unit, a compass failure annunciator, and an alarm belt.

Master Unit

The master unit consists of a shock-mounted, oil-filled binnacle and the gyrocompass element. The master unit is designed for deck mounting and weighs approximately 100 pounds. The compass element is the principle unit of the compass system and is gimballed in the binnacle to allow ±45° of freedom about the pitch and roll axes. Drain plugs are located in the lower bowl for draining the oil.

Control Cabinet

The control cabinet contains all the equipment required for operating and indicating the condition of the master compass except the visual alarm indicator and the alarm bell. The control cabinet houses the control panel, control amplifier, follow-up amplifier, and power supply.

Speed Unit

The speed unit contains the necessary components to produce an electrical signal proportional to ship's speed. Speed information is received from the ship's underwater log equipment or is set in manually by the ship's dummy log system. The speed range of the unit is 0 to 40 knots.

Alarm Control Unit

The alarm control unit contains the necessary relays and components to actuate the lamp on the visual alarm indicator or the bell alarm when certain portions of the system become inoperative.

Compass Failure Annunciator

The compass failure annunciator is a visual alarm indicator. It provides a visual indication of problems within the gyrocompass system. Under normal conditions, the lamp on the indicator is lighted continuously. When a failure occurs within the system, the lamp flashes or goes out. A test push button is provided on the annunciator. In some installations a type B-51 or B-52 alarm panel is used in place of the annunciator.

Alarm Bell

The alarm bell is used with the annunciator to provide an audible indication of problems within the gyrocompass system.

OPERATING THE MK 23 MOD 0 GYROCOMPASS

Instructions for starting and stopping (securing) the compass under normal conditions are on an instruction plate (fig. 4-16). This plate is located on the front of the control cabinet. There are two modes of operation, normal and directional gyro (DG). The normal mode of operation is used for latitudes up to 75°. The DG mode of operation is used for latitudes above 75°. Normally, the compass should be started at least 2 hours before it is needed for service. For additional information on starting the compass, refer to the manufacturer's technical manual.

If it becomes necessary to stop the compass in a heavy sea for any reason other than failure of the follow-up system, the following procedure should be used:

STARTING INSTRUCTION PLATE

Figure 4-16.–Operating procedures for the Sperry Mk 23 Mod 0 gyrocompass.

1. Place the power switch in the AMPL'S position.

2. Wait 30 minutes, and then place the operation switch in the CAGE position.

3. Place the power switch in the OFF position.

In case of follow-up system failure, place the operation switch in the CAGE position immediately and the power switch in the OFF position.

If power to the compass fails, place the power switch in the FIL'S position and the operation switch in the CAGE position. When the power is restored, restart the compass in the usual manner.

Setting Correction Devices

Correction device settings for the Mk 23 gyrocompass include the manual speed setting on the speed unit, the latitude control knob setting on the control panel, and the latitude switch setting on the rear of the control panel.

When you operate the speed unit manually, adjust the speed settings to correspond to the average ship's speed. Change the latitude control knob setting on the control panel when the ship's latitude changes as much as 2°, or as ordered by the ship's navigator. Throw the latitude switch on the rear of the control panel to the 65° position for normal operation when the ship's latitude is above 60°. The position of the latitude switch is immaterial for directional gyro operation.

Indications of Normal Operation

Normal operating conditions for the compass are indicated by the following:

1. The follow-up failure and corrector failure lamps on the control panel should be dark.

2. The master unit should be lukewarm.

3. The speed dial should indicate the ship's speed for normal operation or zero for directional gyro operation.

4. The tilt indicator pointer should be oscillating evenly about the zero position.

WATCH STANDING

When you are assigned the gyrommpass watch, you will be required to maintain the gyrocompass log and to respond to any alarms associated with the gyrocompass system. The gyrocompass log contains hourly readings showing the conditions of the gyrocompass and the power sources available. During an alarm condition, the compass is no longer considered reliable.

MK 23 MOD C-3 GYROCOMPASS SYSTEM

The Mk 23 Mod C-3 gyrocompass system is identical to the Mk 23 Mod 0 system with the exception that the Mk 23 Mod C-3 system uses solid-state devices in place of vacuum tubes in the control cabinet. In addition, two more units are used in the C-3 system. These two additional units are the power supply unit and the power supply control unit.

The power supply unit and the power supply control unit, together with a 120-volt dc battery, are used to form a standby power supply for the compass. This standby power supply provides uninterrupted 120-volt, 400-Hz, 3-phase power to the compass for a limited period of time if the normal ship's supply fails. If the normal ship's supply fails, a red light located on the power supply control unit will come on. When the compass is being supplied power from the standby power supply, power will be cut off to some of the remote repeaters.

The starting and stopping procedures for the compass are basically the same as for the Mk 23. Instructions for starting and stopping the compass under normal conditions are given on the instruction plate (fig. 4-17) located on the front of the control panel. Make sure the ON-OFF switch located in the power supply control unit is in the ON position before starting the compass. For additional information on starting and stopping the compass, refer to the manufacturer's technical manual.

Watch-standing procedures are basically the same as for the Mk 23 Mod 0 gyrocompass system.

SPERRY MK 27 GYROCOMPASS SYSTEM

The Sperry Mk 27 gyrocompass is a rugged, low-voltage electrical compass used as the master compass on small craft and as the auxiliary compass on larger ships.

The Mk 27 gyrocompass is designed to operate on 24-volt dc or 115-volt, 60- or 400-Hz, single-phase power.

A liquid ballistic filled with refined silicone oil provides the gravitational torque needed to make the compass north-seeking. The ballistic consists of two interconnected brass tanks and is mounted directly on the gyrosphere. Direction of rotation of the gyro axle is

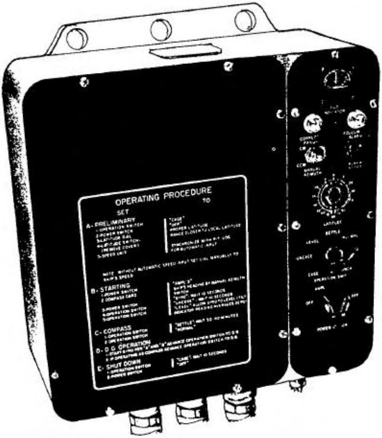


Figure 4-17.--Mk 23 Mod C-3 control cabinet.

reversed to counterclockwise as viewed from the south end of the gyro axle as it was in other ballistic compasses. The direction of the vertical torque is also reversed.

The Mk 27 gyrocompass system (fig. 4-18) consists of a master unit, an electronic control cabinet, and a power converter.

MASTER UNIT

The master unit contains the compass element and receives its electrical and electronic support from the electronic control cabinet. The master unit also contains a bellows assembly to allow for temperature variation, a card viewing window, a cager diaphragm, an electrical connector, and the fluid-filling nozzles.

ELECTRONIC CONTROL CABINET

The electronic control cabinet houses the control panel, power supply, servoamplifier, latitude compensation circuit, and alarm circuit. The electronic control unit has plug-in connectors, which are used to connect the unit to either a power converter or a 24-volt dc supply and to the master unit.

POWER CONVERTER

The power converter is used to convert 115-volt, 60- or 400-Hz, single-phase power to 24-volt dc when 24-volt dc is not available.

OPERATING THE MK 27 GYROCOMPASS

The control panel located on the electronic control cabinet contains all the operating controls necessary for operating the compass. Instructions for starting and securing the compass are listed on an instruction plate located near the electronic control cabinet. For additional information on starting and stopping the compass, refer to the manufacturer's technical manual.

WATCH STANDING

Watch-standing procedures for the Mk 27 gyrocompass are basically the same as for the Mk 23 gyrocompass. Indicator lamps for the power available

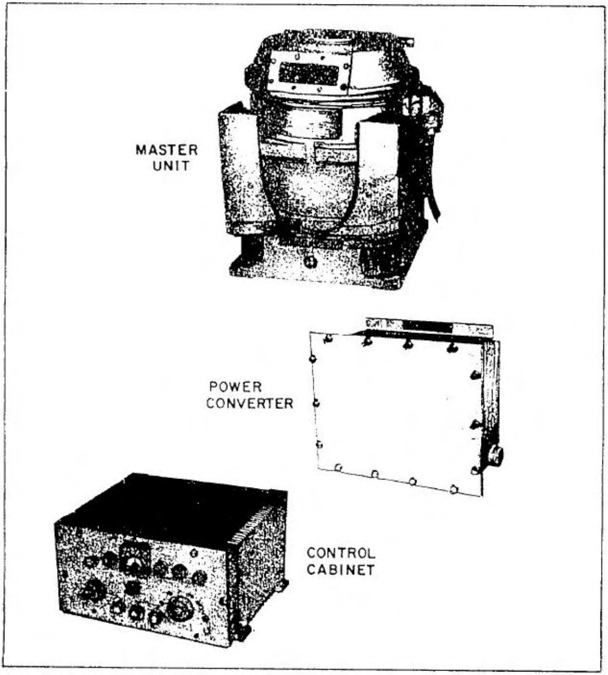


Figure 4- 18.--Mk 27 Mod O gyrocompass equipment.

and follow-up alarm are located on the control panel. When a power failure occurs, the power available lamp will go out. When a follow-up error occurs, the follow-up alarm lamp will light up and an audible alarm will sound.

SPERRY MK 19 MOD 3 GYROCOMPASS SYSTEMS

The Sperry Mk 19 Mod 3 gyrocompass systems furnish roll and pitch angle information as well as heading information. This roll and pitch angle information is used to stabilize gunmounts, missile launchers, and other equipment that must remain level with respect to the earth's surface for proper operation. The Mk 19 Mod 3 gyrocompasses are used as the master compass on Navy combatant ships. Some ships will have two Mk 19 compasses installed; one will be used as the master compass and the other as the backup compass. There have been five modifications to the original Sperry Mk 19 Mod 3 gyrocompass system since it was first introduced. These five modifications will be discussed in the following paragraphs.

MK 19 MOD 3A GYROCOMPASS SYSTEM

The Mk 19 Mod 3A gyrocompass is a navigational and fire control instrument with design features based on unusual requirements. The compass is designed to operate in latitudes up to 80° with an accuracy of 0.1° in azimuth at sea. In addition, it accurately measures and transmits angles of roll and pitch. These features distinguish the Mk 19 Mod 3A from all other shipboard gyrocompasses that preceded it.

Design of the compass is based on the principle that two properly controlled horizontal gyros can, together, furnish a stable reference for the measurement of ship's heading, roll, and pitch. Briefly, the basic unit consists of two gyros placed with their spin axes as shown by figure 4-19. The top gyro is a conventional gyrocompass and is referred to as the north-seeking, or meridian, gyro. Its spin axis is directed along a north-south line.

The lower gyro is a directional gyro with its spin axis slaved to the meridian gyro along an east-west line. It is referred to as the slave gyro and furnishes indications of roll on north-sowb courses and pitch on east-west courses.

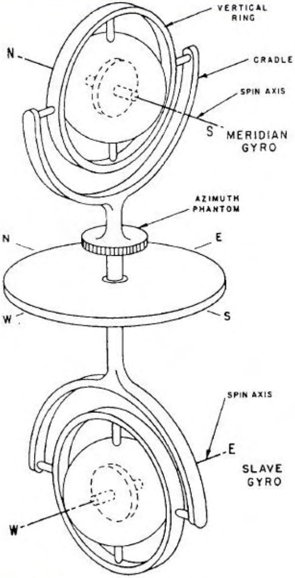


Figure 4-19.--Simplified diagram of the Mk 19 Mod 3A compass element.

An electric control system is used in the Mk 19 Mod 3A gyrocompass to make it seek and indicate true north as well as the zenith. A gravity reference system is employed for detecting gyro tilt, and torques are applied electromagnetically to give the meridian gyro the desired period and damping. Further, signals are generated by the compass, which are used to stabilize the entire sensitive element in roll and pitch, thereby furnishing an indication of the zenith in terms of roll and pitch data.

Both the meridian and slave gyros are enclosed in hermetically seated spheres and suspended in oil. The compass is compensated for northerly and easterly speed and acceleration, earth rate, constant torques, and follow-up errors. The system (fig. 4-20) consists of four major components: the master compass, the control cabinet, the compass failure annunciator, and the standby power supply.

Master Compass Assembly

The master compass assembly (fig. 4-21) is approximately 3 feet high and weighs about 685 pounds. Its two major components are the compass element and the supporting element.

COMPASS ELEMENT.-- The compass element includes the sensitive element (meridian and slave gyros), the gimbal, and the phantom assembly. The phantom assembly includes the azimuth phantom, which indicates the meridian, and the roll and pitch phantom, which measures the angles from the horizontal. The compass element is gimballed in the binnacle to allow ±60° of freedom about the roll axis and ±40° of freedom about the pitch axis.

SUPPORTING ELEMENT.-- The supporting element includes the frame and the binnacle. The compass elements are gimballed in the binnacle by a conventional gimballing system with 62° of freedom about the roll axis mechanically, 60° electrically; and 42° of freedom about the pitch axis mechanically, 40° electrically.

The meridian and slave gyros are similar in construction, with the exception that the slave gyro is inverted and minor changes in wiring are made. The two gyro assemblies are mounted on the inner ring of the

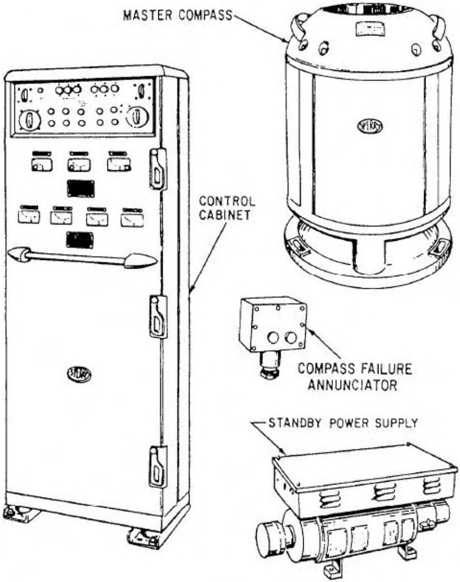


Figure 4-20.--Mk 19 Mod 3A gyrocompass equipment.

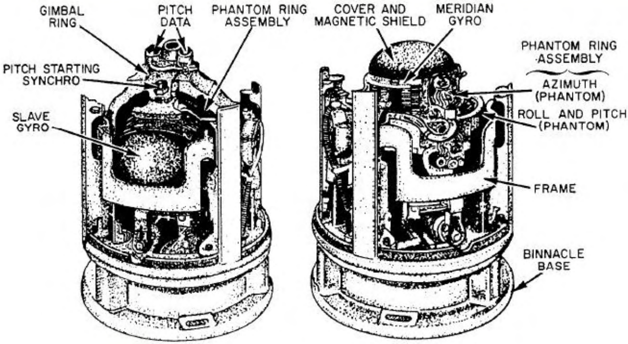


Figure 4-21.–Two views of master compass element and supporting element.

phantom assembly, the meridian gyro on top, and the slave gyro, upside down, on the underside. The gyro motors are 2-pole, 115-volt, 3-phase, 400-Hz squirrel cage induction motors. The meridian gyro rotates approximately 23,600 rpm clockwise viewed from the south, and the slave gyro rotates at the same speed counterclockwise viewed from the east.

The azimuth phantom is made to follow the azimuth motion of the meridian gyro and 1- and 36-speed heading data are transmitted by the azimuth servo and synchro assemblies mounted on the phantom assembly. The roll and pitch phantom is stabilized in roll and pitch, and 2- and 36-speed roll and pitch data are transmitted by the roll and pitch servo and synchro assemblies mounted on the frame and binnacle.

Control Cabinet

The control cabinet (fig. 4-20) contains the control panel, the computer indicator panel, a dc power supply, analog computers, amplifiers, and other assemblies required for operating and indicating the condition of the master compass.

CONTROL PANEL.– The control panel (fig. 4-22) contains all the switches, alarm lamps, and indicator fuses required for operating the system. Only the controls required for normal operation of the system are accessible when the control cabinet is closed. These controls are on a recessed panel to avoid injury to personnel, damage to the controls, or accidental change of setting.

COMPUTER INDICATOR PANEL.– Located below the control panel, and inside the cabinet, are seven computer assemblies for computing data for the systems. The computer indicator panel (fig. 4-23) consists of seven windows. A dial is visible behind each window to indicate the data being computed by its associated computer assembly. These assemblies are discussed later under the control system in which they are used.

COMPUTER CONTROL ASSEMBLY.– To minimize the number of amplifiers used in the system, two types of standard plug-in computer amplifiers are used in 13 applications. As the characteristics and the circuits in which the amplifiers are used vary, other components peculiar to a single circuit must also be used. For this reason, a T-shaped panel, known as the computer control assembly, is located inside the control cabinet. This panel provides a junction box into which the amplifiers may be plugged. This panel also serves as a chassis for the various components required to match the standard amplifiers to the particular circuits concerned. The computer control assembly houses 11 type 1, and 2 type 2 general-purpose computer amplifiers, and all the components required to operate the various computer and torque circuits, other than those contained in the mechanical assemblies or in the master compass.

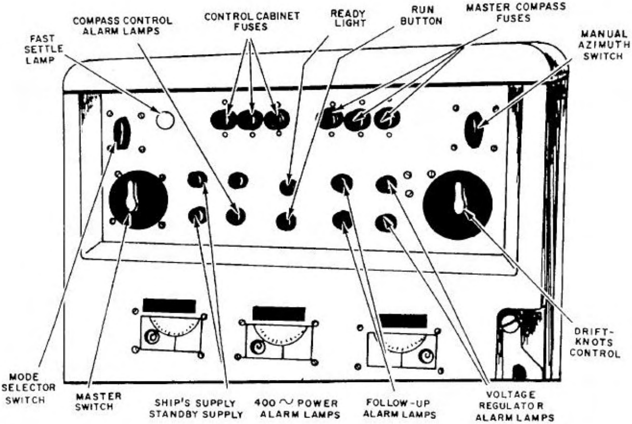


Figure 4-22.--Control panel.

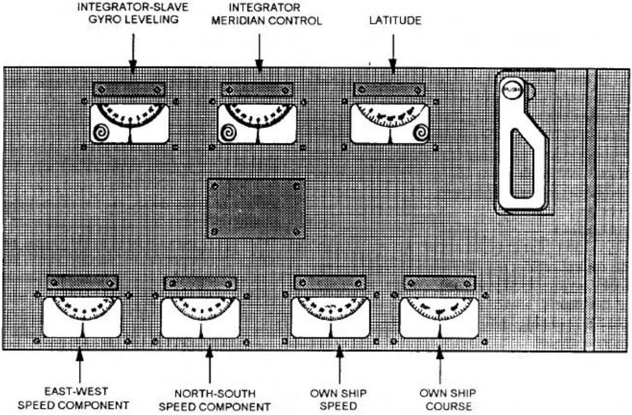


Figure 4-23.--Computer indicators.

SYSTEM CONTROL ASSEMBLY.-- The system control assembly (fig. 4-24) is mounted at the top of the rear section of the control cabinet and includes switches, a time delay and circuits, and a stepping relay for cycling the events automatically. These components are required for starting and operating the compass system. They operate in conjunction with the switches, indicators, and relays on the control panel (fig. 4-22) and elsewhere in the system in performing starting and control functions.

FOLLOW-UP AMPLIFIERS.-- Mounted below the system control assembly are the roll, pitch, and azimuth follow-up amplifiers. The three follow-up amplifiers are identical and interchangeable.

DC POWER SUPPLY.-- Below the follow-up amplifiers is the dc power supply unit (fig. 4-25, view A) containing the power supply component (metallic rectifiers, filters, and so forth), a monitoring meter, and an associated selector switch. The unit operates from the 115-volt, 4(X)-HZ, 3-phase supply and furnishes all dc voltages required for the operation of the various amplifiers and relays in the system.

VOLTAGE REGULATOR.-- Because a supply voltage fluctuation even as low as 2 volts can cause compass errors, a voltage regulator was developed for the Mk 19 Mod 3A system. This regulator is designed to be installed in the bottom of the control cabinet and provides an output of 115 volts, 400 Hz ac regulated within ±0.75 volt for an input of 115 volts ±7 volts. The regulator unit (fig. 4-25, view B) is a single chassis containing a diode rectifier circuit, a dc reference circuit, a differential amplifier, and a corrector circuit. The corrector circuit includes a magnetic amplifier, a servomotor and gear train, a variable autotransformer, and a buck-boost transformer. The buck-boost transformer aids or opposes the line voltage with a voltage supplied from the autotransformer.

An alarm indicator tube is provided to indicate a tube failure and an out-of-tolerance input voltage. In addition, the unit contains a magnetic amplifier balance control, a nominal voltage adjustment control, an automanual switch, and an ac voltmeter to indicate the regulated output voltage.

ADDITIONAL COMPONENTS.-- In addition to the components and assemblies previously mentioned,

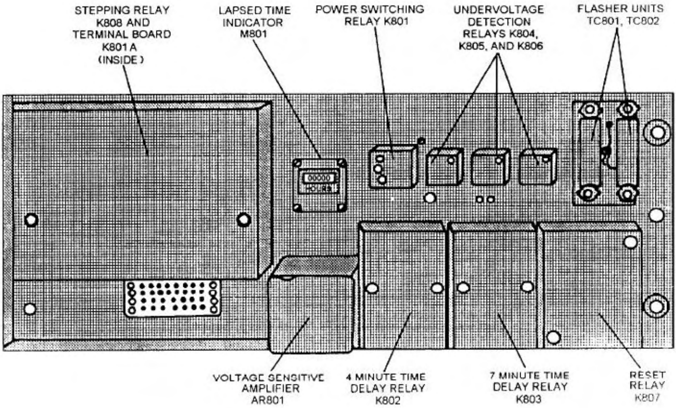
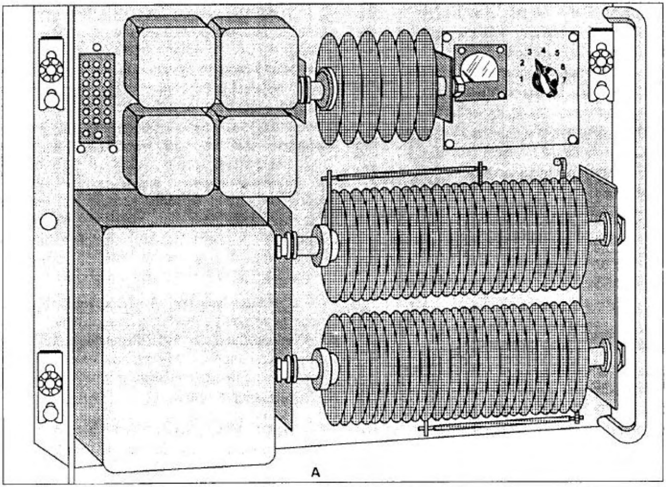


Figure 4-24.--System control assembly.



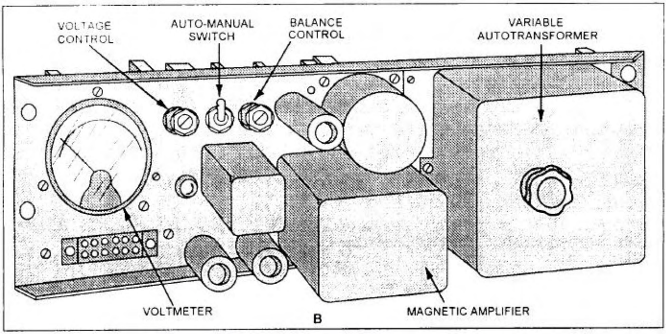


Figure 4-25.--A. Power supply. B. Mk 19 voltage regulator.

the control cabinet also includes an isolation transformer, a ventilating fan, and a spare amplifier.

The isolation transformer is located immediately below the top of the rear portion of the control cabinet and isolates the compass system from the rest of the components connected to the ship's 400-Hz power mains, thus eliminating line-to-ground ptentials in the gyro circuits from the ship's 400-Hz system.

The ventilating fan is located above the isolation transformer and provides ventilation for the interior of the cabinet.

On the bottom right-hand corner of the control cabinet is a spare type 1 computer amplifier.

Compass Failure Annunciator

The compass failure annunciator (fig. 4-20) is a remote visual indicator, of the same type used in the Mk 23 system. Associated with the annunciator is usually a Navy standard type IC/B5DSF4 alarm bell. The alarm bell and annunciator are actuated by the alarm control system to give both a visual and audible indication of system failure. The compass alarm system is discussed later in this chapter.

Standby Power Supply

The standby power supply (fig. 4-20) is a motor-generator set that provides emergency power for the compass system, for a short time, in case of failure of the ship's power supply. Under normal operation the ac section operates as a 115-volt, 400-Hz, 3-phase synchronous motor, driving a 120-volt compound-wound dc genemtor that charges a bank of 20 6-volt storage batteries. If the ship's 400-Hz supply fails, or falls below 105 volts, the ship's line is disconnected automatically and the 120-volt dc generator is driven as a motor by the storage batteries. The ac section now operates as a 115-volt, 4(X)-Hz, 3-phase generator supplying the compass system.

Mk 19 Mod 3A Gyrocompass Controls

All controls for the Mk 19 Mod 3A gyrocompass system (fig. 4-26, views A and B) are contained in four

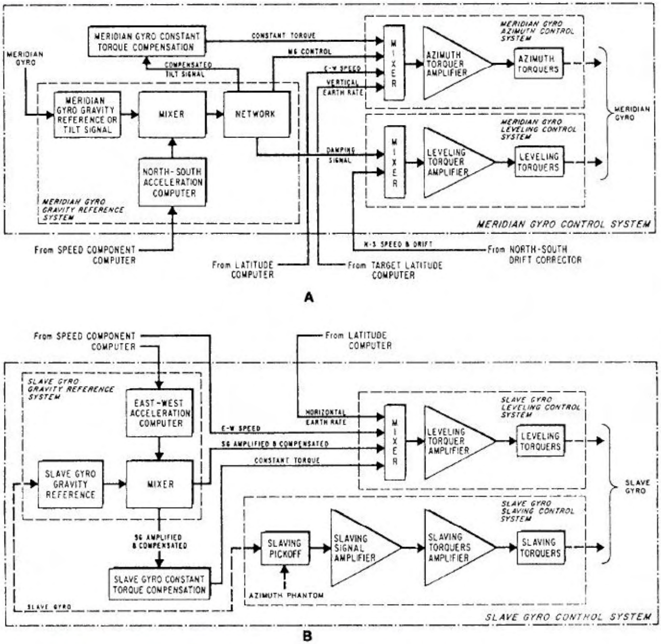


Figure 4-26.--A. Meridian gyro control system. B. Block diagram of a slave gyro control system.

major systems; the meridian gyro control system, the slave gyro control system, the azimuth follow-up system, and the roll and pitch follow-up system.

Meridian Gyro Control System

The meridian gyro control system includes the gravity reference system, the azimuth control system, and the leveling control system. These systems are similar to the Mk 23 compass control system, and they function to control the meridian gyro in the same manner. The compass compensation system is more elaborate, due to the high degree of accuracy required of the Mk 19 Mod 3A gyrocompass, and will be discussed separately.

MERIDIAN GYRO GRAVITY REFERENCE SYSTEM.-- The gravity reference system (fig. 4-26, view A) consists of the meridian gyro gravity reference (the electrolytic bubble level and excitation tmnsformcr), the north-south acceleration computer, a mixer, and its associated network.

The tilt signal from the electrolytic bubble level is fed into the mixer. Here, the tilt signal is mixed with the north-south acceleration signal (a compensation signtil m be discussed later), and the compensated tilt signal is fed into a net work of resistors, potentiometers, and relay contacts. me network has three output signals: the meridian control signal to the azimuth control system, the damping signal to the leveling control system, and the compensated tilt signal to the meridian gyro constant torque compensation system.

MERIDIAN GYRO AZIMUTH CONTROL SYSTEM.-- The azimuth control system consists of a mixer, an azimuth torque amplifier, and the azimuth torquers. (See fig. 4-26, view A.) The mixer input signals are the meridian control signal from the gravity refertnct system, an east-west speed signal from the tangent latitude computer, and a vertical earth rate compensation signal from the latitude computer. The azimuth torque amplifier output is fed to the control fields of the two azimuth torquers, which apply torque to precess the meridian gyro, toward the meridian, in the same manner as described in the Mk 23 system.

MERIDIAN GYRO LEVELING CONTROL. SYSTEM.-- The meridian gyro leveling control system (fig. 4-26, view A) consists of a mixer, the leveling cent amplifier, and the leveling torque. The input signals to the mixer arc the dumping signal from the gravity reference system, and the north-south speed plus drift compensation signal. The amplifier output supplies the leveling torque control field, which produces the torque to level the meridian gyro.

Slave Gyro Control System

The slave gyro control system (fig. 4-26, view B) consists of the slave gyro gravity reference, leveling control, and slaving control systems, and the slave gyro constant torque compensation.

SLAVE GYRO GRAVITY REFERENCE SYSTEM.-- The slave gyro gravity reference system is similar to the meridian gyro gravity reference system. It consists of a gravity reference, a mixer and its network and the east-west acceleration computer. The output of the system is the slave gyro compensated tilt signal, which is fed to the slave gyro leveling control system, and the slave gyro constant torque compensation system.

SLAVE GYRO LEVELING CONTROL SYSTEM.-- The slave gyro leveling control system consists of a mixer, a leveling torque amplifier, and a leveling torque. The input signals to the mixer are the compensated tilt signal fom the slave gyro gravity reference system, and the horizontal earth rate, the east-west speed, and the constant torque compensation signals. The leveling torque, amplifier and leveling torque arc duplicates of those used in the meridian gyro leveling control system. The output of the leveling torque amplifier is sent to the leveling torque control field.

SLAVE GYRO SLAVING CONTROL SYSTEM.-- The slaving control system detects any misalignment between the azimuth phantom and the slave gyro, and slaves the gyro to its proper east-west position. The system consists of the slaving pickoff, the slaving signal amplifier, the slaving torque amplifier (STA), and two slaving torquers. The slaving pickoff is an E-core transformer mounted on the vertical ring. The armature of the pickoff is cemented to the gyrosphere. Thus, a misalignment signal between the azimuth phantom and the slave gyro is obtained from the pickoff in the same manner as described in the Mk 23 system. This signal is fed into the slaving signal amplifier. The output of the slaving signal amplifier is the slaving signal, and it is fed to the slaving torque amplifier. The output of the slaving torque amplifier is the slaving control signal, and it is fed to the slaving torque control fields.

The slaving torquers are duplicates of the azimuth torquers and operate in the same manner. They produce the torque about the slave gyro horizontal axis, which causes precession about the vertical axis to align the slave gyro with the azimuth phantom.

Compensation Signals

There are nine compensation signals in the Mk 19 Mod 3A gyrocompass system. These signals serve to counteract or compensate for certain effects that would otherwise produce azimuth or leveling errors in the master compass.

These effects may be classified as ship, earth, and constant torque effects. The ship effects include speed, course, and acceleration changes. The earth effects are from horizontal and vertical earth rate. Constant torque effects are caused by a mechanical unbalance of the master compass, or any other mechanical defects that would cause the compass to settle with a tilt.

Northerly or southerly ship speed produces a gyrocompass error due to gyro tilt as the ship follows the curvature of the earth. The rate of this gyro tilt is proportional to the product of ship's speed (S), and the cosine of own ship's course (C) and a constant of 0.0166. Easterly speed, however, produces an error equal to the product of ship's speed (S), and the sine of own ship's course (C). Easterly or westerly speed does not cause the meridian gyro to tilt; however, as the slave gyro is aligned east-west it is affected by easterly or westerly speed in the same manner as northerly or southerly speed affects the meridian gyro. Therefore, speed (any direction) causes tilt of one or both gyro elements. Tilt of the meridian gyro causes precession away from the meridian, causing azimuth, roll, and pitch errors. The tilt of the slave gyro causes only errors in roll and pitch. The slave gyro tilt signal is not applied to the azimuth servoloop. The slave gyro vertical ring is positioned by the azimuth servo follow-up motor. The slave gyro is made to follow the vertical ring by the slaving control system.

The Mk 19 compass is compensated for speed errors by applying a compensation signal (north-south speed and drift) to the meridian gyro leveling control system, and a signal (east-west speed) to the slave gyro leveling control system. (See fig. 4-27.) Thus, both gyros are maintained in a level position for any speed or course. These signals are obtained from the own ship's speed repeater and speed component computer (shown in fig. 4-27).

The ship's heading may differ from the true course due to an error caused by the north-south drift of the ship. The north-south speed signal is compensated for drift by a manual corrector located on the front of the control cabinet. This drift setting is made by the compass operator after obtaining the necessary information from the ship's navigator.

Changes in the ship's speed will cause compass errors if not compensated. A tilt signal to compensate for errors from acceleration is produced by the electrolytic bubble level. When the ship accelerates in speed, the inertia will displace the electrolyte in the electrolytic bubble level. Deceleration will cause a displacement in the opposite direction. As a result, tilt signals will be produced even though there is no gyro tilt.

Acceleration compensation is obtained for the meridian gyro by the north-south acceleration computer and for the slave gyro by the east-west acceleration computer.

The east-west acceleration computer operates in the same manner as the north-south acceleration computer. Its input is east-west speed from the speed component computer, and its output is the east-west acceleration compensation signal to the slave gyro gravity reference system.

The effect of vertical earth rate on the meridian gyro is proportional to the product of earth rate at the equator and the sine of the ship's latitude. The effect of horizontal earth rate on the slave gyro is proportional to the product of the earth rate at the equator and the cosine of the ship's latitude. As the effect of vertical earth rate is caused by the speed of the earth's rotation about its north-south axis, a ship traveling in an easterly or westerly direction will either add to or subtract from the earth's rotation. This apparent change in the speed of the earth's rotation will, in effect, produce a comparable change in vertical earth rate. This change, which is the meridian gyro east-west speed error, is proportional to the product of the ship's east-west speed and the tangent of the ship's latitude.

To compensate for these effects on the meridian gyro, we need a compensating signal voltage proportional to the product of earth rate, at the equator and the sine of the ship's latitude, and a compensating signal voltage proportional to the product of east-west speed and the tangent of the ship's latitude.

To compensate the slave gyro for the effect of horizontal earth rate, we need a compensating signal voltage propottional to the product of earth rate and the cosine of the ship's latitude. These compensating signals are obtained from the latitude and tangent latitude computers (fig. 4-27).

If the sensitive elements were perfectly balanced, and there were no other factors that would cause a constant torque on either of the two gyros, the tilt signals from the electrolytic bubble level, over a period of time, would average out to zero. This is true because the gyro controls are designed to keep the gyro axles level at all times. As it is not possible to keep the gyros perfectly balanced at all times because of wear, a constant torque compensation system is provided for both the meridian and slave gyros.

If the magnitudes and durations of accelerations are excessive, during high-speed turns and maneuvers for example, it is desirable to cut out the tilt signal to the integrator. This is accomplished by the north-south

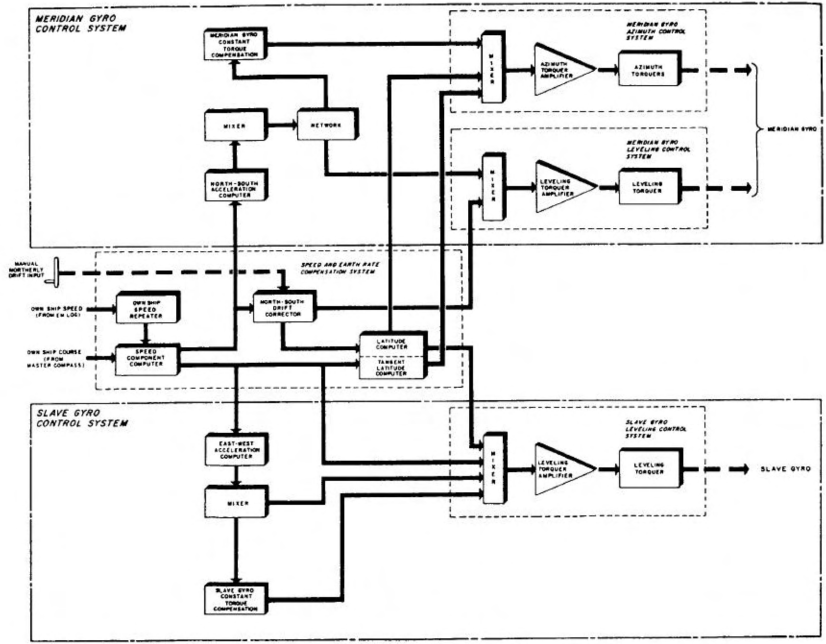


Figure 4-27.—Block diagram of compensation signals.

acceleration signal being fed to the meridian control integrator cutout, which operates a relay, cutting out the tilt signal during excessive accelerations.

For the tilt signal outputs from the electrolytic bubble level to average out to zero, the compass must be in perfect balance, and all compensating signals computed exactly. The constant torque compensation system will then compensate, within limits for errors in computation of other compensating signals.

The constant torque compensation system for the slave gyro is identical to the meridian gyro system.

Operation of Compensation Circuits

The own ship's speed repeater operates on 60-Hz data obtained from the ship's underwater log transmitter. The output of the repeater, however, is 400-Hz data. The repeater contains a 60-Hz servomotor (B1), a 60-Hz synchro control transformer (B2), a 400-Hz linear synchro and dial (B3), and a type 2 computer amplifier (A1). (See figs. 4-27 and 4-28.)

The linear synchro is an induction device like other synchros, but differs from other types in that it has one input rotor winding and one center-tapped output stator winding that produces an output voltage that is a linear function of its rotor position. The rotor winding is excited from the 400-Hz supply. When the rotor is in such a position that the axes of the two windings are separated by 90 electrical degrees, no voltage is induced in the output stator winding. If the rotor is displaced in one direction from this zero voltage position, a voltage is induced in the output winding that is proportional to the amount of rotor displacement. If the rotor is displaced in the opposite direction, a voltage of opposite phase is induced in the output winding that is also proportional to the amount of rotor displacement.

The 60-Hz servomotor is a 2-phase, 2-pole, induction motor, with a fixed field excited from the 60-Hz power line, and a control field connected to the type 2 computer amplifier output.

The input to the repeater is the own ship's speed from the underwater log to the control transformer (B2) (fig. 4-28). The output signal voltage from the control transformer, representing ship's speed, is fed to the input of the type 2 computer amplifier. The servomotor (B1) drives the control transformer rotor to its null position, and at the same time positions the linear synchro rotor (B3) to a position corresponding to the ship's speed. The linear synchro output, then, is a 400-Hz voltage proportional to own ship's speed. A dial is attached to the shaft of the linear synchro to provide a visual indication of own ship's speed.

The own ship's speed signal is applied to the input stage of a type 1 computer amplifier in the speed component computer. The speed computer (fig. 4-28) contains two type 1 computer amplifiers, a speed resolver and dial (B4), a synchro control transformer (B5), and a motor tachometer (B6).

The motor-tachometer (B6) is a 400-Hz servomotor tachometer generator built into the same housing. The motor is a 2-phase, 4-pole, induction motor with a fixed field and a control field. The tachometer generator section consists of a 2-phase, 2-pole stator and a copper shell rotor. One stator field (F1) is excited from the 115-volt, 400-Hz supply. The other stator field (F2) is not excited as long as the rotor is stationary (the axes of the two stator windings are 90° apart). When the shaft of the rotor is turned, a voltage is induced in the rotor and rotor current flow is proportional to rotor speed. This rotor current produces a magnetomotive force proportional to rotor current. This magnetomotive force is combined with the magnetomotive force of the reference winding to produce a resultant field, the axis of which is displaced in the direction of rotation of the rotor cup. The angle between the resultant field axis and the axis of the output winding varies with the speed. Hence, the coupling between the two stator windings varies with speed. Thus, the output voltage varies with the speed. Its frequency is 400 Hz, the same as that of the reference field, and the phase of the output voltage is dependent upon the direction of rotation of the rotor cup.

The own ship's speed signal is amplified and fed to the rotor winding of the speed resolver (B4). Heading data from the master compass is applied to the input of the control transformer (B5), and the output of the control transformer (B5) in series with a damping voltage obtained from the generator section of the motor-tachometer (B6) is fed to the input of the second type 1 computer amplifier. The damping signal voltage from the motor-tachometer is used to stabilize the computer servoloop and to introduce a small time lag in the computer. his time lag is required since the direction of motion of the ship's center of gravity differs from the ship's heading for a short interval after starting a course change. In other words, when rudder is first applied to turn the ship, the ship slides sidewise to some extent so that the original course is maintained for a short interval even though the ship's heading has changed.

The output of the second type 1 computer amplifier excites the control field of the motor section of the motor-tachometer (B6), which drives the tachometer

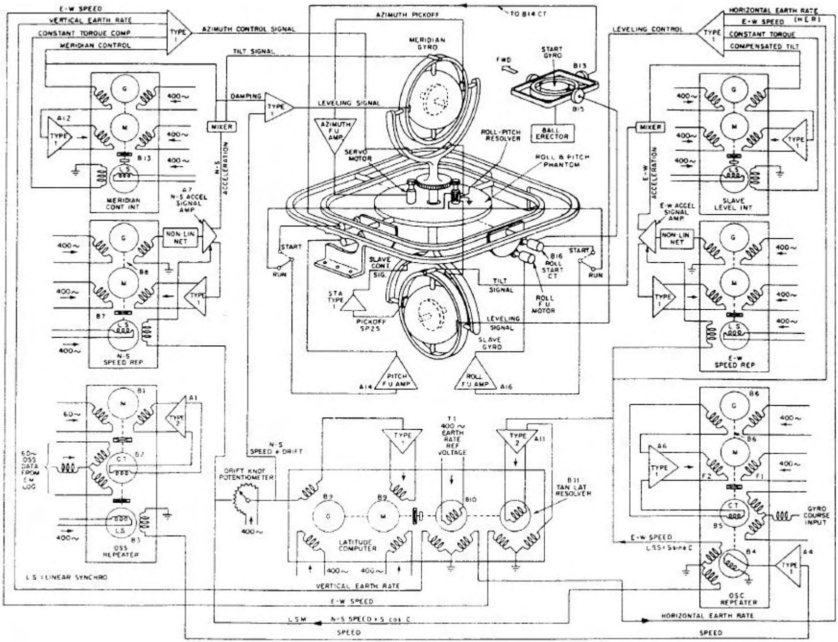


Figure 4-28.—Simplified schematic diagram of a complete compass control system.

generator section, furnishing the damping signal voltage, and at the same time the control transformer rotor of the resolver (B4) is positioned relative to the ship's heading. The resolver (B4) functions to resolve own ship's speed and course inputs into S cos C or north-south speed and S sin C or east-west speed. These are the speed compensation signals needed. A dial is coupled to the shaft of the resolver (B4), indicating own ship's course.

The north-south acceleration computer (fig. 4-28) contains a north-south speed repeater consisting of a linear synchro and dial (B7) and a motor-tachometer (B8). The computer also includes a limiting or nonlinear network, a north-south acceleration signal amplifier, and a type 1 computer amplifier.

The north-south speed signal voltage is fed to the stator of the linear synchro (B7) in series opposition with the stator voltage induced by the synchro rotor, The difference between these two voltages is applied in series with the north-south acceleration signal amplifier output to the input of the type 1 computer amplifier. The output of the type 1 computer amplifier drives the motor section of the motor-tachometer (B8) at a speed proportional to the rate of change of the ship's north-south speed, and positions the rotor of the linear synchro (B7) until the stator voltage due to rotor position equals the north-south speed signal voltage. A voltage proportional to the rate of change of the ship's north-south speed is obtained from the generator section of motor tachometer (B8) and applied through a limiting network to the input of the north-south acceleration signal amplifier, whose output is the north-south acceleration compensation signal to the meridian gyro gravity reference system, When the elcctrolytic bubble is displaced due to accelerations, it starts to return rapidly at first to its neutral position, then slows down. This is due to the viscosity of the electrolyte and the design of the level. By connecting the acceleration signal in series with the linear synchro before applying the voltage to the motor, of the motor-tachometer, the motor speed is made to vary nonlinearly. This nonlinear speed is designed to be proportional to the output of the electrolytic bubble level. In addition, the output signal voltage from the electrolytic bubble level is proportional to the displacement of the bubble over a limited range, beyond which it saturates. If the accelerations are of sufficient magnitude, the electrolytic bubble level will saturate. This factor is also compensated for by applying the output of the tachometer generator to a limiting network of rectifiers. The output of this network is amplified and used as the tachometer feedback voltage to the input of the type 1 computer amplifier.

A dial is attached to the shaft of the linear synchro (B7), indicating the north-south component of own ship's speed.

The latitude computer, which produces the horizontal and vertical earth rate compensation signals, consists of a type 1 computer amplifier, a motor-tachometer (B9), a resolver (B10), and an earth rate reference transformer (T1).

The tangent latitude computer, which produces the meridian gyro east- west compensation signal, consists of a type 2 computer amplifier and a resolver (B11). A dial attached to the shaft of the resolver (B11) indicates the ship's latitude.

The input to the latitude computer is the north-south speed plus drift signal, and the inputs to the tangent latitude computer are the east-west speed signal, and the initial, manual, ship's latitude setting. The latitude is set by the compass operator at the start of a voyage, and thereafter the latitude computer keeps the latitude up to date, automatically, wherever the ship may go.

The north-south speed plus drift signal is fed, in series opposing, with the output of the generator section of the motor tachometer (B9), which produces a damping voltage for stabilization of the servoloop, to the input of the type 1 computer amplifier. The type 1 computer amplifier output drives the motor section of the motor-tachometer (B9) at a speed corresponding to north-south speed plus drift. The motor shaft is geared down (240 million to 1) to position the rotor of the resolver (B10) so that it follows the changing ship's latitude. At any time, the position of the rotor of the resolver (B10) corresponds to the latitude position of the ship. With a reference voltage, representing earth rate, from the transformer (T1) impressed on the rotor of the resolver (B10), and the rotor set at the ship's latitude, the resolver (B10) functions to resolve its earth rate referencc voltage and latitude inputs into an output proportional to earth rate times the cosine of the latitude, or horizontal earth rate and earth rate times the sine of the local latitude or vertical earth rate.

The amplified east-west speed signal from the type 2 computer amplifier is fed to the rotor of the resolver (B11). With this voltage proportional to east-west speed on its rotor, and the rotor positioned to the ship's latitude, the outputs of the two resolver stator windings are proportional to cast-west speed times the sine and cosine of the ship's latitude. The output of the cosine stator winding representing the cosine of east-west speed and latitude, however, is fed back, inversely, to the input of the type 2 computer amplifier so that the resultant output of the amplifier represents the product of east-west

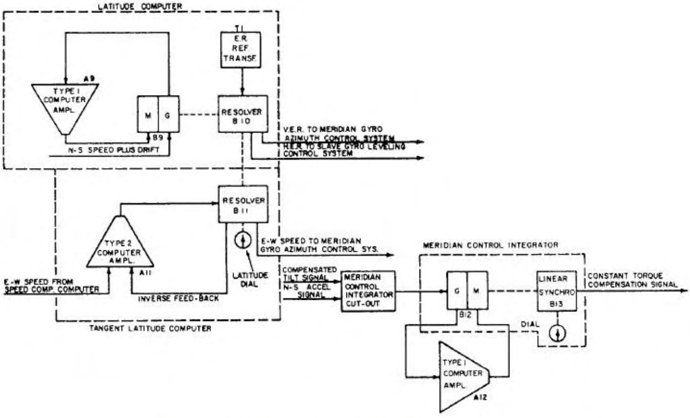


Figure 4-29.--Earth rate and constant torque compensation signals.

speed and the reciprocal of the cosine of the latitude. This output signal on the rotor of the resolver is multiplied by the sine of the ship's latitude in the sine stator winding, being proportional to the product of east-west speed and the tangent of the ship's latitude; the signal is the meridian gyro east-west speed compensation signal.

The meridian gyro constant torque compensation system (fig. 4-29) consists of a type 1 amplifier, an integrator cutout, and a meridian control integrator. The meridian control integrator includes a motor-tachometer (B12) and a linear synchro (B13). The dial provides visual indication of integrator operation.

The meridian gyro compensated tilt signal is fed through a relay in the integrator cutout, in series with the damping voltage output of the generator section of the motor-tachometer (B13) to the input of the type 1 computer amplifier.

The amplifier output drives the motor section of the motor-tachometer (B12), which is geared down (3 million to 1) to the linear synchro. Because of this high gear reduction, it takes a great number of motor revolutions over a period of time to appreciable y rot ate the rotor of the linear synchro (B 13). The linear synchro, therefore, for all practical purposes, does not respond to short-time signals, but responds to long-time signals or the sum of fluctuating and short-time signals. If the average signal from the electrolytic bubble level is not zero, and persists for a long period of time, such as mechanical unbalance of the compass would cause, the rotor of the linear synchro (B 13) will turn gradually at a constant rate. The output voltage, being of opposite phase to the

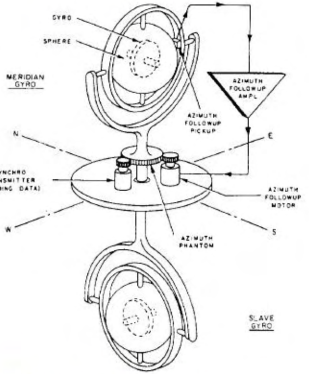


Figure 4-30.--Simplified diagram of the azimuth follow-up system.

tilt signal input, will tend to reduce the input slowly until the voltage output of the linear synchro exactly equals the tilt signal input caused by the unbalance.

The time constant, or rate of change, of the linear synchro output voltage for a given tilt signal is made slow enough so as not to affect the normal settling characteristics of the compass, and yet fast enough to compensate for any constant torque without appreciable delay.

Azimuth Follow-up System

The azimuth follow-up system (fig. 4-30) detects any misalignment between the vertical ring and the gyrosphere and functions to drive the azimuth phantom, and therefore the vertical ring, back into alignment with the gyrosphere.

An azimuth pickoff, consisting of an E-shaped core transformer mounted on the vertical ring and an armature cemented to the gyrosphere, furnishes the misalignment signal to the follow-up amplifier in the conventional manner. The follow-up motor, driven by the azimuth follow-up amplifier output, drives the azimuth phantom, restoring the azimuth pickoff to its neutral position and positioning, through gearing, the 1- and 36-speed heading data synchro transmitters. The follow-up motor also positions the rotor of the roll-pitch resolver (not shown in fig. 4-30) to a position corresponding to ship's heading.

The azimuth follow-up amplifier consists of a preamplifier stage, a demodulator stage with displacement and rate signal networks, and a magnetic amplifier output stage. Associated with the amplifier are two alarm circuits, which actuate the compass alarm in case of excessive pickoff signal or preamplifier tube failure.

Roll and Pitch Follow-up System

The roll and pitch follow-up system (fig. 4-31) detects and eliminates any misalignment between the

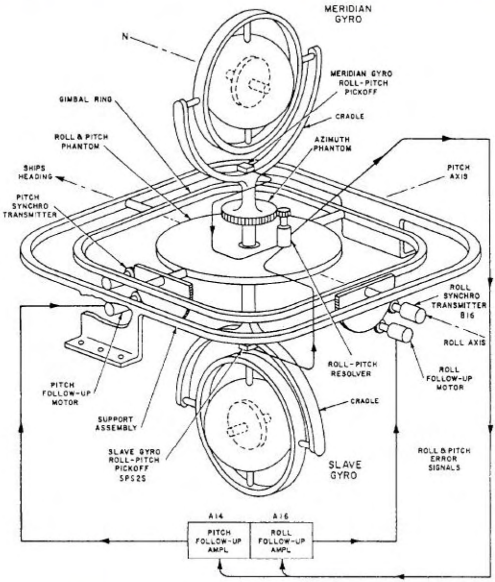


Figure 4-31.--Simplified diagram of the roll and pitch follow-up system.

roll-pitch phantom and the level position maintained by the two gyros. It also positions the roll and pitch synchro data transmitters. The system consists of two E-core pickoffs, two follow-up amplifiers, and two follow-up motors, all duplicates of the corresponding components in the azimuth follow-up system. In addition, the system includes a roll-pitch resolver.

The meridian gyro roll-pitch pickoff is mounted on the meridian gyro cradle and detects any misalignment between the cradle and the meridian gyro's vertical ring. This misalignment is about the meridian gyro's east-west horizontal axis. The roll-pitch phantom, being physically linked to the azimuth phantom, will be identically misaligned with the vertical rings of both gyros.

The slave gyro roll-pitch pickoff is mounted on the slave gyro cradle and detects any misalignment between the cradle and the slave gyro's vertical ring. This misalignment is about the slave gyro's north-south horizontal axis. Thus, any misalignment between the roll-pitch phantom and the vertical ring of either gyro produces a roll-pitch pickoff signal.

A pitch follow-up motor is mounted on the gimbal ring and meshed with the pitch gear on the roll-pitch phantom. It positions the roll-pitch phantom about the pitch axis. A roll follow-up motor is mounted on the support assembly and meshed with the roll gear on the gimbal ring. It positions the roll-pitch phantom about the roll axis, through the gimbal ring.

On a north-south course, the pickoff signal from the meridian gyro roll-pitch pickoff, if fed through the pitch follow-up amplifier to the pitch follow-up motor, would compensate for the effect of pitch. Similarly, if the pickoff signal from the slave gyro roll-pitch pickoff were fed through the roll follow-up amplifier to the roll follow-up motor, it would compensate for the effect of roll.

On an east-west course, however, the meridian gyro roll-pitch pickoff would have to be fed to the roll follow-up amplifier and motor, to compensate for roll, and the slave gyro roll-pitch pickoff would have to be fed to the pitch follow-up amplifier and motor, to compensate for pitch. It follows, therefore, that on any intermediate course, the roll-pitch motions of the ship will have components acting about both north-south and east-west axes, and both roll -pitch pickoffs will react to both roll and pitch. As a result, the two pickoff signals must be divided into proper proportions to each follow-up amplifier and motor to maintain the horizontal stability of the roll-pitch phantom. The own ship's course determines these proper proportions, and they are obtained from the roll-pitch resolver.

The roll-pitch resolver has its rotor positioned corresponding to own ship's course by the azimuth

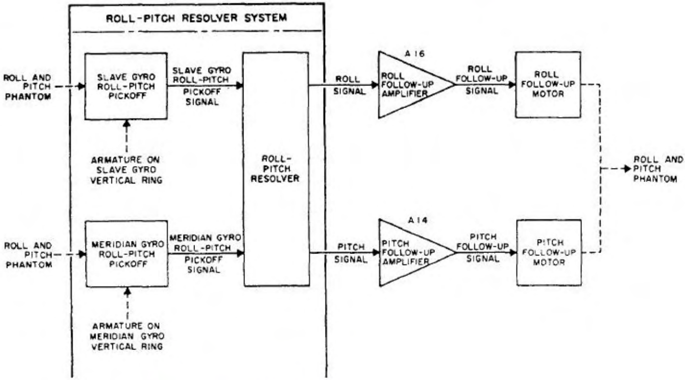


Figure 4-32.--Block diagram of the roll and pitch follow-up system.

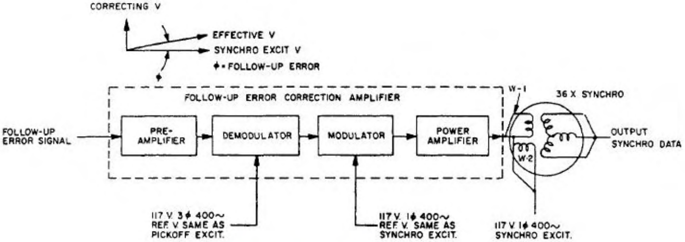


Figure 4-33.--Block diagram of the data correction system.

follow-up system, as mentioned previously. The meridian gyro roll-pitch pickoff signal is fed to one resolver rotor winding, and the slave gyro roll-pitch pickoff signal is fed to the other rotor winding. The resolver functions to resolve its own ship's course and roll-pitch pickoff input signals into output signals of proper proportions to the follow-up amplifiers. The follow-up motors position the roll-pitch phantom until the pickoffs are restored to their neutral position and, at the same time, position 2- and 36-speed roll and pitch synchro data transmitters. Figure 4-32 shows a block diagram of the roll-pitch follow-up sequence.

Due to backlash, spring in gearing, and other effects, follow-up motors may have errors up to 0.05°. These errors are compensated for in the Mk 19 gyrocompass by a data correction system (shown only in fig. 4-33). Three special type synchro transmitters are used with three transistor data correction amplifiers in transmitting the 36-speed heading, roll, and pitch data. Each 36-speed synchro transmitter has an additional rotor winding displaced 90 electrical degrees from the normal rotor winding. When this additional, or quadrature, rotor winding (W1) is excited by a variable voltage, the magnetic field produced reacts with the magnetic field of the normal rotor winding (W2), and thus produces a resultant rotor field that is displaced from the normal rotor winding field. The angle of this displacement is proportional to the magnitude and phase of the voltage applied to the additional rotor winding.

The three transistor data correction amplifiers are sealed and mounted in the bottom of the master compass. The input signals to the amplifier area portion of the azimuth follow-up signal, roll follow-up signal, and pitch follow-up signal. The signal is amplified and demodulated using the pickoff excitation voltage as a reference. The demodulator output (a dc voltage proportional to the pickoff signal) is modulated using the synchro excitation voltage as a reference (as shown in fig. 4-34). The output of the amplifier to the quadrature synchro rotor winding is a voltage proportional to the follow-up error; thus the transmitted data is corrected by an amount equal to the follow-up error. The transmitted data then indicates the true attitude of the gyros rather than the phantom ring assembly.

Alarm System

An alarm system is incorporated in the Mk 19 Mod 3A gyrocompass system to the extent that each loop in

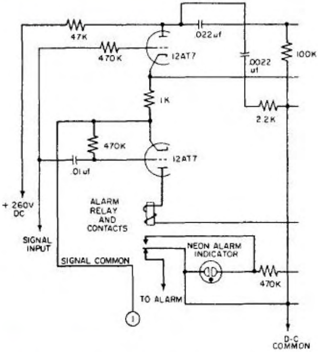


Figure 4-34.--Simplified schematic diagram of an amplifier alarm relay.

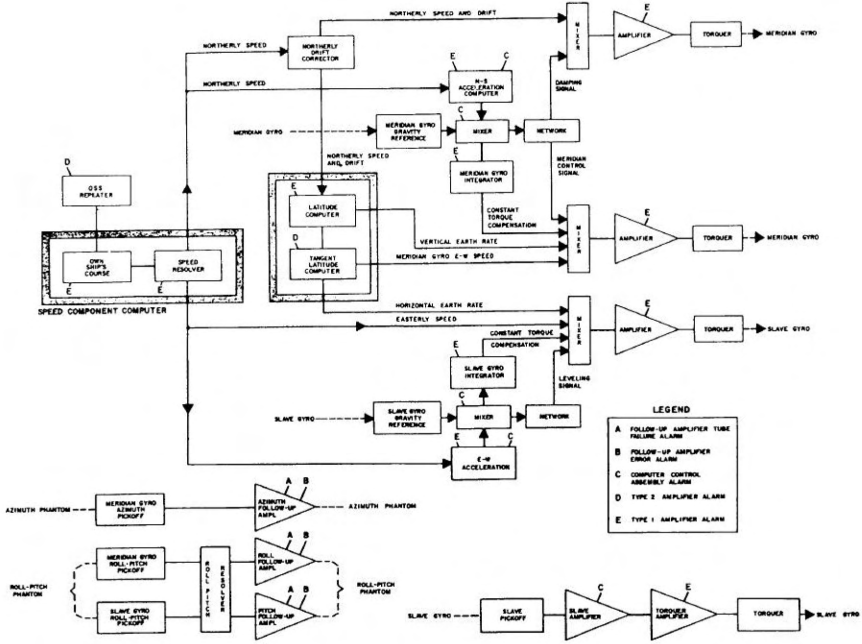


Figure 4-35.—Alarm points in compass control and follow-up circuits.

the system will give multiple alarm warnings when trouble develops in that loop. In addition, as trouble may also develop in the alarm circuits, the circuits are so arranged as to give alarm warnings when they themselves become defective. This is accomplished in each alarm circuit by using normal tube current to energize an alarm relay. (See fig. 4-34). Therefore, if trouble develops within that circuit to reduce tube current, the relay will de-energize and actuate the alarm.

Figure 4-35 shows in block form the points at which each loop in the system is alarmed. This figure does not show every alarm that will give warning, but merely the place in the loop where the initial alarm will occur. The complete alarm system may be divided into four separate systems: the follow-up alarm system, the compass control alarm system, the ship's 400-Hz supply alarm system, and the voltage regulator alarm system.

The follow-up alarm system consists of two alarm circuits in each follow-up amplifier. As the three follow-up amplifiers are identical, the alarms in each are identical. The alarm circuits are the preamplifier tube failure alarm and the follow-up error alarm. Two neon indicating lamps on each amplifier are provided to give a visual indication of the source of trouble when an alarm is actuated.

The compass control alarm system consists of nine computer loops and four torque loops. These 13 computer and torque loops have associated with them 11 type 1 and 2 type 2 computer amplifiers, with alarm circuits. Also, each of the compass control signals pass through the computer control assembly. An alarm circuit is employed that will actuate the compass alarm when any tube in the assembly becomes defective. A failure in any loop circuit will actuate the alarm and cause a neon indicating lamp to light on the associated computer amplifier, or amplifiers, and any tube failure in the computer control assembly will cause a similar indicating lamp to light on the computer control assembly panel.

The ship's 400-Hz supply alarm (not shown in fig. 4-35) is actuated in the event of failure of any phase of the ship's 3-phase, 400-Hz supply, or a drop supply voltage below 104 volts. Undervoltage detection circuits and associated relays in the system control assembly (fig. 4-24) actuate the alarm, disconnect the compass from the ship's supply line, and operate the standby supply as a generator. The ship's supply indicating light (green) on the control panel goes out and the standby supply light (red) comes on, showing that the ship's 400-cycle supply has failed and that the compass is operating on the standby supply.

The voltage regulator failure alarm gives a visual indication of a tube failure in the differential amplifier and for an out-of-tolerance input voltage. A voltage in excess of 122 volts or less than 108 volts will actuate the alarm.

Figure 4-36 shows a block diagram of the action of the complete alarm system. The flashing lamps in the compass failure annunciator are actuated by flasher units in the system control assembly (fig. 4-24).

Starting Control Systems

To aid in starting and operating the master compass, two auxiliary control systems are provided; the starting system and the fast-settling system.

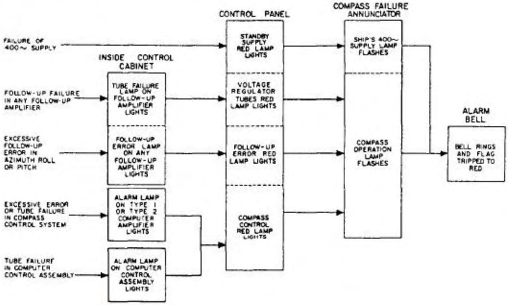


Figure 4-36.--Block diagram of the complete alarm system.

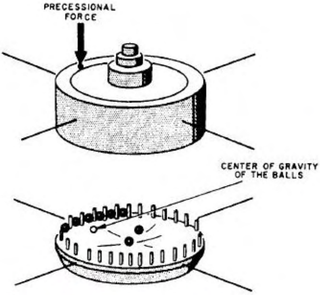


Figure 4-37.--Ball erector diagram.

The starting system functions to level the gyros and bring the meridian gyro to the meridian in as short a time as possible. The starting sequence is accomplished with a minimum number of manual operations by the compass operator. The system includes a fast erect system, a system control assembly, and part of the control panel.

When the compass is to be started, the roll-pitch phantom will be off its level position. A fast-erect system is employed, which greatly reduces the time required to bring the roll-pitch phantom (and therefore the gyros, as they are caged to their vertical rings and the azimuth phantom during starting) to a level position. This system uses a small stabilizer or start gyro mounted in its own gimbal, which, when started, comes very quickly to a vertical position, providing a fairly accurate level reference for the roll-pitch phantom.

The stabilizer gyro rotor is the squirrel cage portion of a 3-phase, 115-volt, 400-Hz induction motor, and spins within the stator at 22,500 rpm in ball bearings that are in the top and bottom of the gyro case. A ball erector mechanism (fig. 4-37) is employed for maintaining the gyro spin axis vertical. This mechanism consists of a flat cylindrical enclosure suspended from the gyro case by means of a ring that also serves as a bearing surface. It is geared to the rotor shaft and rotates at 22 rpm about an axis parallel to the gyro spin axis. When the gyro is vertical, eight small balls are massed in the center of the concave surface of a disk in the bottom cover. Eighteen holder pins are equally spaced near the edge of the concave disk. When the gyro tilts, the balls roll to the lower side of the disk, where they are held loosely by the holder pins and carried ahead, in the direction of rotation, toward the higher side. As each ball reaches a point where it can drop past the holder pin, it falls across the disk and resumes its cycle. The center of gravity of the balls, so displaced, is at a point 90° from the low point, in the direction of rotation. Thus, a torque is created that precesses the gyro in a clockwise direction viewed from above. The ball holder rotates in the same direction and is easily observed because of its slow speed.

Flat roll and pitch synchro transmitters are mounted on the stabilizer gyro (fig. 4-38). The output from the

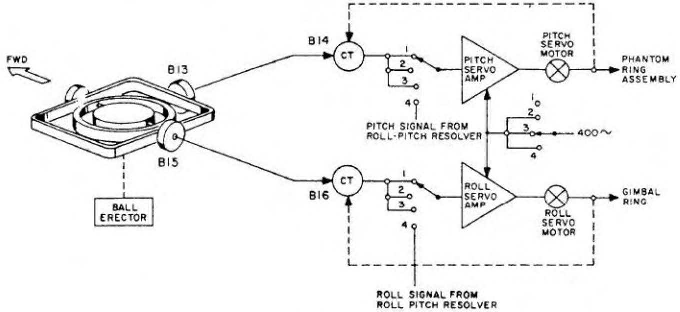


Figure 4-38.--Fast-erect system.

pitch transmitter is fed to a control transformer (B 14) mounted on the master compass and meshed with the pitch gear. The output signal from the control transformer (B14) represents the amount of pitch error in the roll-pitch phantom. This error signal is fed through the pitch follow-up or servoamplifier to the pitch follow-up motor, which positions the roll-pitch phantom until pitch error has been removed.

The output from the roll transmitter is fed to a second control transformer (B16), mounted on the compass frame and meshed with the roll gear. The roll follow-up motor positions the gimbal ring until roll error has been removed.

The roll-pitch signals from the control transformers (B14 and B16) are fed through the first three positions of a stepping relay, to the follow-up amplifiers. The stepping relay automatically disconnects these roll-pitch signals and connects the roll-pitch output signals from the roll-pitch resolver to the proper follow-up amplifier when the main gyros have attained sufficient gyroscopic rigidity to take over the stabilization of the roll-pitch phantom.

The stepping relay is an 11-deck, 5-position, electro-magnet-operated unit located in the system control assembly (fig. 4-24). This relay, with other time delay relays, serves to connect the various components automatically at the proper time during the starting sequence. Many operations are involved in starting the compass, and the steps must be performed in the proper sequence and at the proper time to bring the compass to a usable condition in an optimum amount of time.

STARTING SYSTEM.-- The Mk 19 starting system is made as nearly automatic as possible. The only manual operations required of the compass operator are the master switch, the manual azimuth switch, the fast settle switch, and the run button, located on the compass control panel (fig. 4-22). The manual azimuth switch operates controls for slewing the compass in azimuth that are very similar to those described in the Mk 23 system.

To start the compass at latitudes below 75°, you should perform the following steps:

1. Turn the mode selector switch (fig. 4-22) to the FASTSETTLE mode.

2. Turn the master switch (fig. 4-22) to the FIL' S position, and wait about 30 seconds to allow the tube filaments to heat.

3. Turn the master switch to the ON position. The green ship's supply 400-Hz power green lamp should light at this time to indicate that power is available. The voltage regulator green lamp should also be lighted. The compass control and follow-up alarm lamps on the panel will be lighted either red or green. Now, wait for the blue ready lamp located on the control panel to light (approximately 11 minutes) before proceeding to the next step. When the blue ready lamp comes on, this indicates that the gyrocompass rotors have reached their operating speed of 23,600 rpm and all circuits are warmed up and ready to be placed in the RUN mode.

4. When the blue ready lamp comes on, check the OWN SHIP COURSE dial (fig. 4-23) to see if the compass is aligned with the ship's heading. If the dial does not indicate the ship's heading, you need to slew the compass until the dial is aligned within a maximum of 10°. To slew the compass, turn the manual azimuth switch either CW (clockwise) or CCW (counterclockwise) and hold in this position until the dial indicates the ship's heading as closely as possible. The nearer the OWN SHIP COURSE dial is set to the ship's heading, the quicker the compass will settle.

5. Press the RUN button that is located directly under the blue ready lamp (fig. 4-22), this uncages the compass, and the compass will now begin to settle.

6. Check the LATITUDE COMPUTER dial (fig. 4-23). If the latitude setting is more than 1° off the local latitude, you must adjust the dial to the correct setting. A screwdriver adjustment for adjusting the latitude is located in a hole behind the latitude computer nameplate. To gain access to this adjustment, you need to remove one of the nameplate screws and rotate the nameplate away from the hole.

7. At the end of 2 hours, the compass should be completely settled and transmitting the changes in the ship's actual position with respect to the earth's surface. Now, turn the mode selector switch (fig. 4-22) to the NORMAL mode. All alarm lamps should be lighted green, indicating that the compass is operating correctly. If any of the alarm lamps are lighted red at this time, notify the ship's gyrocompass technician.

FAST-SETTLING SYSTEM.-- The fast-settling system's function is to reduce the compass period and increase the percent of damping during starting. This system reduces the time required for the gyros to assume a true level position and the meridian gyro to settle on the true meridian.

This system is actuated by placing the mode selector switch, located on the front of the compass control panel (fig. 4-22) to the FAST-SETTLE position. This switch completes the energizing circuit to the fast-settle relay, located in the computer control assembly.

When the fast-settle switch is closed, it energizes the 4-pole, double-throw, fast-settle relay. The operated fast-settle relay alters the resistance connections in the meridian gyro gravity reference system, which increases the damping signal output. It also allows the primary voltage of the meridian control step-up transformer to be taken directly from the cathode follower instead of from a potentiometer, thereby increasing the meridian control output signal. When operated, the relay's contacts short a potentiometer in the slave gyro gravity reference system, increasing the slave gyro leveling signal.

The fast-settle switch also disconnects the alarm circuit from the delay relay, rendering the compass failure alarms inoperative when the fast-settling system is in operation. A fast-settle lamp is lighted when the switch is closed, giving visual indication of fast-settle operation.

Operating the Mk 19 Mod 3A Gyrocompass

The Mk 19 Mod 3A gyro system maybe started by setting the fast-settle switch to either the OFF or the ON position. The settling time is much longer when the system is started in the OFF position. Therefore, it is recommended to always start it in the FAST-SETTLE position.

Because the alarm system is NOT in operation while it is in the FAST-SETTLE position, the switch should be reset to ON as soon as practical. The amount of time to settle is least when a ship is sailing at the equator and is greatest at the poles (90° latitude).

Two hours (120 minutes) is the normal period of oscillation at 40° latitude. With the fast-settle switch in the ON position, the period of oscillation is reduced to 50 minutes. These approximate periods are characteristic of all mods of the Mk 19 compass.

NORMAL OPERATION.-- Normal operation of the Mk 19 Mod 3A compass is obtained after the fast-settle switch is moved to the OFF position, which is identified as the normal mode while the ship sails in latitudes (north or south) between the equator and 75°.

Auxiliary operating modes are described later for compass (chiefly submarine) uses between latitudes 75° and 90° near the poles. Operation in the normal mode is generally undesirable in these latitudes because horizontal earth rate (proportional to the cosine of the latitudes) results in the compass period becoming very high, causing slow settling and consequent poor azimuth accuracy.

EMERGENCY OPERATION.-- If the ship's ac power line fails or drops below 105 volts, undervoltage relays open their normal contacts and switch to battery power that is applied to the dc generator so it serves as a motor. Speed of this dc temporary motor is controlled by a centrifugally operated speed regulating device. The ac section then operates as a synchronous generator (driven by the dc section) and, for a period of 15 minutes produces 0.75 kW, without excessive temperature rise.

When the ship's power line is restored above 112 volts ac, the relay automatically returns both units (motor and generator) to their normal functions. The dc section is then generating current and charging the storage batteries.

AUXILIARY OPERATING MODES.-- The fast settle mode is auxiliary to the normal mode. It is used on all Mk 19 compass models for starting.

Two additional auxiliary modes are available on the Mod 3B, identified as high latitude mode and directional mode. Some converted Mod 3A gyros also have them. These two modes of operation will be explained later in this chapter when we discuss the starting procedures for the Mod 3B compass.

Securing the Gyrocompass

When your ship returns to port after an underway period, you must obtain permission before securing the compass. Permission to secure the compass is normally granted by the engineer officer.

To secure the gyrocompass, turn the master switch (fig. 4-22) to the OFF position. After the compass is secured, notify the engineer officer.